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A study of the association between improved sanitation facilities and children's height in Lesotho

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The impact of improved sanitation on the anthropometric status of children under 5 years in Lesotho was investigated using children recruited into a case-control study of diarrhoea morbidity. The children's height-for-age Z-scores were used as an indicator of chronic undernutrition. Classifying children as 'stunted' or 'adequately nourished' revealed some evidence of an association between latrine ownership and attained height. After allowing for confounding variables, the odds of stunting were 18 per cent lower among children in households with latrines (95 per cent confidence interval, 36 per cent lower to 3 per cent higher). More powerful analyses, using height-for-age as a continuous outcome variable, revealed that the mean height-for-age Z-score of children from households with a latrine was 0.27 standard deviations higher than that of children from households without a latrine (95 per cent c.i. = 0.12 to 0.42). These results suggest that the anthropometric status of children may be as responsive to improvements in sanitation facilities as diarrhoea morbidity in some settings.

Water supply and sanitation interventions are thought to improve the health status of young children. Measuring these improvements remains, however, problematic. While two reviews of the literature on the health impact of improved water supplies and sanitation facilities have suggested that a positive impact on diarrhoea and other water-related diseases has occurred in many instances (Esrey, Feachem & Hughes, 1985; Esrey & Habicht, 1986*a*), it has been pointed out that many of these studies had serious methodological limitations (Blum & Feachem, 1983).

Briscoe, Feachem & Rahaman (1986) have reviewed the criteria which should be applied when choosing a measure of the health impact of water supply and sanitation interventions. These include the reliability and validity of the measure, its public health importance, and the anticipated responsiveness of the measure to the intervention under evaluation. While diarrhoea morbidity in children has frequently been used as an indicator of health impact in the past, it has been argued that the anthropometric status of children may constitute an equally appropriate outcome measure (Esrey & Habicht, 1986*b*). Mosley & Chen (1984) have suggested that nutritional status may be the best overall indicator of the health of a population. In addition, anthropometry may be more valid and reliable than some measures of diarrhoea morbidity, particularly those relying on surveillance and recall. The responsiveness of anthropometric

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measures to improvements in water supply and sanitation facilities is, however, unclear.

This paper presents some of the results from a recent health impact evaluation (HIE) of the Rural Sanitation Pilot Project (RSPP) in Lesotho. A case-control approach was used to examine the impact of improved sanitation on childhood diarrhoea, the results of which are presented elsewhere (Daniels *et al.*, 1990). In addition, the association between improved sanitation and the height attained by children was examined, and an analysis of that association is presented here.

Subjects and methods

Study site and population

The activities of the RSPP in Mohale's Hoek District, Lesotho and details of the design of the HIE have been described in detail elsewhere (Daniels *et al.*, 1990). Briefly, children under 5 years of age reporting with diarrhoea to one of four health facilities in the district were recruited as cases, and children of a similar age, reporting with respiratory infections or trauma, were recruited as clinic controls. In addition, children from villages throughout the district were recruited into a community-based survey. All villages in the six constituencies of Mohale's Hoek District in which the RSPP had been active were listed using the village register prepared for the 1986 census. A table of cumulative populations was prepared and from this table a systematic random sample of 25 individuals was selected. The villages in which these individuals lived were visited and a house chosen at random. If a child under 5 years lived in the house she or he was recruited and the next house visited until 32 children had been recruited. If more than one child aged less than 5 years lived in the house, then the youngest child was recruited. If the village was too small to provide 32 children under 5 years of age, recruitment was continued in the next nearest village.

At the time of recruitment details of the episode of illness were noted for those children recruited at the clinics; data on the household's sanitation and water supply facilities and usage, hygiene practices, and a wide variety of potential confounding factors were recorded for all children.

Anthropometry

At the end of the interview each child was measured twice to the nearest 0.1 cm using a length board. All children were measured lying down. The average of the two measurements is used in the following analyses. After the completion of training the enumerators were assessed in the taking of anthropometric measurements. No evidence of any systematic bias was observed.

It has been recommended that the most appropriate measure for assessing short-term effects of nutritional deficiency ('wasting') is weight-for-height (WHO, 1983). Height-for-age provides a measure of the cumulative effect of nutritional insults over a long time period (Waterlow *et al.*, 1977) and for this reason is preferred for assessing longer term effects (WHO, 1983). In this study we were interested in detecting long-term effects of improved sanitation on child growth and therefore in the following analyses we concentrate on the association between latrine ownership and height-for-age. Each child's age was calculated by subtracting their date of birth from the date of interview and the child's height-for-age Z-score relative to the standard reference population compiled by the National Centre for Health Statistics (NCHS) was then computed (Hamill *et al.*, 1979). These calculations were performed on a microcomputer with the software package developed by NCHS, using the HES/HANES standard for children aged between 24 and 36 months (Dibley *et al.*, 1987).

Because the children included in the study were recruited in three different ways, from children presenting at clinics with diarrhoea or with respiratory infections or randomly from the community, and because of the possible association between diarrhoea and anthropometric status, all the analyses described below take into account whether the child was a case of diarrhoea, a clinic control, or a community recruit.

Statistical methods

All questionnaires were checked and coded

prior to double-entry onto microcomputer in Mohale's Hoek and Maseru. Data analysis was performed in Maseru and London using the SPSS/PC+, SAS-PC, NCHS and EGRET software packages. Statistical techniques used include analysis of variance, *t*-tests, chi-squared tests for general association, trend, and for homogeneity of the odds ratio, and logistic regression analysis. Estimates of the odds ratio for stratified analyses were calculated using the method of Mantel & Haenszel (1959). The 95 per cent confidence intervals quoted for these estimates are test-based (Miettinen, 1976).

Results

Between December 1987 and June 1988, 803 children with diarrhoea were recruited at the clinics participating in the study together with 810 clinic controls. In addition, 843 children were recruited in the community. Some striking differences between the three groups were apparent. Community recruits (mean age 25.4 months) were, on average, 10 months or more older than either the diarrhoea cases (15.1 months) or the clinic controls (13.9 months) ($P < 0.0001$). Both diarrhoeal diseases and respiratory infections occur most commonly in children less than 2 years of age. Over 80 per cent of cases and clinic controls fell into this age group. In an attempt to ensure that the age distribution of the community recruits was similar to that of the other two groups, the youngest child (under 5 years) in each household was selected. Nevertheless, fewer than 50 per cent of community recruits were under 2 years of age. The sex distribution of the three groups was similar (cases 51 per cent male, clinic controls 48 per cent male, community recruits 52 per cent male).

A higher proportion of community recruits (51.5 per cent) than cases (16.3 per cent) or clinic controls (11.9 per cent) lived in the constituencies of Taung, Qaqatu and Thaba Telle. More cases (58.3 per cent) and clinic controls (61.2) than community recruits (24.1 per cent) lived in the constituency of Mohale's Hoek. Taung, Qaqatu and Thaba Telle are the most remote and rural of the constituencies included in the study, Mohale's Hoek is the most urban.

Fathers of community recruits were less likely than fathers of cases and clinic controls to be migrant workers (63.5 per cent versus 77.3 per cent and 76.7 per cent respectively). Community controls also tended to come from larger households than cases and clinic controls (mean 5.3 persons versus 4.8 and 4.6 respectively).

After a preliminary examination of the anthropometric data, outlying values 6 or more standard deviations below the mean height-for-age or more than 3 standard deviations above the mean were excluded as recording errors. In addition, height was not recorded for a number of children who had refused to be measured. Thus acceptable height-for-age data were available for 737 cases (92 per cent), 763 clinic controls (94 per cent) and 818 community recruits (97 per cent). The distribution of height-for-age Z-scores in each group of children is shown in Fig. 1.

Children were classified as 'stunted' if their height-for-age Z-score fell two or more standard deviations below the NCHS standard and 'adequately nourished' if it lay above this cut-off point.

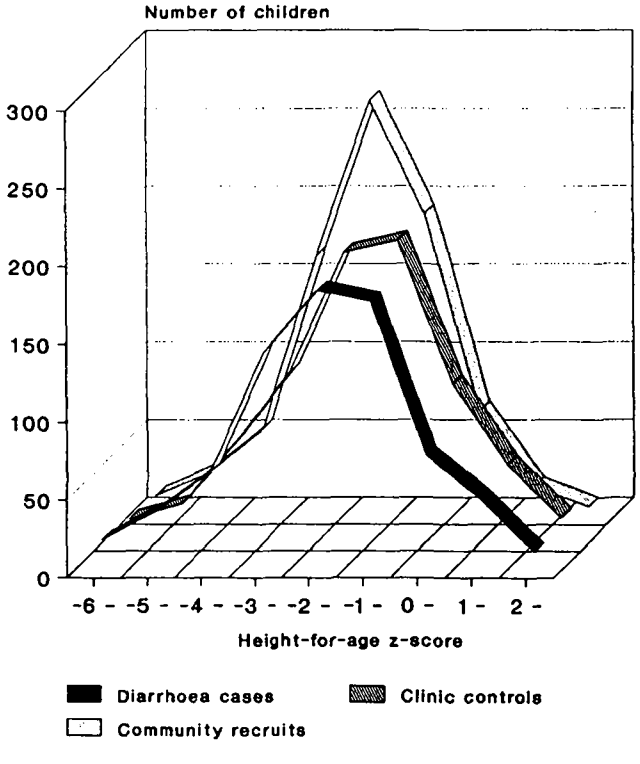

Fig. 1. Distribution of height-for-age Z-scores among diarrhoea cases, clinic controls and community recruits, Mohale's Hoek, Lesotho.

Distribution of stunting

For each group of children age- and sex-specific prevalence rates of stunting were calculated (Table 1). Among the children recruited as diarrhoea cases 35.1 per cent were stunted. Among the clinic controls the percentage was 28.3 per cent and among the community recruits 32.6 per cent. In all three groups the percentage of children classified as stunted was lowest among the 0–5 months age group, reaching a peak in the 1- to 2-year-old age group and falling slightly thereafter. The trend towards increased prevalence of stunting with age was statistically significant ($P < 0.001$). The percentage of children who were classified as stunted was higher among males (35 per cent) than females (28.9 per cent). Most of this excess occurred among the clinic controls and community recruits. After taking account of age the association between sex and stunting remained statistically significant for clinic controls ($P < 0.01$) and community recruits ($P < 0.01$). The increase in the age-adjusted odds of stunting associated with being male was 2 per cent among cases, 59 per cent among clinic controls, and 50 per cent among community recruits.

The distribution of stunting with regard to a wide range of variables including socio-economic indicators, water use, excreta disposal, hygiene practices, access to and utilization of health services was also examined.

Table 1. Distribution of stunting by age and sex among cases, clinic controls and community recruits, Mohale's Hoek District.

	Age (months)	*Males* *Number (%) stunted*	*Females* *Number (%) stunted*
Cases	0–5	10 (22.7)	10 (21.3)
	6–11	39 (31.0)	36 (35.6)
	12–23	54 (38.3)	63 (39.9)
	24–59	28 (45.9)	19 (32.2)
Clinic controls	0–5	29 (22.7)	21 (16.3)
	6–11	22 (30.5)	20 (22.5)
	12–23	43 (44.8)	34 (32.7)
	24–59	25 (38.5)	22 (27.5)
Community recruits	0–5	10 (27.8)	5 (13.2)
	6–11	20 (30.3)	17 (31.5)
	12–23	46 (47.9)	38 (35.5)
	24–59	78 (35.3)	53 (26.5)

Among children recruited at health facilities with diarrhoea and control illnesses the percentage who were stunted rose from December and reached a peak in April. A similar trend was observed in the group of community recruits, with the prevalence of stunting increasing from January until May at which time recruitment ceased. There was also some geographical variation in the prevalence of stunting, higher rates being observed in two of the remoter, more mountainous constituencies ($P < 0.01$). Children were more likely to be adequately nourished if they came from a household in possession of a stove ($P < 0.05$ for all three groups) or a plough ($P < 0.1$ for all three groups). Stunted children were more likely to come from households with fewer rooms ($P < 0.01$ for cases; $P = 0.09$, clinic controls) and their mothers tended to have received fewer years of education than mothers of adequately nourished children ($P = 0.02$).

Children currently breastfeeding were less likely to be stunted than those not receiving breastmilk. After taking account of age, this association remained statistically significant only among the clinic controls ($P = 0.02$). A summary estimate of the odds ratio of the association between breastfeeding and stunting, across all three groups of children, controlling for age, suggests that in this population current breastfeeding may be associated with a reduction in the odds of stunting of 33 per cent (95 per cent confidence interval (c.i.) 12–48 per cent).

Among community recruits, adequately nourished children tended to come from households with access to better water supplies than stunted children ($P = 0.01$). No such trend was evident among cases or clinic controls. Latrine ownership was associated with stunting in all three groups of children (Table 2). Within each group latrine ownership was associated with a reduction in the odds of stunting and the magnitude of that reduction was similar in all three groups (cases 27 per cent; clinic controls 36 per cent; community recruits 37 per cent). A summary estimate across all three groups suggests that latrine ownership

Table 2. Distribution of stunting by latrine ownership for cases, clinic controls and community recruits, Mohale's Hoek District.

	Number of children (%) stunted		
	Cases	*Clinic controls*	*Community recruits*
Latrine	81 (30.6)	76 (23.3)	48 (25.1)
No latrine	178 (37.7)	140 (32.0)	219 (34.9)

Summary (Mantel-Haenszel) estimate of odds ratio = 0.67, 95 per cent test-based confidence interval = (0.55, 0.81); $\chi^2 = 16.40$ (1 d.f.), $P < 0.0001$.

was crudely associated with a 33 per cent reduction in the odds of stunting (95 per cent c.i. 19–45 per cent, $P < 0.001$). Taking account of confounding variables reduced the estimate of the reduction to 18 per cent (95 per cent c.i. −3–36 per cent). Mothers of stunted children were less likely to report bathing daily and slightly more likely to report washing their hands before feeding the child and before eating. Mothers of stunted and adequately nourished children were equally likely to wash their hands after defaecation.

Mothers of stunted children and mothers of adequately nourished children were equally likely to have received health education material. Nor was there any statistically significant association between the attained height-for-age of children and BCG immunization, attendance of health pitso (village meeting) or with visits made to the household by health workers.

Association between latrine ownership and height-for-age

In order to investigate further whether there was any evidence that latrine ownership had an impact on child growth, the association between latrine ownership and height-for-age treated as a continuous outcome variable was examined. Initially one-way analyses of variance (ANOVA) were performed within each group of children (ie cases/clinic controls/community recruits). The results of these analyses reveal a pattern broadly similar to that observed in the analyses of the distribution of stunting. Thus, for example, height-for-age Z-scores tended to deteriorate up to the age of about 2 years. This parallels the increase with age observed in the prevalence of stunting.

The results of a one-way ANOVA reveal that the mean height-for-age of children in latrine-owning households was greater than for children from households without a latrine (Table 3). This was true for all three groups of children (cases, 0.28 SD greater, $P = 0.03$; clinic-controls, 0.42 SD greater, $P < 0.001$; community-controls, 0.39 SD greater, $P < 0.001$), and the variation in the magnitude of the association between the three groups was not statistically significant ($P > 0.50$). On the basis of these results the data were combined to investigate further the relationship between latrine ownership and height-for-age. Over the three groups, latrine ownership was associated with an increase of 0.36 standard deviations in the mean height-for-age Z-score, an association

Table 3. *Comparison of mean height-for-age Z-scores between children in latrine-owning households and those in households without latrines.*

	Mean height-for-age Z-score	*Standard deviation*	*Number of children*	*F-statistic (t-statistic)*	*P-value*
Cases					
With latrine	−1.26	1.68	265	4.95	0.03
No latrine	−1.54	1.62	472	(2.22)	
Clinic controls					
With latrine	−0.97	1.70	326	12.47	0.0004
No latrine	−1.39	1.56	437	(3.53)	
Community recruits					
With latrine	−1.22	1.40	191	12.45	0.0004
No latrine	−1.61	1.35	627	(3.53)	

which was highly statistically significant ($P = 0.0001$).

A series of ANOVA models containing terms for latrine ownership, child's status (case/clinic control/community recruit) and one other variable were then tested for a wide variety of variables of interest. Including a variety of other terms neither removed the significance of the association between latrine ownership and height-for-age, nor substantially altered the magnitude of the association. A model was then developed including all variables which were statistically significant or which altered substantially the estimate of the magnitude of the association between latrine ownership and height-for-age. This model contained terms for the child's age, sex and status as case/clinic control/community recruit, month of recruitment, area of residence, type of roof, possession of a stove, type of water supply, bathing, handwashing before feeding the child, attendance at MCH clinics, and receiving a visit from the health worker. After taking account of all these factors, the association between latrine ownership and height-for-age remained statistically significant ($P < 0.001$). The height-for-age of children in households with latrines was on average 0.27 standard deviations greater than that of children in households without latrines (95 per cent c.i. = 0.12 to 0.42). There was no evidence that the magnitude of this association differed between the three groups of children.

The data were also examined for any evidence of interactions between latrine ownership and the other main effects (variables) included in the model. There was some evidence that two factors, type of roofing and frequency of bathing, modified the association between latrine ownership and height-for-age ($P < 0.05$). Latrine ownership was associated with a substantial improvement in mean height-for-age among children with mothers who reported bathing less than daily (0.32 SD) and among children living in houses with sheet metal roofing (0.44 SD). Among children with mothers who reported bathing daily or living in houses with thatched roofing, latrine ownership was associated with a lower mean height-for-age.

Discussion

The study we report on here was primarily designed to investigate the impact, if any, of improved sanitation on the incidence of childhood diarrhoea in Lesotho. Results presented elsewhere (Daniels *et al.*, 1990) suggest that latrine ownership in Mohale's Hoek District may be associated with a reduction in the incidence of reported diarrhoea of 24 per cent (95 per cent confidence interval, −1–42 per cent). It has been argued that the nutritional status of children is as important and appropriate a measure of the health impact of water and sanitation programmes as diarrhoeal disease (Esrey & Habicht, 1986*b*). Doubts about the use of indicators of nutritional status as outcome measures have centred upon their degree of responsiveness to changes in water supply and sanitation facilities. In this paper we present a re-analysis of data collected during a case-control study of diarrhoea, taking height-for-age as an outcome indicator for chronic undernutrition. The circumstances under which it may be valid to use a case-control design to study two outcomes, namely diarrhoea morbidity and height-for-age, are discussed elsewhere (Cousens, Feachem & Daniels, 1989). Briefly, the presence of a group of children recruited from the community, together with the similarity of the results obtained from that group and the results obtained from the clinic cases and clinic controls, enable us to use all three groups in the analysis of the association between latrine ownership and height-for-age.

A simple analysis of stunting (height-for-age 2 or more standard deviations below the mean of the NCHS reference population) suggested that latrine ownership was associated with a reduction in the odds of stunting (odds ratio = 0.67, 95 per cent c.i. 0.55, 0.81). When more detailed analyses, controlling for confounding variables, were performed the estimate obtained for the odds ratio of this association was 0.82 with a 95 per cent confidence interval of (0.64, 1.03). A more powerful analysis using height-for-age as a continuous outcome variable found that the mean height-for-age of children in latrine-owning households was

0.27 standard deviations above that of children living in households without latrines (95 per cent confidence interval 0.12 to 0.42, $P < 0.001$).

In the analysis of observational studies, one can never exclude entirely the possibility that an observed association has arisen through confounding. In the analyses of these data we considered a wide range (> 30) of potential confounders for inclusion in the logistic regression and analyses of variance models tested. The association between latrine ownership and height-for-age Z-score remained statistically significant throughout all these analyses.

Another potential source of bias lies in misclassification of outcome or exposure. Both the team performing the fieldwork and the respondents were unaware that height-for-age was to be investigated as a second outcome. Any misclassification of outcome (height-for-age) or exposure (to improved sanitation) will almost certainly have been non-differential and will have tended to reduce rather than inflate the observed association. For the community recruits exposure status (latrine ownership) was ascertained in the home and misclassification should have been rare. Data available from follow-up home visits to the clinic recruits suggest that misclassification of exposure status at the clinic was also rare (Daniels *et al.*, 1990). Finally, since one group of children was chosen at random from the community and the association between latrine ownership and height-for-age observed in this group was similar to those observed in the other two groups of children recruited at clinics, it is unlikely that selection bias is responsible for the observed association.

We tested 12 variables for evidence of an interaction with latrine ownership. Two of these variables, bathing and type of housing as measured by roofing, appeared to modify the association between latrine ownership and height-for-age ($P < 0.05$). Latrine ownership was associated with improved height-for-age among children whose mothers bathed less than daily but with decreased height-for-age among children of mothers bathing more frequently. This finding might be explained if Lesotho lies at the 'saturated' end of the threshold-saturation theory of Shuval *et al.* (1981). The analyses of the association between latrine ownership and diarrhoea morbidity, on the other hand, suggest that if anything these communities lie at the 'threshold' end of the theory (Daniels *et al.*, 1990). Spurious effect modification may arise through misclassification of confounding variables. It should also be remembered that a substantial number of variables have been examined for evidence of effect modification and thus the apparent statistical significance of these findings overestimates the true statistical significance. The apparent effect modification should be interpreted with great caution.

A number of other studies have examined the impact of water supply and sanitation interventions on anthropometric measures. Two quasi-experimental studies, one conducted in St Lucia (Henry, 1986), the other in Bangladesh (Rahaman *et al.*, 1986), found little or no evidence of any impact of improvements in water supply and/or sanitation facilities on children's height-for-age. A cross-sectional study in the Philippines found no conclusive association between improved facilities and weight-for-age (Magnani & Tourkin, 1986). In all three studies improvements in water supply and sanitation facilities were more strongly associated with reductions in diarrhoea morbidity than they were with improvements in anthropometric measures. More recently, a longitudinal study conducted in Lesotho found that children living in households exclusively using improved sources had better growth rates than children in households using both improved and unimproved sources (Esrey *et al.*, 1988). This evidence is weakened, however, by the study's failure to demonstrate any difference in growth rates between exclusive users of improved sources and exclusive users of unimproved sources. A case-control study conducted in Sri Lanka observed a reduction in the incidence of reported diarrhoea associated with the use of improved water sources. However, no association between water source and height-for-age or weight-for-height was observed (Cousens, Mertens & Fernando, 1990). A longitudinal evaluation of a water and sanitation intervention in

Bangladesh found a 25 per cent reduction in the incidence of diarrhoea associated with the intervention but no evidence of any impact on nutritional status (Hasan *et al.*, 1989).

Stanton & Clemens (1987) have reported on a randomized controlled trial of a hygiene education programme in Bangladesh which was associated with a reduction in the incidence of childhood diarrhoea of about 20 per cent. However, no association was observed between the intervention and anthropometric status (Stanton, Clemens & Khair, 1988). Also in Bangladesh, Briend *et al.* (1989) found no evidence of any long-term impact of diarrhoea on anthropometric status. On the basis of their results, both sets of authors infer that interventions for the control of diarrhoea may not lead to any long-term improvements in anthropometric status. Stanton *et al.* (1988), noting that the role of diarrhoea in determining a child's nutritional status may vary from setting to setting, emphasize the need to assess the nutritional impact of (hygiene) interventions in a range of environments.

The present study provides some evidence, perhaps for the first time, that in some settings anthropometric measures may be as responsive to improvements in water supply and sanitation facilities as diarrhoea morbidity. In our population, improved sanitation appears to be associated with a 24 per cent reduction in the incidence of reported diarrhoea together with an increase of 0.27 standard deviations in height-for-age Z-score. While a reduction in diarrhoea morbidity is one 'route' through which improved sanitation might be expected to be associated with improved anthropometric status, there are others, for example, through a reduction in the prevalence of intestinal parasites. Esrey *et al.* (1989), in a survey of 267 pre-school children in Lesotho, found very low rates of infection with intestinal helminths (< 3 per cent). Protozoal infections were more common, with nearly 24 per cent of children infected with *Giardia lamblia*. There was, however, no evidence of any association between infection with *G. lamblia* and latrine ownership. On the basis of these data, it seems unlikely that in this setting improved sanitation has much of an impact on anthropometric status through a reduction in the prevalence of intestinal parasites.

Interest in the application of the case-control method to the study of the impact of improvements in environmental sanitation on diarrhoea morbidity has been stimulated by the issue of a series of documents over the past few years (Briscoe *et al.*, 1985, 1986; Cousens *et al.*, 1988). A number of such studies have now been completed with encouraging results (Baltazar *et al.*, 1988; Young & Briscoe, 1988; Sandiford, 1988; Mertens *et al.*, 1990). However, a number of problems have also been revealed. The results presented in this paper suggest that cross-sectional studies of anthropometric measures may offer an alternative to such studies which would avoid the problems of selection bias, common to all case-control studies, and of working in busy clinics where neither staff nor mothers have much time to spare.

Two further points of interest arise from the results of this study. First, it has sometimes been suggested that for cultural reasons female children in developing countries may suffer more from undernutrition than male children, but we found no evidence to support this view. Females were, if anything, somewhat less likely to be stunted than males. This finding is in accord with a review published recently (WHO, 1988) which found no clear trend towards females being less well nourished than males. Second, it has been suggested recently that prolonged breast-feeding (> 12 months) may adversely affect a child's growth (Brakohiapa *et al.*, 1988). Our data do not support this theory.

The results of this study in Lesotho suggest that substantial health benefits may arise from improved sanitation, particularly when programmes are integrated with water supply and health education activities. Cross-sectional studies of anthropometric measures may provide a relatively quick and simple way of evaluating the health impact of water and sanitation programmes.

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