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Chapter 3

SEASONAL VARIATION IN CHILD AND OLD-AGE MORTALITY IN RURAL GHANA

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ABSTRACT

Mortality in tropical countries varies considerably from season to season. As many of these countries have seen mortality moving from child mortality to old-age mortality, we have studied seasonal variation in child and old-age mortality in a rural area in Ghana that currently undergoes an epidemiologic transition. In an annual survey from 2002 through 2011, we followed 29,642 individuals and obtained the cause and month of death from 1,406 deceased individuals by making use of verbal autopsies. When comparing the seasons, we observed a trend for higher mortality during the wet season. When comparing separate months, we observed 34% more deaths than expected in September (95% CI:1.04-1.69, p=0.024) at the end of the wet season and 43% more deaths in April (95% CI:1.13-1.80, p=0.004) at the end of the dry season, while there were 42% less deaths than expected in December (95% CI:0.52-0.70, p=0.003) shortly after the wet season. Cause-specific analysis indicated that the peak at the end of the wet season was due to excess mortality from infectious diseases in children and older people alike, whereas the peak in old-age mortality at the end of the dry season was due to non-infectious causes in older people only. Taken together, our data suggest that during the epidemiologic transition, mortality not only shifts from child to old-age and from infectious to non-infectious, but also from the wet to the dry season.

INTRODUCTION

Worldwide, there is variation in mortality depending on the season.[1-7] In tropical countries with a distinct dry and wet season, this is characterised mostly by excess mortality during the wet season.[8,9] Most studies analysing seasonal mortality have examined these patterns only for mother and child mortality.[10,11] It was found that excess mortality in the wet season is best explained by an increase in gastrointestinal infections and malaria.[8-11]

Currently, many of these tropical countries are experiencing an epidemiologic transition, with mortality moving from child mortality to old-age mortality.[12-15] This is primarily due to improved living conditions and a lower risk to die from infectious diseases.[15-17] At the same time deaths from chronic diseases are on the rise.[14] It is yet unclear how the seasonal variation in mortality has evolved now that many of these countries have undergone major changes in their mortality patterns.

In this study, we have analysed seasonal patterns of mortality among children and older people from a unique population in rural Ghana, which currently experiences the epidemiologic transition. Additionally, we collected the causes of death using verbal autopsies. We first studied whether the dry and the wet season involved a proportional number of deaths and second, whether each month comprised an equal number of deaths. We stratified for age and studied the causes of death to further explore the observed patterns.

MATERIALS & METHODS

Study area & population

The study is conducted in the Garu-Tempane district, which is situated in the Upper East region of Ghana. This region is far less developed than the southern part of Ghana and is highly endemic for malaria (85% of the population is infected with *Plasmodium falciparum*), typhoid fever, meningococcal disease and intestinal helminth infections.[18-22] The research area is situated close to the village of Garu and measures approximately 375 km^2, with almost 30,000 individuals living in around 40 villages. The people in the research area live in polygamous extended families, with an average of 15 people per household. The families live together in compounds: clay structures with thatched roofs, connected by clay walls.[23,24] There are 1,719 compounds in the research area. Most people rely on traditional healers, which are equally distributed throughout the area. Although there are a few basic health care facilities (Community-based Health Planning and Services compounds) in the area, there is no medical doctor present, and the nearest hospital is 40 km away.[21] The vast majority of the population are farmers, and the total agricultural process is done by hand. The local economy is dominated by the Barter system, where goods are directly exchanged for other goods or services.[25,26] From around 1970 onwards, water boreholes that use hand operated pumps to deliver ground water, were introduced to the region. These boreholes were distributed throughout the area by a non governmental organisation, independent of the socioeconomic status of surrounding households. Drinking water source has been assessed at the household level in 2007. In spite of the boreholes, some of the villages still depend on rainwater and water from small streams that flow through the area. Water from boreholes has been found to contain less pathogens and is considered to be safe drinking water, water drawn from either open wells or from rivers was found to contain more pathogens and is therefore considered to be unsafe drinking water.[22]

Climate

The research area is characterized by a pronounced dry and wet season. The area is drier than southern areas of Ghana and is proximate to the Sahel and the Sahara. The dry season is influenced by the Harmattan, a dry and dusty desert wind that blows from the northeast. During this period the humidity is very low and rainfall is entirely absent, resulting in hot days and cool nights. The wet season is influenced by the tropical maritime air mass, which provides the area with rain.[27,28] Exact data of temperature and rainfall in the research area were available from a research project between 1991 and 2004.[23] (Ghana Government Data from the Garu Tempane district provided by Roger Blench)

Between 1991 and 2004, the daily mean temperature is 28.5 °C. The mean minimum monthly temperature is 25 °C, whereas the mean maximum monthly temperature is 32 °C. From November to March, the minimal night temperature is 15 °C and the maximum day temperature 45 °C. The annual mean temperature was 28.9 °C and the annual amount of precipitation 996 mm.

Verbal autopsies

To obtain the causes and time of death, we used the validated verbal autopsy questionnaires from the World Health Organization (WHO).[29-31] In 2011 we performed the verbal autopsies in the area to identify the causes of death in both elderly and children. The WHO verbal autopsy method is based on a semi-structured questionnaire to conduct interviews with relatives or caretakers of deceased individuals. We have translated the English questionnaires into the two major local languages; Bimoba and Kusaal. To test whether the questionnaires were translated correctly, we performed back translations by an independent translator. In cases of discrepancy, the final translation was decided upon after group discussions with native speakers and medical experts. We trained local people from the two main tribes in the area to perform the interviews in people from their tribe in the field. They were instructed to search for the most appropriate respondent, which was in most cases a relative or caretaker of the deceased. The questionnaires were systematically checked by supervisors from the field staff who regularly participated during the field visits as well. From the total of 1,406 individuals that had died from 2003 to 2011 and were registered in the database, we were able to complete 1,263 verbal autopsies (90%). From 10% we were not able to perform a verbal autopsy interview due to various reasons, such as absence at the time of the field visit, no appropriate respondent found or in a few cases refusal to participate. Informed consent was obtained by reading the consent statement from the verbal autopsy protocol of the World Health Organisation aloud in the local language.[29] Consent was documented by signature or thumbprint of the participant. The study was approved by the Ghana Health Service Ethical Review Committee. To assign the causes of death we used a physician review method. In the first round, two physicians assigned the causes of death independently, blinded for each other. The agreement of the first two physicians in assigning the causes of death was in line with other studies using verbal autopsies with an average kappa of 0.41. If there was discrepancy between the first two diagnoses of the physicians, a third physician, who was not blinded for the diagnoses of the first two physicians, gave an independent assessment. A cause of death was determined if at least two of the medical doctors agreed, otherwise the cause of death was classified as unknown. To code the causes of death we used the International Classification of Diseases (ICD) VA-10 coding, according to the WHO verbal autopsy method.[31] To study the seasonal variation in mortality we compiled the various causes of death into two categories: infectious diseases and non-infectious diseases. To test the repeatability of the verbal autopsy interviews, we performed re-interviews in a random selection of 10% of the original interviews. We tested the agreement between the diagnosis of the original interview and the re-interview and found an agreement with a kappa of 0.41. Since a proportion of the local population is not used to using dates and months, data on the exact month of death was not always available. Therefore, we additionally added a question about the season of death (dry or wet).

Socioeconomic status

In 2007 we measured socioeconomic status at the household level using the Demographic and Health Survey (DHS) methods, specifically designed for our research area.[32] First we developed a questionnaire to assess the socioeconomic status of the study participants by using a listing technique whereby we asked people from different villages of the research area, in focus group discussions, to list the household items of most value. We than applied the method used to calculate the DHS-wealth index. For analysis, the results of this DHS-wealth index were split by the median in households with low socioeconomic status (poor) and households with high socioeconomic status (rich). For a detailed description of these methods we refer to an earlier publication of this study.[33]

Statistical Analysis

We used a Fishers exact test to assess whether the observed monthly mortality was significantly different than expected under the null-hypothesis that seasonal variation is absent.[34] We calculated the confidence intervals of the count data based on a Poisson distribution.[35,36] To test for agreement between physicians who assigned the causes of death, and the repeatability of the verbal autopsy interview, kappa values were calculated. All these analyses were carried out using SPSS 18 (SPSS Inc., Chicago, IL, USA). Additionally, we further analysed the data using STL: a seasonal-trend decomposition procedure based on Loess.[37] This is a filtering procedure for decomposing a time series into trend, seasonal and remainder components and was carried out in R.

RESULTS

From 2002 through 2011 we followed 29,642 individuals for mortality in the Garu Tempane District of the Upper East Region of Ghana, as shown in Figure 1.

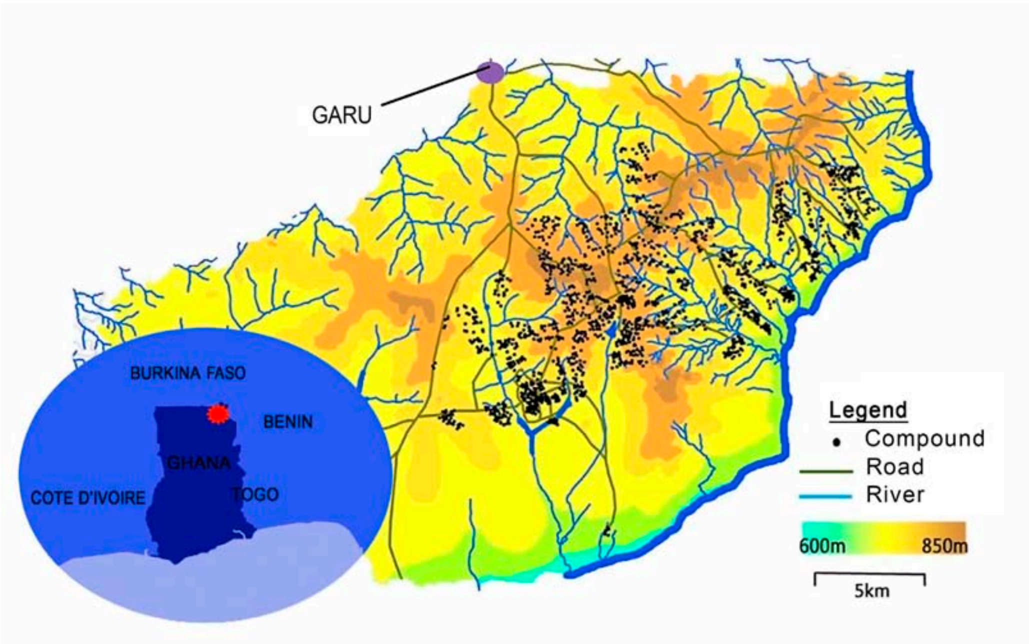

Figure 1. Map of the research area in the Garu-Tempane District in the Upper East Region in Ghana.

The general characteristics of the study population are summarized in table 1. Most individuals lived in compounds with a high socioeconomic status (61%) and had access to safe drinking water (79%). The Bimoba tribe was most represented (66%), followed by Kusasi (26%). Other tribes, including Mamprusi and Fulani together made up to 8% of the deceased individuals.

Table 1. Characteristics of the study population from 2002 trough 2011.

	Study population n (%)	Number of deaths n (%)
Total	29,642 (100%)	1,406 (100%)
Sex		
Men	13,628 (46%)	786 (56%)
Women	16,014 (54%)	620 (44%)
Socioeconomic status		
Poor	10,205 (35%)	580 (41%)
Rich	18,414 (61%)	795 (57%)
Unknown	1,025 (4%)	31 (2%)
Drinking water		
Unsafe	5,677 (19%)	308 (22%)
Safe	23,428 (79%)	1,095 (78%)
Unknown	537 (2%)	3 (0%)
Age		
Children (0-14)	12,613 (43%)	401 (29%)
Adults (15-64)	15,369 (52%)	494 (35%)
Elderly (65+)	1,660 (6%)	511 (36%)
Tribe		
Bimoba	19,451 (66%)	893 (64%)
Kusasi	7,777 (26%)	418 (30%)
Other/Unknown	2,415 (8%)	95 (7%)

During the period of follow-up we observed 1,406 deaths, of which 786 (56%) were men and 620 (44%) were women. Indicative for the on-going epidemiologic transition we observed a decline in the ratio of infectious- over non-infectious causes from 1.2 to 0.7 over the nine years observation period (p for trend 0.014). From the total of 1,406 deceased individuals, we were able to obtain the season of death for 1,061 (75%) individuals and for 627 (45%) we could additionally recollect the exact month of death. These three groups did not differ significantly in their baseline characteristics or recall period.

The monthly variation in the average temperature and rainfall in the research area is presented in Figure 2. Temperature ranges from a mean of 26.8 °C in August to 32.4 °C in March and April, whereas rainfall varies from a mean of 0.2 mm in January and December to a peak of 263.1 mm in August. The area has two distinct seasons, a dry season that lasts for seven months from October to April and a wet season that lasts for five months from May to September.

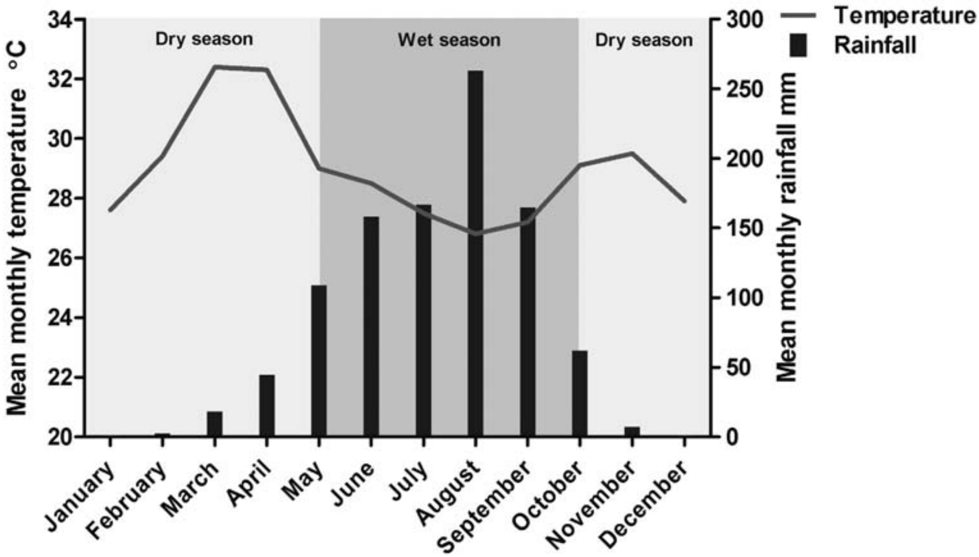

Figure 2: Climatologic variation in the research area, indicated by the mean monthly temperature and mean monthly rainfall. The annual mean temperature was 28.9 °C and the annual amount of precipitation 996 mm. Source: Ghana Government, provided by Roger Blench.

We first analysed the observed number of deaths per month between the wet and the dry season (table 2). Overall there was a trend for higher mortality during the wet season. When stratifying for socioeconomic status, we observed higher mortality during the wet season in both rich and poor households. Finally, we observed that only people who made use of safe drinking water had lower mortality during the wet season.

Table 2. Number of deaths per month in wet and dry season for various subgroups.

	Wet season		Dry season	
	Number of deaths per month	(95% CI)	Number of deaths per month	(95% CI)
All deaths	95	(77-116)	84	(67-101)
Age				
Child (0-14 years)	26	(17-38)	21	(14-33)
Adult (15-64 years)	33	(23-46)	30	(20-43)
Old-age (65+ years)	36	(25-50)	32	(22-45)
Socioeconomic status				
Poor	38	(27-52)	33	(23-46)
Rich	56	(42-73)	49	(36-65)
Drinking water				
Unsafe	26	(17-38)	18	(11-29)
Safe	59	(45-76)	66	(51-84)

* The number of deaths per month were calculated by dividing the observed number of deaths in a season by the number of months in that season. CI = confidence interval.

Next, we examined the longitudinal data series in a seasonal-trend decomposition procedure. We decomposed the mortality data in a seasonal component, a secular trend and remaining variation, as shown in Figure 3. The model identified mortality peaks in April and September and low mortality in December. When comparing the separate months, we observed 34% more deaths than expected in September (95% CI: 1.04-1.69, p=0.024) at the end of the wet season and 43% more deaths in April (95% CI: 1.13-1.80, p=0.004) at the end of the dry season, while there were 42% less deaths than expected in December (95% CI: 0.52-0.70, p=0.003) shortly after the wet season. This seasonal variation overlapped for 44% with the data, while the secular mortality trend overlapped with 51% of the data. Comparing the seasonal trends over calendar time, the mortality peak in April was most pronounced in recent years (data not shown).

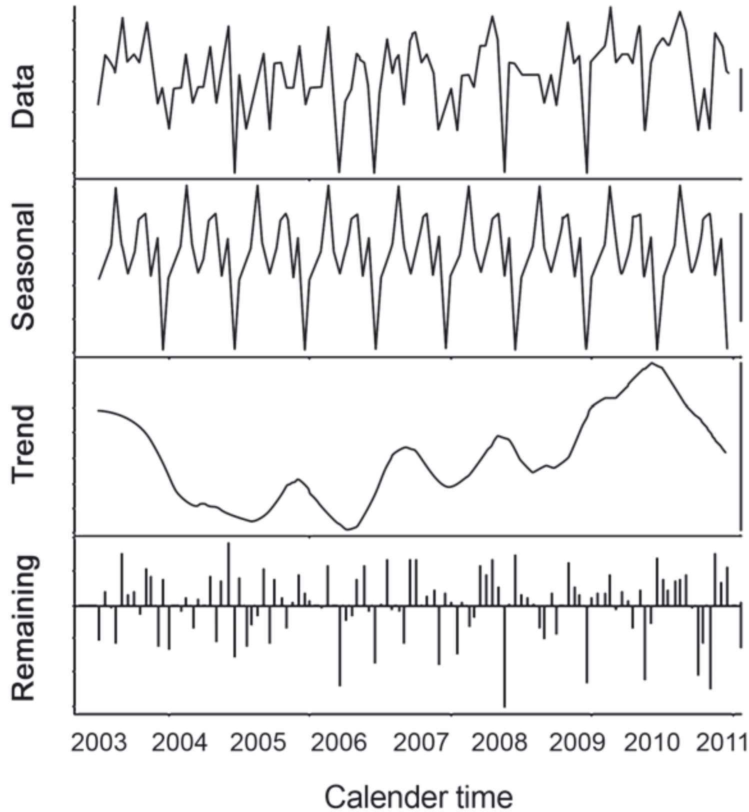

Figure 3. The seasonal variation in mortality over the months from 2003 through 2011. This filtering procedure decomposes the raw data into a seasonal component, a trend and remaining variation.

To further explore the causes of the seasonal variation, we stratified for child and old-age mortality. Figure 4 illustrates that child mortality shows one mortality peak during the wet season in September with 74% (95% CI: 1.09-2.63, p=0.021) more deaths than expected, whereas there was 69% less lower than expected in January (95% CI: 0.08-0.78, p=0.007). In contrast, old-age mortality shows two mortality peaks: in September there were 54% (95% CI: 1.06-2.18, p=0.025) more deaths than expected and in April there were 40% (95% CI: 1.06-2.18, p=0.098) more deaths than expected. In December there were 39% less deaths than expected (95% CI: 0.32-1.04, p=0.073).

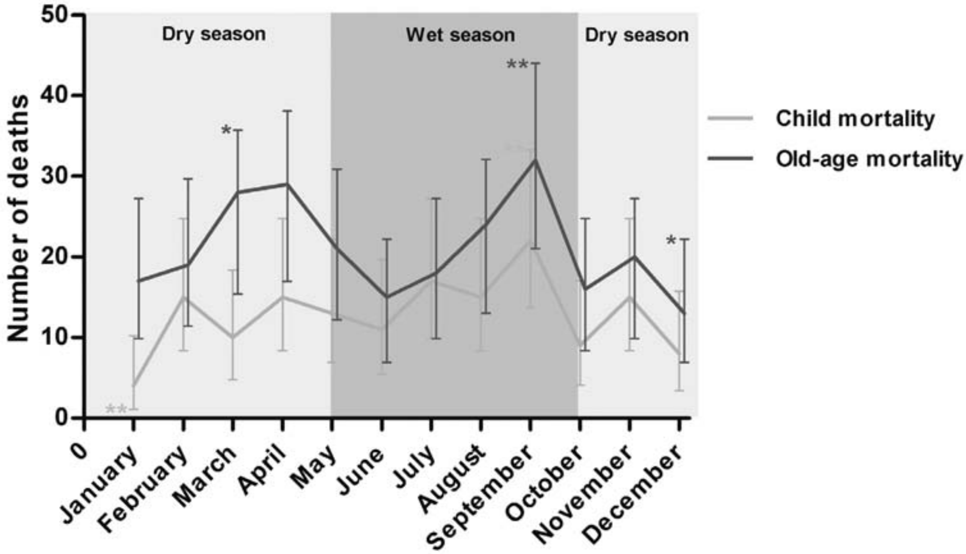

Figure 4. Seasonal variation in child mortality and old-age mortality. Mortality is expressed as number of deaths per month with error bars indicating 95% confidence interval. Stars indicate whether the observed number of deaths in that month are significantly higher than expected. *p<0.1, ** p<0.05

Figure 5 shows the seasonal variation in the number of deaths due to infectious- and non-infectious causes. Among children (panel A), 68% of the deaths were due to infectious diseases and appeared 75% (95% CI: 1.42-2.19, p=0.057) higher in September at the end of the wet season. In January there was 66 % (95% CI: 0.19-0.59, p=0.048) mortality from infectious diseases. Mortality from non-infectious causes appeared to be equally distributed over the months. Among older people (panel B), infectious and non-infectious causes of death were equally common. Mortality from infectious causes in old age peaked in September with 74 % (95% CI: 0.97-2.87, p=0.061) higher mortality, whereas mortality from non-infectious causes peaked with 52% higher mortality in both September and April, (95% CI: 0.87-2.47, p=0.0138).

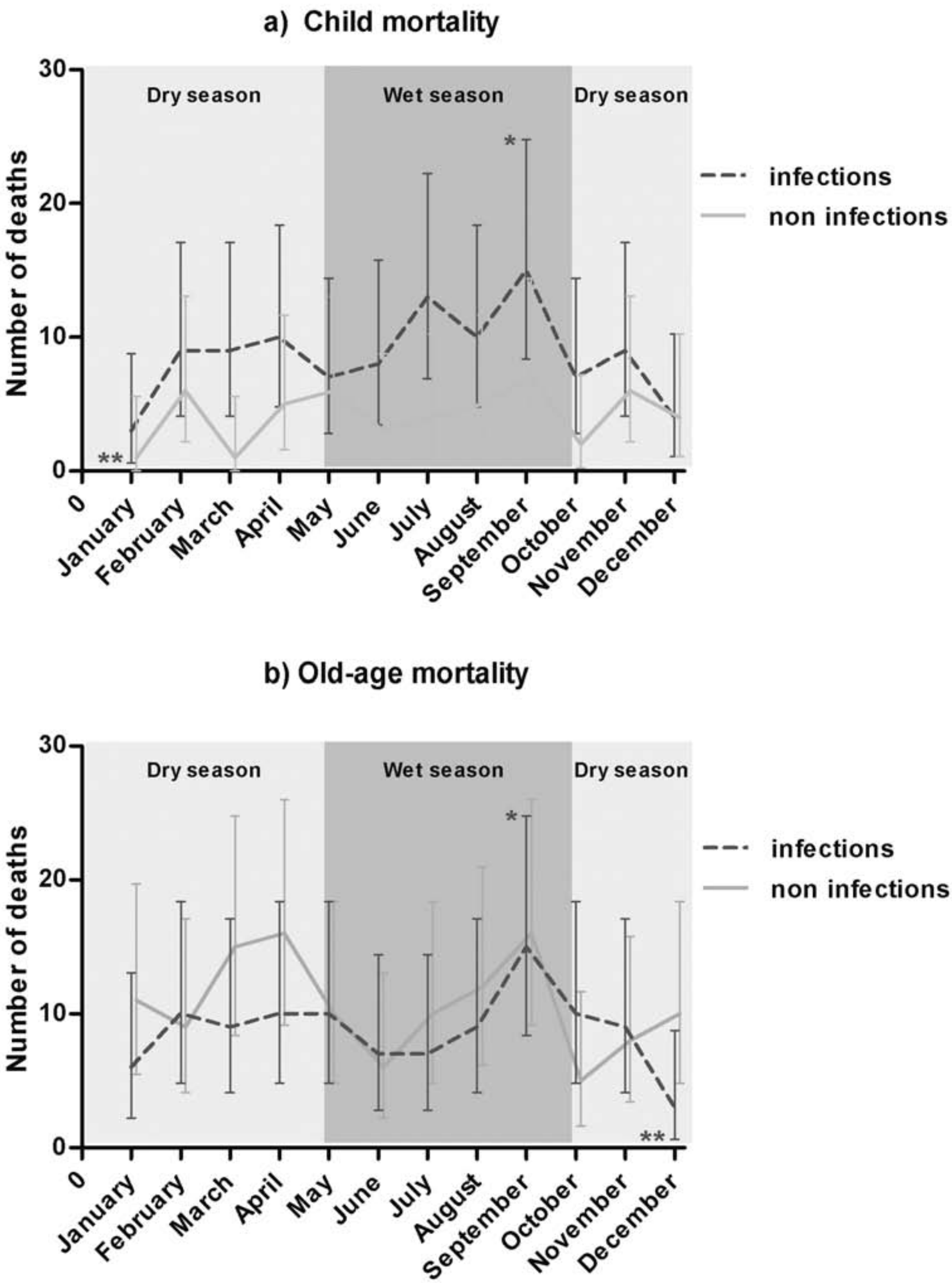

Figure 5. Seasonal variation in mortality from infectious and other causes in child mortality (panel A) and old-age mortality (panel B). Mortality is expressed as number of deaths per month with error bars indicating 95% confidence interval. Stars indicate whether the observed number of deaths in that month are significantly higher than expected. *p<0.1, ** p<0.05

DISCUSSION

In a rural area in Ghana, we have observed a mortality peak in the wet season for both child and old-age mortality that can be explained by an increased number of deaths from infections. There was however, a second mortality peak at the end of the dry season among older people due to non-infectious causes. There was low mortality in the months succeeding the wet season.

Variation in mortality is both, driven by geographical factors such as climatic influences and by individual or household determinants.[38] Therefore, we additionally studied the role of socioeconomic status and the use of (un)safe drinking water. Mortality during the wet season was higher for people from both rich and poor households. Although the effect size was similar for both groups, it was only significant in the (larger) group of the rich. By contrast, water source did influence the seasonal variation in mortality as indicated by the higher mortality during the wet season in individuals using unsafe drinking water. It is tempting to speculate that the observed excess mortality during the wet season in people drinking unsafe water could be explained by contamination of drinking water during the wet season, when unsafe open wells are flooded with surface water.

Climate could influence mortality via its effects on agriculture and disease transmission. Overall, it has been found that sub-Saharan African countries with long lasting rainy seasons have lower mortality rates when compared to countries that have shorter wet seasons. Most likely this is due to the fact that longer wet seasons foster agriculture and hence food abundance.[38] In line with this interpretation we observed low mortality for all age groups in December and January, directly following the wet season. The increased mortality during the wet season has been mostly explained by an increase in gastrointestinal infections and malaria during that season.[8,9,39,40] Our findings in the research area are in line with these data. Prior examination of our group has indicated that guinea worm, schistosomiasis and malaria have a high prevalence at the end of the wet season and the transmission of malaria is highest at that time.[18,39] Compared to the dry season, the wet season shows increased parasitemia and severe anaemia rates in children.[41] Since children and older people are most susceptible to malaria, these factors possibly contribute to the excess mortality at the end of the wet season that we have observed.[40] Also, the incidence of gastrointestinal infections, skin infection and snake bites are higher during the wet season.[40]

The mortality peak during the wet season in September was driven by infectious diseases and affected children and older people alike. By contrast, mortality among older people showed a second peak during the dry season in April, due to non-infectious causes. The excess mortality for elderly could be partly explained by the harsh conditions at the end of this season, when food is limited and expensive, as reflected in the prices of crop and livestock.[23] This is however, not reflected in a higher mortality among children. Perhaps more important for older people, average temperature is highest at the end of the dry season in March and April. This will mostly affect older people with underlying cardiovascular diseases, that are especially prone for heat-associated mortality. During the epidemiologic transition in the area, infectious deceases are decreasing together with an increase in the prevalence of chronic diseases, and this could well be reflected by a change in patterns of seasonal variation in mortality. Hence, the peak in September is most likely to decrease, whereas mortality among older people at the end of the dry season in April will probably increase in the future. This reasoning is supported by the observation that the peak in April was more prominent in recent years.

The clustering of mortality over calendar time is in line with earlier findings in the research area, where we have described significant clustering of mortality, dependent on family and household characteristics, such as socioeconomic status.[42-45] Next to clustering on a geographical and family level we now show that mortality is clustering in time also.

We believe that studying whether mortality is seasonal and in what months we can expect excess mortality are relevant research questions, especially in such a rural environment with high infection pressure. Further insights in the seasonal variation in mortality in rural Ghana can be a first step towards better prevention and public health. We believe we have shown both, that mortality is seasonal and the effect size, or amount of excess mortality in specific months.

Several strengths and weaknesses of this study should be discussed. In a developing country with no available municipal registries, our longitudinal data set is a unique opportunity to study such a remote rural population. The verbal autopsy method is commonly used to assign causes of death in developing countries.[46,47] A limitation of our study is that we performed the verbal autopsy interviews in 2011 with a maximum recall period of eight years. Large variations in recall period could influence the data and it has hence been recommended that verbal autopsies should be performed only within two years after the deaths occurred.[48] However, in our data, the proportion of unspecified causes of deaths was not dependent on the recall period. This could be partly explained by the fact that we only distinguished within the broader categories of infectious versus non-infectious causes of death. An additional explanation could be that since the majority of the people in the study area are farmers and the seasons are clearly linked to distinct agricultural activities, most do not have difficulty to recall the season of death. There was a moderate level of agreement between the adjudicating physicians, and between the original interviews and the re-interviews, which we have considered acceptable given the nature of verbal autopsies. A further limitation is that we lack precise data on fertility and migration rates. If fertility would have a seasonal pattern, this could be reflected in the variation in mortality as well. Migration will have especially influenced our results in young adults, as at this age individuals are most likely to move in and out of the area. It is less plausible that this has influenced child and old-age mortality.

All in all, this study shows that during the epidemiologic transition in tropical countries, mortality not only shifts from child mortality to old-age mortality, and from infectious to non-infectious causes of death, but that the distribution of deaths over the seasons probably changes as well. A better understanding of seasonal variation in mortality is of prime importance for public health policies.

Authors contributions

FE, UE, DvB and RW conceived the study; FE and UE designed the study protocol and collected data; FE and DvB performed the analysis and interpretation of these data. FE, JM and DvB drafted the manuscript; RW and UE critically revised the manuscript. All authors read and approved the final manuscript.

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Competing interests

We have no competing interest.

Ethical approval

Ethical approval was given by the Ethical Review Committee of the Ghana Health Service, the Medical Ethical Committee of the Leiden University Medical Centre in Leiden, The Netherlands and by the local chiefs and elders of the research area.

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