Housing characteristics and infant mortality in Ghana; secondary analysis of 2003 and 2008 Demographic and Health Survey data

Masterthesis

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“ONDERGETEKENDE

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SAMENVATTING

Achtergrond: Kindersterfte in Ghana is tussen 1990 en 2012 met 35% afgenomen. Desondanks stierven er in 2012 nog 38.000 kinderen voor hun eerste verjaardag. Teneinde een verdere afname van de kindersterfte te realiseren, is het belangrijk om inzicht te hebben in de determinanten die geassocieerd zijn met kindersterfte in Ghana. Resultaten uit eerder onderzoek impliceerden een beschermend effect van goede huisvesting, maar het bewijs voor de associatie tussen kenmerken van huisvesting en kindersterfte is tegenstrijdig.

Doel: De associatie onderzoeken tussen kenmerken van huisvesting en kindersterfte in Ghana, controlerend voor socio-economische en demografische kenmerken.

Methode: Deze studie is een secundaire analyse van data uit de geboortebestanden van de Ghanese Demographic and Health Surveys uit 2003 en 2008. Multivariabele logistische regressie is uitgevoerd, zowel cross-sectioneel als longitudinaal.

Resultaten: Het zijn vooral socio-economische en demografische kenmerken die significant geassocieerd zijn met kindersterfte in Ghana. Van de kenmerken van huisvesting zijn 'niet-verbeterd drinkwater', 'onafgewerkte vloeren' en 'vaste brandstof' significant geassocieerd met kindersterfte. Het gebruik van vaste brandstof doet het risico op kindersterfte toenemen, terwijl niet-verbeterd drinkwater en onafgewerkte vloeren het risico op kindersterfte verlagen. In de loop van de tijd nam het risico op kindersterfte af.

Conclusie: Dit onderzoek heeft aangetoond dat vaste brandstof het risico op kindersterfte in Ghana doet toenemen. Andere kenmerken van huisvesting lijken geen (belangrijke) determinanten voor kindersterfte.

Klinische relevantie: Het verminderen van de kindersterfte in Ghana middels huisvesting zal naar verwachting slechts beperkt resultaat hebben. Nieuwe, longitudinale data waarbij het effect van verbetering van huisvesting op kindersterfte wordt gemeten, verschaffen hopelijk een duidelijker beeld over de werkelijke associatie tussen huisvesting en kindersterfte.

ABSTRACT

Background: Despite a 35% reduction in infant mortality rate (IMR) in Ghana between 1990 and 2012, there were still 38,000 infants in 2012 that died before their first birthday. In order to address a further reduction of infant mortality (IM) and IMR it is important to gain insight into the determinants that are associated with IM in Ghana. Results from previous research implied a protective effect of good housing, but the evidence for the association between housing characteristics and IM is conflicting.

Aim: To examine the association between housing characteristics and IM in Ghana, controlling for socio-economic and demographic variables.

Methods: Secondary analyses of data from the birth recode files of the 2003 and 2008 Ghanaian Demographic and Health Surveys were performed, using multivariable logistic regression for both cross-sectional and longitudinal analyses.

Results: Results showed that it is mostly socio-economic and demographic variables that were significantly associated with IM in Ghana. Housing characteristics significantly associated with IM were unimproved drinking water, unfinished flooring and solid fuel use. The use of solid fuels increased the risk of IM, whereas unimproved drinking water and unfinished flooring decreased the risk of IM. In addition, the risk of IM decreased across time.

Conclusion: Solid fuel use was associated with an increased risk of IM in Ghana, whereas other housing characteristics did not seem to be (important) determinants of IM.

Clinical Relevance: Reducing IM in Ghana through housing is expected to have only limited results. New, longitudinal data on the effect of housing upgrading on IM hopefully provide a clear insight into the association between housing characteristics and IM.

Keywords: infant mortality, housing, Ghana, Demographic and Health Survey (DHS), secondary analysis

INTRODUCTION

Worldwide, 4.8 million children under the age of one year died in 2012 [1]. This translates into an infant mortality rate (IMR) of approximately 35 infant deaths per 1,000 live births globally [2]. Regional differences indicate that the IMR is highest in sub-Saharan Africa [3]. Children born in this region run the biggest risk of dying before their first birthday [4].

It is one of the United Nations' Millennium Development Goals (MDG4) to reduce infant mortality (IM) –and consequently the IMR– by two-thirds between 1990 and 2015 [5]. Between 1990 and 2012 the global IMR decreased from 63 to 35 deaths per 1,000 live births (-44%) and the IMR in sub-Saharan Africa decreased with 40%; from 107 to 64 infant deaths per 1,000 live births [3]. Despite these decreases, further reductions are required to achieve MDG4.

In order to further reduce IM / IMR and meet MDG4, a variety of interventions in the medical and healthcare field have been performed in the last years. These include improvement of ante- and perinatal care, and prevention and treatment of diseases [6]. However, interventions may also be directed to other determinants of IM. Previous studies demonstrated that socio-economic and demographic characteristics of mother and child are associated with IM [7-10]. In addition, infant deaths seem to be attributable to housing quality [9, 11, 12]. Low-quality housing is strongly associated with disease and it is mainly children that are at risk to become ill and die [7, 13]. Therefore, studies have been performed on the association between housing characteristics and IM, suggesting that safe drinking water, hygienic sanitary facilities, the availability of electricity, finished floors and the use of non-solid cooking fuel are related with a decreased risk of IM [8, 12, 14-17].

Studies on the impact of housing characteristics on IM show inconsistencies (appendix 1). Although some studies demonstrate that poor housing characteristics are associated with an increased risk of IM [8-11, 18-20], other studies indicate that there is no such association [17, 21, 22]. The inconsistencies can potentially be explained by the use of different, incomparable (inter)national databases that are used for analysis. Moreover, some studies control for socio-economic and demographic characteristics [10, 11, 23], while others do not [15, 24, 25]. In addition, some authors use IM as outcome measure, while others use under-five mortality which includes both IM and deaths of children aged one to five [10-12, 20, 23]. Furthermore, most of the studies describing the relation between housing characteristics and IM are cross-sectional, making it impossible to demonstrate causal relationships [21].

Problem statement

In Ghana, a country in sub-Saharan Africa, the IMR declined with 35% from 77 deaths per 1,000 live births in 1990 to 50 deaths per 1,000 live births in 2012 [5]. Despite this reduction, still 38,000 infants died in Ghana in 2012 [2]. In order to achieve MDG4, IMR in Ghana should further diminish to 25 deaths per 1,000 live births [5]. It seems unlikely, however, that Ghana will achieve this target on time, i.e. 2015 [5]. Therefore, efforts should be reinforced and multiple interventions are required, not only in the medical, healthcare and socio-economic field, but also in the field of housing [26]. It would be interesting to know if housing provides opportunities to reduce IM. Very few studies on the association between housing characteristics and IM in Ghana have been conducted, with contradictory results [19, 22]. Data on housing characteristics and IM, however, are available from the Demographic and Health Surveys (DHS) that were carried out in Ghana in various years: 1988, 1993, 1998, 2003 and 2008 [7]. In the surveys, cross-sectional data on housing was obtained as well as information on IM in the five years preceding the survey [7].

Research question

This study seeks to answer the question whether housing characteristics are related –both cross-sectionally and longitudinally– to infant mortality in Ghana, using 2003 and 2008 DHS data.

Aim

The aim of this study is to gain insight in the association between (changes in) housing characteristics and infant mortality in Ghana. If it is known if and which housing characteristics are related to infant mortality, measures can be taken to improve housing conditions, thereby potentially reducing infant mortality in Ghana and contributing to achieving MDG4.

Objectives

The objectives of this study are to 1) explore which changes in housing characteristics in Ghana can be determined for the period 2003-2008; 2) explore which changes in infant mortality rate in Ghana can be determined for the period 1999-2008; 3) examine whether there is a cross-sectional and longitudinal association between housing characteristics and infant mortality in Ghana, based on the 2003 and 2008 DHS data.

METHODS

Study area

The Republic of Ghana is located on the African West coast [7]. Ghana's population was approximately 24.6 million in 2012 and 3.1% of the population was infant [27]. In 2012, the World Bank labelled Ghana as a lower middle-income country [28]. As a result of fast economic growth in recent years, many people migrated from rural to urban areas, resulting in a housing deficit and deteriorating housing conditions in urban areas [29].

Study design

An exploratory observational study was conducted, consisting of secondary analyses of Ghanaian data. Cross-sectional analyses were performed to investigate the association between housing characteristics and IM for the 2003 and 2008 survey separately. For the association over time, longitudinal analyses were used.

Data sources for secondary analysis

This study used data from the Ghanaian DHS. These national population-level sample surveys are performed by The DHS Program and designed to provide data to monitor the population and health situation in Ghana [7]. A two-stage sampling design was used to 1) select clusters and 2) select households from these clusters. All women (15-49 years of age) and men (15-59 years of age) in the selected households were eligible to participate in the survey [7]. They provided information about their current situation regarding socio-economic status, demographic characteristics and housing as well as information on events such as pregnancy, birth and death of a child in the five years preceding the survey [7]. For this study, the 2003 and 2008 birth recode files were used. These are the most recent datasets with similar variables, allowing comparison.

Variables

<u>Outcome</u>

IM is a dichotomous variable that indicates whether or not a child survived up to its first birthday. For this study, births were eligible that occurred in the five years preceding the survey in de jure households. Living children that went through infancy in this period were included as well as children that died between birth and first birthday in the five years preceding the survey.

<u>Explanatory variables</u>

Five housing characteristics were taken into account as explanatory variable: source of drinking water, type of sanitary facility, availability of electricity, type of flooring material and type of cooking fuel. Additionally, the analyses were controlled for six socio-economic and demographic characteristics: place of residence, wealth, age and educational level of the mother, gender of the child and being of multiple birth. For the longitudinal analysis an extra variable for 'year' was added. In order to simplify analyses, variables were recoded (table 1).

Missing data

The DHS Program already imputed missing information that could be replaced by using dates "to avoid incomplete reporting or inconsistent information" [30]. However, not all missing data were imputed. As justified by Langkamp et al. (2010), cases with incomplete information on the explanatory variables were eliminated from the database if the number of cases with missing data was less than 10% of the total number of eligible cases [31]. Otherwise, imputation was applied.

Sample size

It has been suggested that for logistic regression a minimum of 5-15 cases per variable is needed to draw precise and accurate conclusions [32, 33]. In this study 11 variables were included in the separate years and 12 variables were included for the pooled data (table 1). Therefore, 55-165 and 60-180 cases were required respectively. For logistic regression, the number of events that occurs the least in the dichotomous outcome is leading [34].

Statistical analysis

A merged database with recoded variables was created, containing the pooled data from the 2003 and 2008 survey.

Descriptive statistics were performed on dependent and independent variables. Pearson's X^2 was used to test whether the distribution of the variables was spread equally between both years and to explore the changes in housing characteristics and IM (table 2). Significant differences ($p<.05$) justified longitudinal analysis, apart from cross-sectional analysis.

Before entering the explanatory variables in the logistic regression models, Variance Inflation Factor (VIF) was used to test for multicollinearity between explanatory variables. A VIF >5 was considered problematic, requiring elimination of one of the variables from the model [35].

Univariable logistic regression was performed to assess the association between IM and all explanatory variables separately. Explanatory variables were considered statistically significant if $p<.20$. This liberal p-value is common in association research for keeping truly important variables in the model, outweighing the inclusion of unimportant variables [32].

Significant variables were then entered in a multivariable logistic regression model using method Enter. Since housing characteristics were the variables under study, they were included in the multivariable analysis regardless of their significance. For analysis of association over time the pooled data were used with an extra variable for year.

All analyses were conducted using sample-weighted data. IBM SPSS Statistics version 21 for windows was used for statistical analysis.

Ethical considerations

Permission for this secondary analysis of 2003 and 2008 Ghanaian DHS data was obtained from the Medical Ethics Review Committee (MERC) of the University Medical Center Utrecht. The DHS Program (www.dhsprogram.com; Rockville, Maryland, USA) approved the data usage for this study.

RESULTS

Characteristics of the study samples

Of all eligible cases (i.e. living and dead infants), 0.51% of the cases (n=18) in the 2003 survey and 0.49% of the cases (n=14) in the 2008 survey had missing data with regard to any of the explanatory variables. Therefore, these cases were deleted from the database. A total of 3,515 infants were included in the 2003 database: 3,294 living infants and 221 infant deaths. In the 2008 database 2,838 infants were included: 2,700 living infants and 138 infant deaths (table 2). Since the smallest number of cases was 138 infant deaths, the required number of cases was met and the sample size was presumably large enough to provide reliable answers to the research question.

Trends in housing characteristics

Significant differences in housing characteristics existed between 2003 and 2008 (table 2). In general, housing conditions improved in Ghana during this period. More households had access to improved drinking water and electricity and the use of non-solid fuels increased. However, a higher percentage of households used unimproved sanitary facilities and resided in houses with unfinished floors.

Trends in infant mortality

In the period 2004 - 2008, a lower percentage of infants died than in the period 1999 – 2003 (table 3). The IMR decreased from 61.6 per 1,000 live births (224/3,638) in the period 1999-2003 to 47.8 per 1,000 live births (139/2,910) in the period 2004-2008: a 22% decrease. The IMR fluctuated between 1999 and 2008, but showed a steady decline through the years (figure 1).

Multicollinearity

With a maximum of 3.872, all VIF's were below the cut-off value of 5 (appendix 2). Thus, there was reason to believe that multicollinearity was limited and no variables had to be eliminated from the model.

Univariable logistic regression

The results of the univariable (unadjusted) analyses are presented in table 4. It is particularly socio-economic and demographic variables that are significantly associated with IM, especially in the pooled data. Housing characteristics only appear to be of limited significance for IM. In the 2003 data, unfinished flooring and solid fuel use were significantly associated with IM. Unfinished flooring decreased the odds ratio (OR) of IM with 25% as compared to finished flooring. Solid fuel use was found to increase to OR of IM with 132%. In the 2008 data, unimproved drinking water was the only housing characteristic that was significantly associated with IM; it diminished the OR of IM with 66%. Finally, the results for the pooled data showed that unimproved drinking water and solid fuel were significantly associated with IM. Unimproved drinking water diminished the OR of IM with 41% as compared to (improved) piped water. The use of solid fuel increased the OR of IM with 91%. Sanitary facilities and the availability of electricity were not significantly associated with IM, neither cross-sectionally nor longitudinally.

Multivariable logistic regression

The results of the multivariable analyses, controlling for all variables, are presented in table 5.
Again, it were mostly socio-economic and demographic variables that were significantly associated with IM, both cross-sectional and longitudinal. Primary education of the mother, being a boy and rural residency increased the OR of IM in the 2003 data and over time. Being of multiple birth increased the OR of IM in the 2003, 2008 and pooled data. Lastly, lower wealth was associated with a higher OR of IM in the 2008 data. In short, these socio-economic and demographic variables increased the risk of IM.
Unimproved drinking water diminished the OR of IM in the 2003, 2008 and pooled data. In 2003 and 2008, the risk of IM among users of unimproved drinking water reduced by 56% and 69% respectively, as compared to users of (improved) piped water. Unfinished flooring significantly reduced the OR of IM in the 2003 data. Furthermore, solid fuel use increased the OR of IM, thereby enlarging the risk of IM, both in the 2003 data and longitudinally.
For the pooled data, an extra variable was added (year of survey). Across time, the OR of IM decreased.

DISCUSSION

Key results

This study examined the cross-sectional and longitudinal association between housing characteristics and IM in Ghana, based on the 2003 and 2008 DHS data. In addition, changes in housing characteristics and IMR across time were explored.

The study revealed that most housing conditions significantly improved in Ghana in the period 2003-2008. Several efforts have been made in these years to ameliorate housing conditions, such as increasing access to safe drinking water and hygienic sanitary facilities, slum upgrading projects and electrification [36, 37]. Despite these efforts, the percentage of households with unimproved sanitary facilities and unfinished floors increased between 2003 and 2008. This is most likely due to ongoing urbanization and slum growth [38] as was already suggested by Van de Poel et al. (2009): "It seems likely that this characteristic [unfinished floors] identifies slum dwellings" [12]. However, one would also expect the quality of other housing characteristics to be diminished [38].

Furthermore, the IMR decreased between the first and second period under study. Again, multiple efforts –particularly in the medical and healthcare field– have been made to achieve a decrease in IM, such as the introduction of various vaccines, strategies to address malnutrition, distribution of insecticide-treated nets and the expansion of health services [5]. The reduction of IM is reflected in table 2 and 3 as well as in the results of the multivariable logistic regression of the pooled data, which show a diminished risk of IM in 2008 as compared to 2003.

This study demonstrated that the use of poor quality (solid) cooking fuel is associated with an increased OR of IM, both in the 2003 data and in the pooled data. Since infants often spent much time indoors, they are easily exposed to indoor air pollution from burning solid fuels such as firewood or animal dung [21]. Exposure to indoor air pollution can lead to acute respiratory infection, which is one of the major causes of infant death worldwide [39, 40]. This result is consistent with previous findings that show that the use of solid fuels enlarges the risk of infant death [10, 37]. Consequently, the use of cleaner and safer non-solid fuels can potentially contribute to a decrease of IM [21, 40]. For many households however, solid fuels are more easily available than non-solid fuels. In addition, research indicates that even when people have access to non-solid fuels, many cannot afford them [37].

Paradoxically, poorer quality drinking water and unfinished flooring lowered the OR of IM, suggesting a protective effect. This unexpected association might be due to the fact that households living in poor housing conditions are more aware of the adverse effects on infant health and are deliberately trying to avoid the risks associated with poor housing quality [41]. Another explanation for the unexpected association between housing characteristics and IM could simply be a limited impact of poor housing conditions on infant health. Most of these young children are breastfed, they do not use sanitary facilities as older children or adults do and they are probably carried a relatively large amount of the time [7]. Therefore, type of drinking water, sanitation, electricity and flooring material might be of less importance. These suggestions may explain why other studies also do not find evidence for the association between poor housing and increased odds of IM [12, 22]. However, the findings from this study are inconsistent with the results from the majority of studies on this subject. Multiple studies explicitly suggest a strongly protective effect of high quality drinking water and finished flooring against IM [8, 12, 14, 16, 25].

Apart from the association between housing characteristics and IM, this study revealed that socio-economic and demographic variables appear to be important determinants of IM. The results suggest that improving the educational level of the mother and increasing wealth through income might also contribute to a decline in IM. The high(er) risk of IM in rural areas can partly be explained by harmful and undesirable living conditions but also by a reduced availability of and a lower proximity to health care facilities and lower quality of health services [12]. Therefore, increasing adequate distribution of high-quality health care facilities in rural areas could also help to reduce IM.

Strengths

This study has several strengths. First, not only cross-sectional analyses were performed in this study, but also longitudinal analyses. Combining data from different surveys taken at different times allowed these longitudinal analyses. As a consequence, this study stands out from other studies, which often only analyze data from one survey. Second, not only housing characteristics, but also socio-economic and demographic variables were included in the study. This results in a more complete analysis of the association between housing characteristics and IM, controlling for as many covariates that are closely associated with IM as possible. Third, the data used for this analysis is collected and processed by The DHS Program in a highly standardized way, resulting in high-quality data that is comparable over time.

Limitations

This study has several limitations. First, cases of IM were included that occurred in a 5-year period preceding the survey to ensure a large enough sample of infant deaths. However, it is conceivable that housing characteristics and socio-economic and demographic variables changed in that period. As a consequence, characteristics of the explanatory variables as collected during the survey differ from the characteristics at the time of infant death. This could potentially result in a biased association between IM and housing. Additionally, a common problem with survey data is the misreporting of infant deaths. This is especially the case when children die early in infancy, among women who have several children or in cases where IM took place a long time ago [7]. This may result in underestimation of IMR. Second, based on the method that was used to calculate the required number of cases, the sample size was large enough to provide reliable results. However, other methods for determining the sample size result in a larger required number of cases. For example, Machin et al. (2009) suggest that at least 10(r+1) cases should be included, with r being the number of regression parameters to be estimated [42]. For the analyses in the separate years 30 regression parameters were included (table 1), resulting in 310 required cases. In the pooled data 32 regression parameters were included (table 1), which required 330 cases. This means that the sample size would have been to small for the cross-sectional analyses. As a consequence, it would be less likely to detect existing associations [43]. Lastly, the wealth index is relative to survey and year and therefore it is not properly comparable between years. Currently, it is investigated if a comparative wealth index can be composed. Up till now, tests are mainly focused on cross-national data and not on intra-country data. Therefore, it is not possible yet to use a comparative wealth index in longitudinal analyses of national data. Consequently, it is best to use the regular wealth index for comparison across time [44].

Generalisability

For both surveys data was collected in a large, randomly selected sample, reflecting the whole target population in Ghana. The sampling procedure, a stratified two-stage sample design, minimized selection bias. Therefore, the findings of this study can be generalized to the country as a whole and possibly to other, similar countries.

Future research

There has already been a considerable amount of research into the association between housing characteristics and IM, albeit not specifically in Ghana. Most of that research is based on survey data and many of these studies show contradictory results. In many studies a clear association has been found between poor quality housing and the risk of IM. In other studies, however, this association has not been demonstrated. Therefore, future research should preferably focus on the measurement of the effectiveness of housing upgrading, linked with clear outcome measures such as IM.

CONCLUSION

In this study the association between housing characteristics and IM in Ghana was explored using the DHS birth recode databases of 2003 and 2008. Controlling for socio-economic and demographic variables, the results of both the cross-sectional and longitudinal analyses demonstrate an increased risk of IM due to the use of solid fuels and, paradoxically, a protective effect of unimproved drinking water and unfinished flooring on IM.

Between 2003 and 2008 housing conditions improved and IMR diminished. However, there is no clear association between both developments. On the contrary: in general, poor housing characteristics appear to be protective against IM. Consequently, one would have expected an increase in IM as housing conditions improved over the years.

Given the results, this study adds to the conflicting evidence for the association between housing characteristics and IM. This means that a clear insight into the association between housing characteristics and IM is still lacking.

In conclusion, housing characteristics –with the exception of solid fuels– do not seem to be important determinants of IM in Ghana. Therefore it is expected that in Ghana, reducing IM through housing has only limited results.

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Tables

Table 1. Overview, explanation and coding of explanatory variables

Explanatory variable	Explanation	DHS categories	Classification after categorization
Drinking water	Source of drinking water was categorized using the drinking-water ladder of the WHO Unicef Joint Monitor Programme (JMP) for water supply and sanitation [45].	piped into dwelling / indoor piped to yard /plot	piped water on premises (ref)
		public tap / standpipe / tube well / borehole / protected well / spring rainwater	otherwise improved
		river / dam / lake / pond / stream / canal / irrigation channel	surface water
		unprotected well / spring cart with small tank bottled water / sachet water / tanker truck	otherwise unimproved
Sanitary facilities	Type of sanitary facility was categorized using the sanitation ladder of the WHO Unicef Joint Monitor Programme (JMP) for water supply and sanitation [45].	flush / pour flush to • piped sewer system • septic tank • pit latrine composting toilet pit latrine with slab ventilated improved pit latrine (VIP)	improved sanitary facilities (ref)
		flush / pour flush to • flush to somewhere else • flush, don't know where pit latrine without slab / open pit bucket / pan toilet	unimproved sanitary facilities
		no facility / bush / field	

Table 1 continued

Explanatory variable	Explanation	DHS categories	Classification after categorization
Electricity	A household either has access to electricity or not.	available	available (ref)
		not available	not available
Flooring material	Floors are either finished or unfinished.	parquet / polished wood vinyl / asphalt strips woollen / synthetic carpets ceramic tiles / terrazzo / cement linoleum / rubber carpet wood planks palm / bamboo	finished floor (ref)
		earth / sand / dung	unfinished floor
Cooking fuel	Type of cooking fuel can be categorized as either non-solid or solid.	electricity LPG natural gas / biogas / kerosene	non-solid fuel (ref)
		coal / lignite / charcoal wood / firewood straw / shrubs / grass agricultural crops animal dung	solid fuel
Place of residence	Living in an urban area appears to be protective against IM, probably due to the presence and availability of health care facilities in cities [10, 20, 46, 47]. However, the protective effect of urban residence seems to have diminished, possibly as a result of urbanisation and slum growth [46].	urban	urban (ref)
		rural	rural

Table 1 continued

Explanatory variable	Explanation	DHS categories	Classification after categorization
Wealth index	Wealth is found to be protective against IM [10, 47]. Based on the DHS data a wealth index is composed using information on a household's possession of multiple consumer items and services. Furthermore, wealth quintiles are constructed, that form an indicator of the level of wealth [48].	richest	highest (ref)
		richer	higher
		middle	middle
		poorer	lower
		poorest	lowest
Age of mother	Research suggest that births to young mothers (< 20 years) and older mothers (> 35 years) are at an elevated risk of dying [7]. In contrast, research by Folasade suggests that the higher the age of the mother the better the chance of child survival [9].		15-19 years 20-24 years (ref) 25-34 years 35-49 years
Highest educational level mother	Mother's education seems to be inversely related to IM. Children of women with no education are much more likely to die in the first year than children of educated women [7, 8].	more than secondary some secondary / completed secondary	secondary and higher (ref)
		some primary / completed primary	primary
		no education	no education
Sex of the infant	Research suggests that IM is higher for males than females. The increased mortality risk for boys is probably due to their higher biological risk during the first month of life [7, 8, 10].	female	female (ref)
		male	male
Infant is twin	Being part of a multiple birth is a risk factor for infant mortality [8].	single birth	single birth (ref)
		1st of multiple / 2nd of multiple / 3rd of multiple / 4th of multiple / 5th of multiple	multiple birth
Year of survey		2003	2003 (ref)
		2008	2008

Table 2. Descriptive statistics, 2003-2008

	2003 (n=3,515)		2008 (n=2,838)		
	n	%	*n*	%	*p**
Age of the mother at time of survey					
- 15-19 years	116	3.3	116	4.1	
- 20-24 years	658	18.7	545	19.2	
- 25-34 years	1,711	48.7	1372	48.3	
- 35-49 years	1,030	29.3	805	28.4	.338
Highest educational level mother					
- secondary or higher	1,294	36.8	1,210	42.6	
- primary	820	23.3	699	24.6	
- no education	1,401	39.9	930	32.8	**.000**
Child is alive					
- yes	3,294	93.7	2,700	95.1	
- no	221	6.3	138	4.9	**.014**
Sex of child					
- girl	1,733	49.3	1,369	48.2	
- boy	1,783	50.7	1,469	51.8	.405
Child is twin					
- single birth	3,380	96.2	2,717	95.7	
- multiple birth	135	3.8	121	4.3	.394
Place of residence					
- urban	1,162	33.1	1,077	37.9	
- rural	2,353	66.9	1,762	62.1	**.000**
Wealth quintile					
- highest	538	15.3	405	14.3	
- higher	594	16.9	550	19.4	
- middle	699	19.9	531	18.7	
- lower	782	22.2	677	22.1	
- lowest	903	25.7	726	25.6	.105
Drinking water					
- piped on premises	365	10.4	255	9.0	
- otherwise improved	1,786	50.8	1,932	68.1	
- surface water	815	23.2	357	12.6	
- otherwise unimproved	549	15.6	294	10.4	**.000**
Sanitary facilities					
- improved facilities	2,429	69.1	1,721	60.6	
- unimproved facilities	1,086	30.9	1,117	39.4	**.000**
Electricity available					
- yes	1,254	35.7	1,396	49.2	
- no	2,261	64.3	1,442	50.8	**.000**
Flooring material					
- finished floor	2,944	83.8	2,287	80.6	
- unfinished floor	571	16.2	552	19.4	**.001**
Cooking fuel					
- non-solid fuel	182	5.2	245	8.6	
- solid fuel	3,333	94.8	2,593	91.4	**.000**

* p-values in bold indicate a significant difference between 2003 and 2008 at the 5% level

Table 3. Infant mortality rate per year (1999 – 2008)*

Year / *period*	Live births (a)	Infant deaths (b)	IMR (b/(a/1000))
1999	679	41	60.4
2000	785	59	75.2
2001	700	36	51.4
2002	734	34	46.3
2003	740	54	73.0
1999 – 2003	*3,638*	*224*	*61.6*
2004	609	34	52.7
2005	540	24	41.1
2006	532	27	50.8
2007	584	29	53.7
2008	645	25	41.1
2004 – 2008	*2,910*	*139*	*47.8*

* IMR's per year were derived from the original DHS birth recode databases. Numbers of live births and infant deaths include 1) all children from both de jure (usual) households and de facto (including visitors who spent the night preceding the interview in the household and who were present at the time of the interview) households; 2) complete cases and cases with missing data. Therefore, the numbers in this table differ from the number of included cases in the analyses. For calculation of the IMR, however, it is more accurate to use these numbers.

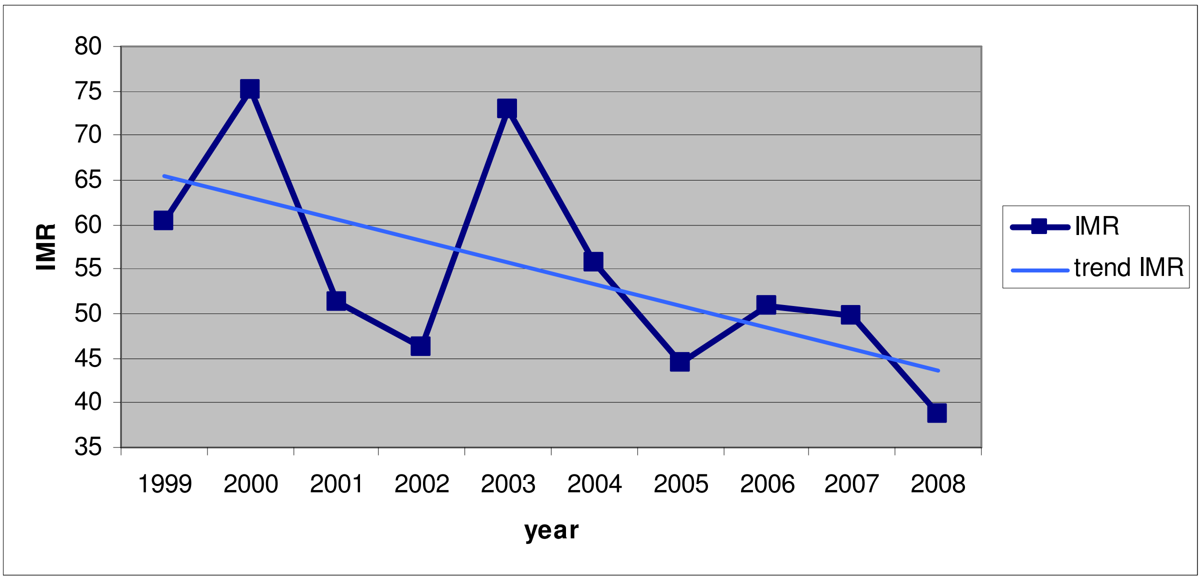

Figure 1. Infant mortality rate in Ghana, DHS birth recode file 2003 and 2008

Table 4. Results of univariable logistic regression for infant mortality

	2003		2008		pooled data	
	OR (CI)	*p**	OR (CI)	*p**	OR (CI)	*p**
Age of the mother at time of survey						
- 15-19 years	1.151 (0.513 – 2.583)	.734	0.683 (0.234 – 1.991)	.485	0.923 (0.485 – 1.756)	.807
- 20-24 years	1.0		1.0		1.0	
- 25-34 years	1.099 (0.749 – 1.613)	.630	0.849 (0.532 – 1.354)	.491	0.996 (0.741 – 1.339)	.977
- 35-49 years	1.215 (0.807 – 1.829)	.352	1.243 (0.767 – 2.014)	.377	1.229 (0.899 – 1.679)	**.196**
Highest educational level mother						
- secondary and higher	1.0		1.0		1.0	
- primary	1.515 (1.072 – 2.141)	**.019**	1.227 (0.801 – 1.881)	.348	1.402 (1.072 – 1.833)	**.013**
- no education	1.088 (0.786 – 1.506)	.613	1.139 (0.762 – 1.701)	.526	1.126 (0.875 – 1.449)	.355
Sex of child						
- girl	1.0		1.0		1.0	
- boy	1.275 (0.969 – 1.678)	**.082**	1.188 (0.842 – 1.675)	.327	1.237 (0.998 – 1.533)	**.052**
Child is twin						
- single birth	1.0		1.0		1.0	
- multiple birth	4.249 (2.732 – 6.609)	**.000**	3.413 (1.975 – 5.899)	**.000**	3.847 (2.731 - 5.418)	**.000**
Place of residence						
- urban	1.0		1.0		1.0	
- rural	1.305 (0.964 – 1.766)	**.085**	1.116 (0.781 – 1.595)	.546	1.240 (0.985-1.561)	**.067**
Wealth quintile						
- highest	1.0		1.0		1.0	
- higher	0.815 (0.497 – 1.334)	.415	1.277 (0.667 – 2.444)	.461	0.946 (0.642 – 1.395)	.780
- middle	1.140 (0.732 – 1.777)	.562	1.809 (0.973 – 3.364)	**.061**	1.341 (0.937 – 1.919)	**.109**
- lower	0.962 (0.615 – 1.504)	.864	0.988 (0.509 – 1.918)	.972	0.962 (0.664 – 1.392)	.836
- lowest	0.893 (0.575 – 1.387)	.615	1.513 (0.825 – 2.773)	**.181**	1.078 (0.757 – 1.534)	.678

* p-values in bold indicate significant OR's at the 20% level

Table 4 continued

	2003		2008		pooled data	
	OR (CI)	*p**	OR (CI)	*p* *	OR (CI)	*p**
Drinking water						
- piped water on premises	1.0		1.0		1.0	
- otherwise improved	0.959 (0.607 – 1.516)	.859	0.925 (0.523 – 1.636)	.789	0.927 (0.649 – 1.323)	.675
- surface water	1.153 (0.705 – 1.884)	.571	0.861 (0.420 – 1.767)	.683	1.089 (0.729 – 1.625)	.678
- otherwise unimproved	0.699 (0.393 – 1.243)	.223	0.344 (0.130 – 0.912)	**.032**	0.591 (0.364 – 0.959)	**.033**
Sanitary facilities						
- improved facilities	1.0		1.0		1.0	
- unimproved facilities	1.050 (0.784 – 1.407)	.742	0.863 (0.605 – 1.232)	.417	0.946 (0.755 – 1.185)	.628
Electricity available						
- yes	1.0		1.0		1.0	
- no	1.049 (0.788 – 1.396)	.743	0.927 (0.659 – 1.305)	.664	1.035 (0.833-1.284)	.758
Flooring material						
- finished floor	1.0		1.0		1.0	
- unfinished floor	0.749 (0.500 – 1.122)	**.161**	1.279 (0.853 – 1.918)	.234	0.945 (0.711 – 1.254)	.693
Cooking fuel						
- non-solid fuel	1.0		1.0		1.0	
- solid fuel	2.323 (0.967 – 5.581)	**.060**	1.526 (0.744 – 3.129)	.248	1.905 (1.095 – 3.311)	**.022**

* p-values in bold indicate significant OR's at the 20% level

Table 5. Results of multivariable logistic regression for infant mortality

	2003		2008		pooled data	
	OR (CI)	*p**	OR (CI)	*p**	OR (CI)	*p**
Age of the mother at time of survey						
- 15-19 years					0.920 (0.480 – 1.763)	.802
- 20-24 years					.0	
- 25-34 years					0.960 (0.711 – 1.298)	.792
- 35-49 years					1.146 (0.832 – 1.579)	.405
Highest educational level mother						
- secondary and higher	1.0				1.0	
- primary	1.524 (1.062 – 2.185)	**.022**			1.383 (1.044 – 1.831)	**.024**
- no education	1.094 (0.748 – 1.598)	.644			1.135 (0.843 – 1.527)	.404
Sex of child						
- girl	1.0				1.0	
- boy	1.305 (0.989 – 1.724)	.060			1.244 (1.002 – 1.545)	**.048**
Child is twin						
- single birth	1.0		1.0		1.0	
- multiple birth	4.402 (2.808 – 6.901)	**.000**	3.485 (1.997 – 6.081)	**.000**	3.805 (2.685 – 5.394)	**.000**
Place of residence						
- urban	1.0				1.0	
- rural	1.394 (0.936 – 2.078)	.102			1.368 (0.992 – 1.886)	.056
Wealth quintile						
- highest			1.0		1.0	
- higher			1.268 (0.591 – 2.718)	.542	0.803 (0.509 – 1.267)	.347
- middle			1.913 (0.842 – 4.349)	.121	0.998 (0.600 – 1.660)	.994
- lower			1.267 (0.501 – 3.207)	.617	0.693 (0.383 – 1.253)	.225
- lowest			2.114 (0.752 –5.944)	.156	0.746 (0.394 –1.412)	.368

* p-values in bold indicate significant OR's at the 5% level and underlined p-values indicate significant OR's at the 20% level

Table 5 continued

	2003		2008		pooled data	
	OR (CI)	*p**	OR (CI)	*p**	OR (CI)	*p**
Drinking water						
- piped water on premises	1.0		1.0		1.0	
- otherwise improved	0.616 (0.358 – 1.058)	.079	0.804 (0.405 – 1.594)	.532	0.768 (0.491 – 1.200)	.246
- surface water	0.724 (0.385 – 1.363)	.317	0.713 (0.299 – 1.702)	.446	0.830 (0.491 – 1.402)	.486
- otherwise unimproved	0.441 (0.227 – 0.858)	**.016**	0.307 (0.112 – 0.839)	**.021**	0.481 (0.277 – 0.836)	**.010**
Sanitary facilities						
- improved facilities	1.0		1.0		1.0	
- unimproved facilities	1.064 (0.762 – 1.486)	.716	0.769 (0.499 – 1.186)	.235	0.964 (0.734 – 1.267)	.794
Electricity available						
- yes	1.0		1.0		1.0	
- no	0.930 (0.645 – 1.341)	.698	0.754 (0.452 – 1.259)	.281	0.969 (0.701 – 1.341)	.851
Flooring material						
- finished floor	1.0		1.0		1.0	
- unfinished floor	0.648 (0.422 – 0.996)	**.048**	1.286 (0.786 – 2.105)	.316	0.934 (0.681 – 1.281)	.672
Cooking fuel						
- non-solid fuel	1.0		1.0		1.0	
- solid fuel	2.482 (0.974 – 6.324)	.057	0.984 (0.407 – 2.380)	.972	1.773 (0.945 – 3.323)	.074
Year of survey						
- 2003					1.0	
- 2008					0.769 (0.609 – 0.970)	**.027**

* p-values in bold indicate significant OR's at the 5% level and underlined p-values indicate significant OR's at the 20% level

APPENDICES

Appendix 1. Evidence on the effect of housing characteristics on infant mortality

Housing characteristic	Evidence
Drinking water	The protective effect of safe drinking water on child survival have been demonstrated in multiple studies [8-12, 14, 16, 18, 20, 25, 49-51]. Studies by Fink et al. (2011), Rutstein (2000), Van de Poel et al. (2009) and Cheng et al. (2012) explicitly suggest a strongly protective effect of high quality drinking water on IM [8, 12, 14, 16]. Increased availability of safe drinking water diminishes the risk of IM [16]. Safe and clean water enables parents to nurture their infants hygienically, thereby diminishing disease transmission [9, 14]. Oloo (2005) and Cheng et al. (2012) go as far as to state that access to safe drinking water is key to a substantial reduction in IM [14, 51]. In several studies, these conclusions were slightly adjusted. Bassani et al. (2010) demonstrated that the use of unsafe drinking water is associated with an increased risk of IM in boys and not in girls [21]. Study results of Durkin et al. (1994) indicated that poor quality drinking water is only significantly associated with IM in urban areas and not in rural areas [52]. On the other hand, Wang (2003) concluded that source of drinking water is not associated with IM in urban areas. In rural areas however, source of drinking water affects infant survival only slightly, albeit not significantly [17]. In contrast, some authors reached a different conclusion. Awini et al. (2010) demonstrated that the use of unsafe water affected infant survival chances in one region. However, in another region with high IM, the source of drinking water was not associated with infant survival changes [19]. Likewise, it was shown in the study by Shier et al. (1996) that “there was no evidence that the source of drinking water was associated with IMR” [22].
Sanitary facilities	Several studies demonstrated that increased access to improved sanitary facilities was significantly and positively associated with a decrease of IM [8, 14, 17, 25]. Fink et al. (2011) demonstrated that high quality sanitation reduces the risk of IM by 15-23% as compared to low quality sanitation [8]. In addition, Folasade (2000) revealed that infant survival may be endangered by open defecation and unimproved sanitary facilities, such as pit latrines [9]. Kayode et al. (2012) draw the same conclusion: “homes with bad toilet facilities increased odds of U5M by 98% compared to homes with good toilet facilities” [10]. There are, however, studies that conclude that poor sanitary facilities did not appear to be related to U5M [19]. Durkin et al. (1994) for example, indicate that in urban Pakistan and in the rural areas in Bangladesh and Pakistan U5M was not associated with low quality sanitation [52]. Van de Poel et al. (2009) demonstrated that “having a toilet is not significantly correlated with IM risk in either urban or rural areas” [12]. The study by Wang (2003) demonstrates the same results [17].

Appendix 1 continued

Housing characteristic	Evidence
Electricity	Availability of electricity contributes to health, for example by facilitating hygienic storage of food and improving the indoor climate [12]. In sub-Saharan Africa, numerous countries have limited or no access to electricity [37]. Additionally, electricity access levels vary between urban (54%) and rural areas (11%) and between levels of wealth with only 4% of the lowest wealth quintile having access to electricity as compared to 74% of the highest quintile [37]. Households with access to electricity appear to have a reduced risk of infant mortality [12, 16, 17, 40]. The results of some studies indicated that access to electricity has a stronger protective effect in rural areas than in urban areas [12, 52]. However, Wang (2003) found evidence that access to electricity has a larger impact on IM in urban areas than in rural areas [17].
Flooring material	Flooring materials of good quality decrease the risk of IM [16]. Rutstein (2000) demonstrated that "a decrease in the percentage of households with a dirt floor is related to a decline in infant mortality" [16]. Finished floors, covered with tiles or carpets, contribute to a save and hygienic environment. In contrast, unfinished floors made of dirt, mud, sand, clay and / or dung, form a source of infection and increase the risk of contagion [9, 16]. Most research findings suggest that unfinished floors are associated with infant mortality. However, some studies indicate that finished floors are only significantly associated with infant survival in urban areas [12, 52]. In rural areas, on the other hand, earth floors have a protective effect against infant mortality [52]. Although Durkin et al. (1994) did not elaborate on this paradox, Van de Poel et al. (2009) find it plausible that earth floors in urban areas characterize slum dwellings and the poor living and health conditions that distinguish these areas [12].
Cooking fuel	Multiple studies show that the use of solid fuels is associated with an increased risk of infant and child mortality [10, 15, 37, 39]. Some studies show strong evidence [10, 37]. However, Tielsch et al. (2009) stated that: "the strength of evidence for the association between solid fuel use and infant mortality was weak" [40]. The risk of IM is only slightly higher for households that use solid fuel as compared to household that use clean, non-solid fuels [40]. Bassani et al. (2010), on the contrary, concluded that IM was not attributed to solid fuel use [21]. Furthermore, their research suggested that the negative effect of solid fuel use on infant survival was overrated in earlier studies [21]. Nevertheless, Bassani et al. (2010) recommend the use of cleaner, safer non-solid fuels as a means to prevent infant mortality [21].

Appendix 2. Testing for multicollinearity

	Collinearity statistics	
	Tolerance	VIF
Age of the mother at time of survey	.973	1.028
Highest educational level mother	.715	1.399
Sex of the child	.999	1.001
Child is twin	.994	1.006
Place of residence	.528	1.894
Wealth quintile	.258	3.872
Drinking water	.898	1.114
Sanitary facility	.722	1.385
Has electricity	.455	2.198
Type of flooring material	.843	1.230
Type of cooking fuel	.813	1.186

VIF: variance inflation factor