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Spatial and social factors drive anemia in Congolese women

Jane P. Messina [a,*], Kashamuka Mwandagalirwa [b], Steve M. Taylor [c,d], Michael Emch [e,f], Steven R. Meshnick [c]

[a] Department of Zoology, University of Oxford, Oxford, UK
[b] Kinshasa General Hospital (HGBK), Kinshasa-Gombe, The Democratic Republic of the Congo
[c] Department of Epidemiology, Gillings School of Global Public Health, University of North Carolina, Chapel Hill, NC, USA
[d] Division of Infectious Diseases and International Health, Duke University Medical Center, Durham, NC, USA
[e] Department of Geography, University of North Carolina, Chapel Hill, NC, USA
[f] Carolina Population Center, University of North Carolina, Chapel Hill, NC, USA

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ABSTRACT

Anemia is common in women of child-bearing age in the Democratic Republic of the Congo (DRC). As part of the 2007 DRC Demographic and Health Survey (DHS), 4638 women of childbearing age (including 526 pregnant women) were tested for HIV and had the hemoglobin content of their blood recorded. We used the leftover dried blood spots to assess malaria prevalence using PCR assays. The DHS provided extensive information on individuals, as well as the geographic coordinates of household clusters which enabled us to derive several variables that characterize the spatial context of these clusters. Multilevel analyses were conducted to determine individual and contextual risk factors for anemia. Prevalence varied geographically; the odds of anemia were associated with both one's ethnic group and the amount and type of nearby agriculture. The odds were not affected by HIV or malaria status.

1. Background

1.1. Anemia globally and in the DRC

Anemia is a global public health problem. Since 1985, global prevalence estimates for anemia have risen drastically (Stoltzfus, 2001). Estimates are particularly high in Sub-Saharan Africa, where 40–80% of women are estimated to be anemic (Ngnie-Teta et al., 2007b; Ngnie-Teta, 2009). In the Democratic Republic of the Congo (DRC), 52.8% of non-pregnant women and 67.3% of pregnant women were estimated by the World Health Organization (WHO) to be anemic (less than 11 g/dl hemoglobin in the blood), making anemia a severe public health problem in the country (WHO, 2008). In women, anemia is associated with lowered productivity as well as higher risk for maternal morbidity and mortality, and pregnant women have been found to be at higher risk for anemia in developing countries (Bencaiova et al., 2012). Maternal anemia may also lead to higher risk for premature births, perinatal and neonatal death, and low birth weight (Ngnie-Teta, 2009). Symptoms can range from fatigue, weakness, dizziness, and fainting to depression, severe impairment of cognitive function, chest pain, and even heart failure (Ludwig and Strasser, 2001).

There are a variety of causes of anemia. The principal cause is malnutrition, which is common in Sub-Saharan Africa (Conway and Sechler, 2000). Anemia in adults is also the result of deficiencies in specific nutrients such as iron and vitamin B-12 (Dugdale, 2001). Infectious diseases such as malaria, HIV, schistosomiasis, and hookworm have also been implicated as major causes of anemia (Guyatt, 2001; Van Eijk et al., 2002; Ter Kuile et al., 2004). Guyatt (2001) estimated that 26% of cases of anemia in pregnant women in Sub-Saharan Africa are due to malaria (Guyatt, 2001), but the relative contributions of infectious diseases to the overall anemia burden are not known.

Public health interventions which may control anemia include iron supplementation, mass de-worming, and malaria control programs (Pasricha et al., 2013). Iron supplementation programs are common and thought to mitigate anemia, although the evidence for their success is mixed (Stoltzfus, 2001; Scholl, 1994; Palupi, 1997). More information about the causes of anemia could lead to more appropriate applications of these interventions.

1.2. Disease ecology of anemia

The examination of population, behavioral, and habitat factors simultaneously falls under the medical geographic theory of the

* Corresponding author. Tel.: +44 771346 3537.
E-mail addresses: jane.messina@gmail.com (J.P. Messina), mkashamuka@yahoo.com (K. Mwandagalirwa), stevemyertaylor@gmail.com (S.M. Taylor), emch@email.unc.edu (M. Emch), meshnick@unc.edu (S.R. Meshnick).

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cultural ecology of disease, sometimes referred to simply as disease ecology. Although several twentieth century scientists including Jacques May, René Dubos, and Ralph Audy contributed to the formulation of this theory, it was synthesized by Melinda Meade in the 1970s (Meade, 1977) and continues to be an important framework for conducting medical geographic research (Meade and Earickson, 2000; Meade and Emch, 2010; Mayer and Meade, 1994; Mayer, 1996, 2000; Emch, 1999; Meade, 1986, Learmonth, 1988; Gesler et al., 1997). Meade established the "triangle" of human ecology in which habitat, population, and cultural behavior are considered as three nexuses. Habitat is meant as the social, natural, and built environments in which people live; population considers humans as biological organisms with age, gender, and genetic characteristics which make them more or less likely to be hosts of specific diseases; behavior encompasses the beliefs, social organization, and technologies specific to a culture in which a disease may occur.

While much past work has focused on the population and behavioral factors associated with anemia risk and prevalence (Guyatt, 2001; Ayoya et al., 2006; Pasricba et al., 2008; Lartey, 2008; Thomson et al., 2011; Rogerson et al., 2000; Levine et al., 2001; Antelman et al., 2000), little work has explicitly explored habitat factors in relation to anemia. While May (1965) described the ecology of malnutrition in west Africa up until 1965, no studies have specifically addressed the prevalence of anemia in African women from a disease ecology perspective, representing an important gap in anemia literature. Another important gap is the lack of subnational anemia prevalence maps in Sub-Saharan Africa. Microscopically-diagnosed malaria has been found to contribute to higher anemia prevalence (Steketee et al., 2001; Faich and Mason, 1975). However, most malaria infections are submicroscopic and can only be diagnosed by PCR (Okell et al., 2009). The relationship between all malaria infections and anemia has not previously been examined until this study.

1.3. DRC geography and socio-political context

The enormous, low-lying central basin of the DRC slopes toward the west and is covered by tropical rainforest. This area is surrounded by mountain terraces in the west, plateaus which merge into savannas in the south and southwest, and dense grasslands in the north which extend beyond the Congo River (Winternitz, 1989). The extreme eastern region is characterized by highlands. Influenced by this topography, climate, and hydrography, the soil of the DRC offers varied mineral and agricultural potential, but decades of sustained violence and population displacement have negatively affected its physical landscape (United Nations Environment Programme., 2011). Progress has also declined in terms of land restoration, human rights, and the economy, meaning that priorities such as health, education, and infrastructure are extremely difficult to address in the absence of a minimally functioning state (Reyntjens, 2001). As such, many deaths in the country occur as a result of malnutrition despite the vast agricultural potential (Coghlan et al., 2006, 2009). The lack of effective health care systems also means that the distribution and burden of highly prevalent diseases like anemia are poorly understood in the DRC.

1.4. Study aims

The 2007 DRC Demographic and Health Survey (DHS) is the first of its kind in the country, making this study an important starting point for assessing the effects of population, behavioral, and environmental change on the nutritional status of the country's population. Here, in addition to estimating the subnational distribution of anemia in the DRC using the 2007 DRC Demographic and Health Survey (DHS) (Scholl et al., 1994a), population factors such as pregnancy and malaria parasitemia, behavioral factors such as ethnic group and wealth, and habitat factors such as proximity to urban areas, agricultural land cover, and population density are all considered in relation to anemia prevalence. While our data for anemia outcome is from 2007 only and thus does not allow us to directly compare the anemia response over time to important factors such as war, migration, or displacement, in light of the political context, we include all available spatial information regarding the DRC conflict in our analysis (Raleigh et al., 2010). The rich information provided by the DHS survey along with our consideration of an array of individual, environmental, and socio-political factors allows us to provide the broadest, most comprehensive understanding of the determinants of anemia prevalence in the DRC using a framework which has not been used to study anemia in past literature.

2. Methods

2.1. Demographic and Health Surveys

DHSs provide reliable demographic data in developing countries via large population-representative surveys and in some countries also include blood sampling for HIV surveillance. Nine thousand households were surveyed in the 2007 DRC DHS and 99.3% were successfully identified and interviewed. This included 9995 women aged 15–59 years, 4638 of whom were tested for HIV and had the hemoglobin content of their blood recorded using a portable device. Hemoglobin level was communicated immediately to all participants, and those with severe anemia (<7 g/dl for non-pregnant women, and <9 g/dl for pregnant women) were referred to local medical care facilities. Of these 4638 women, 526 reported being pregnant at the time of the interview. While HIV serostatus was determined as part of the survey, malaria status was not. Genomic DNA was extracted from the dried blood spots for testing in real-time PCR assays for *Plasmodium falciparum*, malariae, and ovale as previously described (Taylor et al., 2010; Taylor, 2010). For the current study, altitude-adjusted hemoglobin levels were used and high malaria parasitemia was defined as a cycle threshold (Ct) value lower than 30. Data on clinical symptoms were not part of the DHS database.

2.2. Mapping of anemia prevalence in the DRC

Geographic coordinates of clusters of households were collected with global positioning system receivers. To ensure privacy, the coordinates of the 300 DRC DHS clusters were randomly displaced by 5 km in rural areas and 2 km in urban areas. The number of female respondents per cluster ranged from 6 to 30, with an average of 15. Anemia prevalence was computed for each cluster using the survey's sampling weights and altitude-adjusted hemoglobin levels. The percent anemic in each cluster was computed with a cutoff of 11 g/dl hemoglobin in the blood according to WHO standards for moderate anemia (mild anemia = 11–12 g/dl, moderate anemia = 8–11 g/dl, severe anemia). A smoothed map of the spatial pattern of anemia prevalence in the DRC was then created in a geographic information system (GIS) using inverse distance weighting (IDW) spatial interpolation in ArcGIS 9.3 (ESRI, Redlands CA), an algorithm which uses nearby values to predict prevalence in unmeasured locations. The prevalence values of the 12 closest clusters to an unmeasured location were used to interpolate its prevalence value, with closer clusters having a greater influence than those further away. Compared to other geostatistical interpolation techniques which eliminate high and low values, inverse distance weighting maintains