The Butajira project in Ethiopia: a nested case–referent study of under-five mortality and its public health determinants

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During one year of follow-up, 306 deaths of children under the age of 5 years were included in a concurrent case–referent study that was based on a population estimated at 28 780 in 1987. A total of 612 live referents, matched for age, sex and study area, were also selected from the study population through density sampling. Data were collected by lay reporters by verbal autopsy.

For the study period the estimated cumulative under-five mortality rate was 293 and the infant (0–11 months old) mortality rate was 136 per 1000. Major probable causes of death were diarrhoeal disease or acute respiratory infections (ARI). The relative importance of parental and environmental characteristics was assessed using conditional multiple logistic regression analysis. Under-five mortality was associated with paternal illiteracy, maternal ethnicity, and not being in the committee of people's organizations. Parental factors affected the infants relatively more than they did the children, especially with regard to ARI mortality. This was also noted with "absence of window", a proxy measure for evaluating the type of housing. In terms of etiological fractions a greater number of under-five deaths could be ascribed to parental than environmental conditions, with relatively more infants being affected than children.

Introduction

Diarrhoeal disease and acute respiratory tract infections (ARI) are the leading causes of morbidity and mortality in developing countries among under–5-year-olds (*1–3*). Factors identified as determinants of these disease entities are maternal education and occupation, duration of breast-feeding, place of residence, household income, infant's birth weight, and the birth order and interval (*1, 3–6*). The beneficial effect of mothers' education on the survival of under–5-year-olds has repeatedly been discussed (*7–11*). Improvements in access to water and sanitation have also contributed to a reduction in child mortality (*12–14*).

Epidemiological studies in developing countries, particularly in Africa, are often cross-sectional or longitudinal and based on prospective home visits (*2, 6, 10*). The case–referent approach, however, which is cost-effective, has not been used as much as one would expect (*15–17*). Ideally data are needed either from a well organized system of registration of vital events or from a prospective cohort of newborns to study determinants like the ones mentioned above. The former approach is not often used as there are generally no such reliable systems operating in developing countries; the latter approach is frequently avoided because of the costs involved and problems of follow-up over a long period of time. One has therefore often resorted to estimations of mortality rates by indirect techniques such as reports of recalled events from interviews with mothers (*18–20*).

In 1986 a census was performed in ten study populations sampled from 86 rural communities in the Butajira district, 130 km south of Addis Ababa. The population is organized through Peasants' Associations (PA) in the rural areas (where farming is the main occupation) and Urban Dwellers' Associations (UDA) in the towns. Most people in the district live in traditional round huts (*tukuls*) with thatched roofs. Water sources, for all purposes, are either unprotected rivers or wells. The census was followed by

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continuous household surveillance based on monthly home visits. Vital events have been recorded since 1987, starting with a baseline population of 28 780 living in 6258 households (*21*). The dynamic population has during the first four years of surveillance generated close to 125 000 person-years of follow-up, around 21 000 of which were under-5-year-olds.

This population-based framework can be used for epidemiological analyses and interventions. Demographic surveillance provided age- and cause-specific mortality rates, from which life expectancies as well as mortality patterns were estimated (*21*). This paper, which analyses the determinants of under-five mortality using a concurrent case–referent technique, focuses on parental and environmental correlates and discusses their relative importance for the planning of public health interventions.

Materials and methods

Four possible sets of determinants of infant (0–11 months old) and child (1–4 years old) mortality have been identified and analysed as preconditions for mortality according to a conceptual framework (Fig. 1). The postulated causal web behind under-five mortality includes parental determinants (age, education, religion, marital status, and ethnicity) coupled with environmental factors, such as sanitation and hygiene and modified by the parents' health behaviour and practices. On the basis of climate and geographical conditions, the study area was divided into highland and lowland.

All the children within the ten study populations could be regarded as a cohort followed over time through demographic surveillance (*21*). Trained interviewers collected information on births, deaths, probable causes of death, and migrations during monthly visits to individual households. All under-five deaths from 1 October 1988 to 30 September 1989 were potential cases in the study (Fig. 2).

For each case, two live referents (matched for age, sex and study area) were selected from the

Fig. 1. **Factors that determine under-five mortality.**

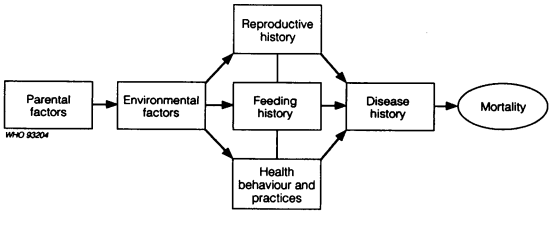
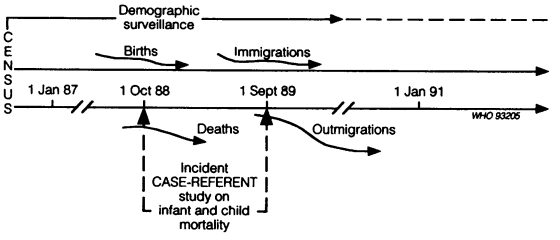


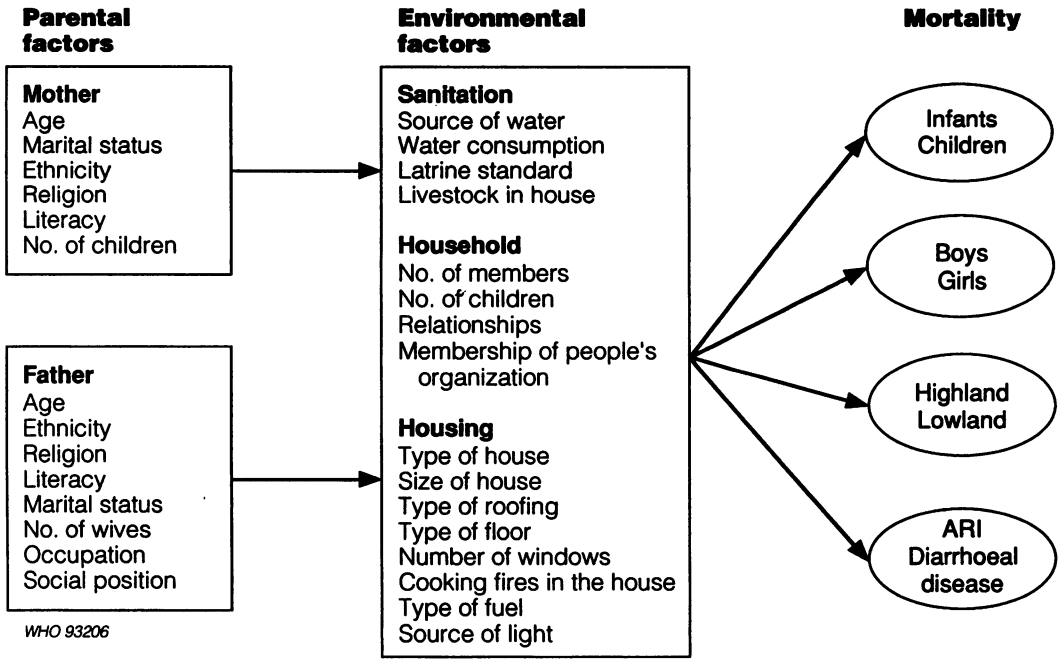
Fig. 2. **Timing of data collection.**



continuously updated register of the study population. The households with cases and referents, so identified, were then visited within a period of one month by two specially trained field workers (non-medical personnel) and information was collected by the use of a pretested, structured questionnaire on demographic characteristics, sociocultural patterns, type of housing, and environmental factors (Fig. 3). Disease history and behavioural factors as well as reproductive history, feeding practices and health behaviour were also included in the questionnaire. The interviewers were closely supervised by a nurse in charge of the field station of the demographic surveillance. Out of the 351 deaths registered during the monthly demographic surveillance, 45 (13%) could not be included in the study because the families had left the area after the death, or refused to participate, or were not at home. Thanks to the study base, within which referents and cases were matched, we were able to take some baseline characteristics for the 45 cases that were lost to follow-up; these, when compared with the 306 cases that were included in the study, were not different with regard to sex. However, a greater proportion of children aged 1–4 years (15%) than infants (7%) was lost to follow-up. Losses to follow-up were also greater among cases in the highlands (17%) than in the lowlands (11%).

A verbal autopsy procedure, with symptom-prompted questions in a structured questionnaire, was used for a broad classification of probable immediate causes of death (*22–24*). The records were independently reviewed by three physicians, who then determined the diagnostic category by consensus. Three categories were used: ARI (including measles and whooping cough), diarrhoeal diseases, and other causes (unspecified fevers, malnutrition, accidents, etc.). The method was validated prior to implementation in this study (L. Muhe et al., Department of Pediatrics, Addis Ababa University, manuscript in preparation). The interview with the mother/father/guardian was conducted in a single session for both the cases and referents.

Fig. 3. **Information collected on potential public health determinants of mortality.**



Statistical methods

The 306 cases and 612 referents were analysed retaining the matching, i.e., as 306 triplets. For bivariate analyses, Mantel-Haenszel procedures (*25*) were used to calculate odds ratios as estimates of relative risks. Assuming a statistical power of 80% and a two-sided significance level of 5%, the possibilities of "detecting" a certain excess relative risk may be calculated as a function of the exposure prevalence. Thus, if 20% of the referents have a certain characteristic, which is thought of as a risk factor for under-five mortality, we are bound to "find" this if it is associated with a relative risk of 1.6 or more. If, however, the same exposure specifically affects infants only (128 cases), the relative risk has to be at least 2.0.

For the modelling of under-five mortality as determined by postulated determinants and to assess the relative importance of various variables, we have applied conditional multiple logistic regression (CLR) analysis using the EGRET software program (*26*). Initially, risk categories of each of the characteristics selected were identified by means of bivariate matched analyses. These variables were then included in the logistic regression analysis. From the associated beta-coefficients, odds ratios and their 95% confidence limits were generated. Significant (P <0.05) factors from the multivariate analyses were included as indicator components in summary indices of the parental and the environmental risk factor "load", respectively. These were transformed into attributable risks ("etiologic" fractions) to estimate the potential impact of parental and environmental determinants on infants and children, as well as for boys and girls, highland and lowland communities, and deaths due to acute respiratory infections and diarrhoeal disease respectively.

Results

During the one year of follow-up a total of 351 cases of under-five deaths were registered. This corresponds to a cumulative under-five mortality rate of 293 and an infant mortality rate of 136 per 1000, with higher mortality among boys than girls. The majority of deaths occurred in the four lowland communities implying a threefold greater under-five mortality risk compared with the highland communities. The major probable causes of infant deaths were ARI (33%) and diarrhoeal disease (23%); for chil-

dren aged 1–4 years, diarrhoea accounted for 32% and ARI for 20% of the deaths. The results given below show the relative importance of parental and environmental characteristics as assessed by the matched case–referent analyses.

Parental factors

Since the population of mothers was homogeneous with respect to literacy (93% were illiterate) and marital status (96% were married), these variables could not be assessed as potential determinants. Also, because the correlation between maternal and paternal ethnicity as well as religion was almost unity, we opted to use the maternal factors in these cases.

Table 1 shows that all the potential parental risk indicators seem to be associated with excess under-five mortality, except for polygamy. Three of these (Silti ethnicity, illiteracy of the father, and non-membership of people's organizations) were still retained in the multivariate model. When these factor levels were related to a parental score (0, 1, 2, 3), the dose-response association (Table 2) showed a 4.6-fold risk of under-five mortality for a child with all versus a child with none of the indicators, while still matched for age, sex and area. Stratifying for the matching variables showed a greater impact from parental factors on infants than children and in highland than lowland areas. The impact was equal on boys and girls, but ARI mortality was clearly more affected than diarrhoeal disease mortality.

Environmental factors

Sanitary conditions were analysed in terms of the type of water source, distance to this source, volume of consumption, latrine standard, and whether livestock was kept in the house. Since access to piped water was extremely rare (available in only a few urban households), rivers and wells were the only source for comparison.

Housing was assessed in terms of shape and size, space for living, and the availability of a win-

Table 1: **Influence of parental and environmental risk factors on under-five mortality** (based on bivariate matched and conditional logistic regression respectively)

Risk factor	No. of cases	No. of referents	Bivariate odds ratio	Multivariate odds ratio
Parental problem:				
Mother 15–24 or ≥35 years	129	235	1.29 (0.97–1.71)[a]	—
Father ≥35 years	228	425	1.33 (0.95–1.88)	—
Mother Silti	82	130	1.67 (1.13–2.44)	1.74 (1.21–3.16)
Father Silti	81	132	1.41 (0.95–2.08)	—
Mother Muslim	218	440	1.16 (0.81–1.66)	—
Father illiterate	208	378	1.47 (1.06–2.04)	1.45 (1.01–2.06)
More than one wife	79	163	1.00 (0.72–1.38)	—
Not in a people's organization	280	511	2.09 (1.33–3.27)	1.95 (1.15–2.63)
Child lacking parent(s)	38	42	1.90 (1.20–3.01)	—
Environmental problem:				
Water from well	202	398	1.14 (0.69–1.90)	—
Distance to water ≥5 min	188	396	0.80 (0.56–1.14)	—
Water consumption <6 l/person/day	148	286	1.11 (0.83–1.47)	—
Latrine poor or lacking	262	506	1.37 (0.87–2.16)	—
Livestock in house	252	512	0.94 (0.63–1.42)	—
Siblings under-five	197	403	0.93 (0.69–1.26)	—
Tukul hut	279	543	1.74 (0.88–3.46)	—
Single room	237	472	1.03 (0.70–1.49)	—
No window in house	227	412	1.57 (1.10–2.25)	1.54 (1.08–2.21)
Cooking fires in the house	292	578	1.29 (0.63–2.63)	—
Fuel dung	131	259	1.04 (0.71–1.51)	—
No electricity	293	584	1.31 (0.37–4.61)	—
Living area <6 m^2/person	156	301	1.09 (0.82–1.46)	—

[a] Figures in parentheses are 95% confidence limits.

dow, electricity and facilities for cooking. As only few of the households had electricity, this predictor was difficult to assess. In the multivariate model, lack of a window was the only indicator retained; as an environmental marker it was associated with a 2.7–fold relative risk of infant mortality (Table 2). The lack of a window when used as a dependent variable in a logistic regression was related to the parental, hygienic, crowding and housing indicators, and showed that crowding and poor housing were both significantly related to the absence of a window. Specifically, single rooms and *tukul* huts were the underlying characteristics of these components. Of 128 deceased infants, 101 lived in houses without a window; no sex or area differences were seen. However, the ARI mortality risks were again more pronounced than the diarrhoeal disease mortality risks. For infants, a fivefold ARI mortality risk associated with lack of a window could be demonstrated.

Discussion

Factors influencing infant and child mortality in a developing country have, to our knowledge, not previously been studied by means of the case–referent method with a concurrent and nested approach with a high population participation. The present study illustrates the potential usefulness of this approach. The verbal autopsy technique of classifying probable causes of death is a useful instrument in the field situation and was validated for sensitivity and specificity prior to implementation in this study by comparing the results of the field workers with that of a paediatrician (agreement of 80% and 95% for sensitivity and specificity, respectively) (L. Muhe et al., unpublished data).

Among parental factors, under-five mortality was significantly and independently associated with ethnicity, paternal illiteracy, and non-membership of people's organizations. The effect of maternal education could not be assessed as almost all the mothers were illiterate. In previous studies, education of the mother has been a strong predictor of infant and child survival (*5, 9, 27*); the usefulness of this variable diminishes when one has a homogeneous population. Mortality was associated with younger (<25 years) and older (≥35 years) ages of mothers. Similar associations were observed in other studies (*5, 11, 28*). In our multivariate model, maternal age was however not retained. Neither did an excess under-five mortality in children lacking one or both parents remain in the multivariate model.

Silti ethnicity was associated with increased under-five mortality. Differences in under-five mortality by religion (*5*) and ethnicity may be related to culturally determined differences in health behaviour. Clearly, anthropological studies are needed to understand this.

Paternal illiteracy has been significantly associated with increased under-five mortality. This was reported in a Nigerian study (*6*), where the risk was threefold greater with non-educated fathers. An interesting finding is the association of lower mortality with close involvement in the work of people's organisations; there was no obvious confounding from literacy, but the relative risk associated with non-involvement was higher among illiterate than among literate fathers. Because those who become involved are better educated, have easier access to health care, and can afford to pay for it, this indicator is a good proxy measure for higher income and power.

Table 2: **Dose-response associations among subgroups of under-five children, by parental and environmental scores composed of indicator variables from multiple logistic regression**

	Odds ratio for subgroups								
Factor score	All under-fives	Infants	Children	Boys	Girls	Highland	Lowland	ARI	Diarrhoea
Parental:									
0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
1	1.6	1.4	1.4	1.7	1.5	2.3	1.2	4.6	0.8
2	2.3	2.9	1.7	2.5	2.1	3.4	1.8	4.2	1.3
3	4.6	10.7	2.5	4.5	4.7	15.5	2.8	14.8	2.4
Environmental:									
0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
1[a]	1.7	2.7	1.2	1.7	1.7	1.7	1.7	1.8	1.3

[a] Lack of a window was the sole indicator.

Unfavourable housing and environmental conditions, like living in traditional *tukuls* or homes without windows, poor latrines, crowding, cooking fires in the house, and small amounts of water consumed were represented by the "no window" indicator, which affected infants more than children, specially for ARI. It was shown that this indicator was actually a proxy measure for housing and crowding characteristics rather than for parental and hygienic factors; these associations have been reported by others (*5, 9, 12, 13, 28*). In this study, however, the water source did not come out as equally important as in other studies, mainly because the rural population was homogeneous with respect to this variable, in terms of both water quality and distance from the source.

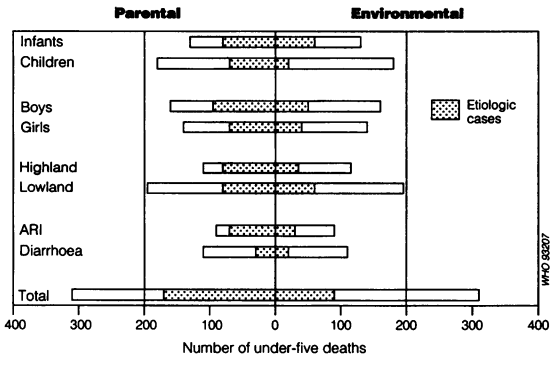
The identification of certain parental and environmental factors which represent major determinants of under-five mortality does not mean that the factors are the *causal* ones. Rather, they are to be interpreted in varying degrees as representatives of parental and environmental causal factors. Regarding the entry-points for intervention, the relative importance of parental and environmental factors may be considered in various subgroups. For these purposes the multivariate assessments were made separately with parental and environmental score factors. Specific patterns emerged where the parental factors seemed to affect the infants relatively more than they did the children. The greater vulnerability of infants was also related to poor housing conditions. The fact that the potential impact of parental scores seemed less in the lowlands might be due to the epidemic situation since individuals were affected more by a local outbreak of malaria and meningitis (*21*) than by "endemic" poverty. When comparing ARI and diarrhoea mortality, it is reasonable to assume that parental influence through health-care-seeking behaviour predisposes to ARI, especially among infants. This will be further analysed in a forthcoming study.

Alternatively, the relative importance of the various factors can be assessed in terms of attributable risks ("etiologic" fractions), i.e., the proportions of cases that are estimated to be "due to" unfavourable parental or environmental characteristics. Thus, 62% of infant deaths could be attributed to parental factors as compared to 40% of child deaths (Fig. 4); the potentially higher vulnerability of infants to poor environmental conditions is also demonstrated through the etiologic fractions of 50% and 9%, respectively. Fig. 4 also illustrates the greater impact of parental factors in the highlands and the relative cause-specific impact.

Ultimately, "etiologic" fractions show the hypothesized potential impacts from interventions—changing the distribution of risk factors or "eradicating" certain unfavourable characteristics. Obviously, such intervention would have to be specifically targeted, e.g., infants and children, in highland and lowland areas and be differently composed to prevent more diarrhoeal disease than ARI mortality. Thus, it could be shown that paternal illiteracy meant a sixfold greater risk of diarrhoeal disease mortality and that the potential benefit from close involvement in the work of people's organizations seems greater among children with illiterate fathers as well as in the highland, especially urban, areas. Among the environmental factors, keeping livestock in the house meant a significant and more than twofold under-five mortality risk. A postulated association between ARI mortality and indoor air pollution, as indicated by the presence of cooking fires inside the house, did not reach statistical significance owing to the homogeneity of this characteristic. This issue will be further explored in a prospective morbidity study. In a further analysis of parental and environmental factors, D. Shamebo et al. (unpublished data) identified prolonged breast feeding as having a positive impact on infant and child survival, specifically preventing deaths due to diarrhoea; none of the sanitary factors seemed to predispose to ARI mortality, while a poor latrine standard and low water consumption both significantly increased diarrhoeal disease mortality.

In conclusion, if the unfavourable parental or environmental factors should be removed, we could hypothesize (based on our multivariate analyses of 306 under-five deaths) obtaining a public health impact of 55% or 31% fewer deaths, respectively. These findings not only challenge the common view that rural populations in the Third World live under homogeneously poor conditions but also support further epidemiological and action-oriented public health research.

Fig. 4. Potential impact of public health determinants, in terms of attributable risks, on under-five mortality.



Résumé

Projet Butajira en Ethiopie: une étude cas/témoins de la mortalité chez les moins de cinq ans et ses déterminants en rapport avec la santé publique

Au cours d'une période de suivi d'un an, 306 décès d'enfants de moins de cinq ans ont été inclus dans une étude cas/témoins basée sur une population évaluée à 28 780 habitants en 1987. On a sélectionné comme témoins 612 enfants, appariés pour l'âge, le sexe et la zone d'étude, par échantillonnage dans la population. Les données ont été recueillies par des agents de santé sans formation médicale, par autopsie verbale.

Pour la période étudiée, le taux cumulatif estimé de mortalité chez les moins de cinq ans était de 293 pour 1000 et le taux de mortalité chez les nourrissons (0–11 mois), de 136 pour 1000. Les principales causes probables du décès étaient une maladie diarrhéique ou une infection respiratoire aiguë (IRA). L'importance relative des paramètres parentaux et environnementaux a été évaluée par analyse de régression logistique multiple. La mortalité chez les moins de cinq ans était associée à l'analphabétisme paternel, l'origine ethnique de la mère et avec le fait que les parents ne faisaient pas partie des organisations des comités du peuple. Les facteurs parentaux influaient encore davantage sur la mortalité des nourrissons, surtout par IRA. Ce type de relation a également été observé avec "l'absence de fenêtre", une mesure approximative d'évaluation du type de logement. En ce qui concerne les relations étiologiques, un plus grand nombre de décès avant l'âge de cinq ans pourrait être imputé à des paramètres parentaux plutôt qu'environnementaux, les nourrissons étant relativement plus touchés que les enfants.

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