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Pulmonary function and respiratory health of rural farmers and artisanal and small scale gold miners in Ghana

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ABSTRACT

The recent increase in artisanal and small scale gold mining (ASGM) worldwide has elicited a number of public health concerns for miners and mining communities, including respiratory health. The two primary inhalational exposures of concern are crystalline silica expected to be present in gold ore and smoke from biomass fuels used in cooking. Here, measurements of pulmonary function and of respiratory symptoms were performed in an ASGM community, Kejetia, and a comparison agricultural community, Gorogo, in the Upper East Region of Ghana in May-July 2011. Of 172 participants, 159 performed spirometry, yielding 119 and 95 valid measurements for FEV_1 and FVC, respectively. Percent predicted FEV_1, FVC and FEV_1/FVC, which were lower than predicted for a healthy population, were not significantly different between Kejetia and Gorogo or by mining status in Kejetia. Abnormal lung function was elevated for predicted FEV_1 (15.0%) and FEV_1/FVC (22.0%) beyond an expected five percent in healthy populations. This first examination of pulmonary function in an ASGM community in Ghana (and possibly worldwide) did not show an obvious relationship between mining involvement and lung function abnormality, but did show associations between the use of biomass fuels, adverse respiratory symptoms, and reduced pulmonary function in both populations. A number of factors including age differences between the populations and the required lag time after silica exposure for the onset of respiratory disease may have affected results. Additional research is needed with larger sample sizes and with more detailed questionnaires to further assess the impact of multiple stressors on respiratory health in ASGM communities.

1. Introduction

Artisanal and small-scale gold mining (ASGM) is rapidly growing worldwide with upwards of 15 million miners estimated to be directly involved in the sector and potentially 100 million people living in ASGM communities (World Health Organization, 2016; United Nations, 2012). There are a number of public health concerns in ASGM communities (Basu et al., 2015a). For example, mineworkers and the surrounding community may be exposed to chemical agents present in the gold ore or added intentionally for processing, such as mercury used to form amalgams (Basu et al., 2011; Paruchuri et al., 2010; Rajaee et al., 2015a). Miners often work without personal respiratory protection, protective gloves, or boots (Paruchuri et al., 2010; Calys-Tagoe et al., 2015). Key infrastructure, such as sanitation and health clinics, are often lacking as many ASGM sites exist in impoverished areas (Barry, 1996).

One possible issue of notable concern within ASGM communities is related to respiratory health, though little empirical information exists on related exposures and outcomes. The crushing, grinding, and sifting of gold-containing ore generates dust. Crystalline silica (SiO_2) content of dust associated with some gold ore can exceed 30% (Greenberg et al., 2007), and airborne levels of crystalline silica in ASGM sites can exceed exposure limits (Gottesfeld et al., 2015). Long-term inhalation and/or high-level exposure to crystalline silica can lead to the development of silicosis, an irreversible pulmonary fibrosis disease that can develop from five to 45 years after exposure to silica dust (Greenberg et al., 2007). Silicosis is classically identified by the presence of bronchial opacities on chest radiographs. Exposure to silica can accelerate

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decrements to lung function, which can occur even in the absence of such opacities on a chest x-ray. Silicosis has been shown to accelerate substantial pulmonary function loss among miners, with the degree of the decrease proportional to the severity of silicosis (Ehrlich et al., 2011; Cowie, 1998).

ASGM sites are often situated in resource-limited, rural settings, and thus workers and community members may be exposed to biomass fuel (BMF) smoke. Cooking is often performed either outdoors or inside mud-brick dwellings without windows or roof ventilation, typically using BMF in coal pots or open fires. Cooking smoke from BMFs can affect respiratory health, especially when coupled with lack of ventilation (Fullerton et al., 2008). For example, studies among women who cook with BMFs have shown a correlation between duration of BMF smoke exposure and a decline in pulmonary function (Regalado et al., 2006), an increased likelihood of developing chronic bronchitis (Dossing et al., 1994; Ekici et al., 2005), as well as morbidity and mortality associated with the development of Chronic Obstructive Pulmonary Disorder (COPD) similar to that seen in tobacco smokers (Ramírez-Venegas et al., 2006). It should be noted that acute respiratory infections in children under five years of age comprise the largest single category of deaths from indoor air pollution from BMFs (Smith and Mehta, 2003). It is also important to consider the contribution of tobacco smoke exposure in the development of COPD and other respiratory illnesses (Behera and Jindal, 1991).

Ghana is one of the most important gold-producing countries in the world. Within the country ASGM accounts for 10.5% of Ghana's national gold production and employs between 500,000 and 1 million people mostly in rural areas (Basu et al., 2015b). Since 2009, our research team has conducted field studies to examine associations between a range of exposures and health outcomes in ASGM communities in the Talensi-Nabdam District of Ghana's Upper East Region (Paruchuri et al., 2010; Basu et al., 2011; Renne et al., 2011; Long et al., 2015, 2013; Rajaee et al., 2015b, 2015c). To increase understanding of potential respiratory health effects in ASGM communities, here we conducted a comparative study in the Talensi-Nabdam District of Ghana to compare exposure-outcome relationships between an ASGM community and a non-mining, subsistence farming community, and also focus on two main *a priori* areas of concern for potential adverse respiratory effects to workers and the surrounding community: 1) inhalational exposure to dust and potentially crystalline silica that may be present in gold ore, which is directly associated with the mining process; and 2) the use of biomass fuels for cooking, associated with the general living conditions of such communities.

2. Materials and methods

2.1. Study populations

Data were collected May-July 2011 from participants in an ASGM community, Kejetia, and one non-mining comparison community in the Talensi-Nabdam District in Ghana's Upper East Region. The non-mining community, Gorogo, was selected over other communities because of its lack of gold mining, comparable population size, ease of access, and its hydrologically upstream location relative to local gold mining sites. Institutional Review Board (IRB) approval was obtained through the University of Michigan (HUM00028444). Permission to work with the communities was given by each community's traditional chief.

2.2. Participant sampling strategy

Neither site had community maps, distinct village boundaries, or official population estimates, creating challenges for random sampling. Households in Kejetia and Gorogo were defined by individuals who eat food that is prepared at the same place, in accordance with local cultural norms (Ghana Statistical Service and Ghana Health Service, 2009). In Kejetia, a set of coordinates was recorded for every household in the community using a handheld global positioning system (GPS; Oregon 450; Garmin International, Inc., Olathe, KS). Households were then assigned to twenty clusters of approximately 20 households each based on geographic proximity. Each household was then assigned a number within its cluster. Each day, households were selected by randomly pulling numbers from a bag. Up to three households were interviewed per day, each from a different cluster. Each cluster had two to three participating households in total. If a household was not eligible or declined participation, another number from within the cluster was pulled from the bag until an appropriate household was found (Hoshaw-Woodward, 2001). In Gorogo, the greater geographic dispersion of the community made definition of clusters not feasible. Instead, convenience sampling was done by spinning a plastic bottle at a landmark at the geographic middle of the community and selecting the house that the bottle pointed to most closely. The bottle was then spun from each participating household to find the next household to be surveyed, and from different geographic locations throughout the community. If a household was not eligible or declined participation, a replacement house was chosen by re-spinning the bottle in the same location as the previous spin. The convenience sampling method did appear to cover a substantial fraction of the geographic spread of the community.

2.3. Surveys

Surveys written in English were administered by a team of university students and verbally translated by local Ghanaian translators in the language of choice of the participants (Talen, Nabt, Gurune, Twi, Dagbani, or Hausa). Translators were trained prior to conducting interviews on the appropriate vocabulary and medical terms for health outcomes in the local languages. At each identified household, a request was made to identify the head of household (HOH). Preference for the interviews was given to the HOH, followed by their spouse or any adult (age 18 or older) who appeared knowledgeable about the individuals in the household. The HOH or identified alternative completed a survey on demographics and relationships of people in the household, as well as household characteristics and amenities, including cooking methods to assess BMF exposure. Participants were asked to list all cooking fuels ever used in the household as well as their main source of cooking fuel and cooking locations (to assess indoor and outdoor cooking, where indoor cooking locations included in the house and in a separate building).

A maximum of four adults per household, including the HOH, were administered a separate adult member survey, which included occupational history, smoking history, and respiratory symptoms. Adults were also offered spirometry. When there were more than four adults, decisions on who to interview were made with guidance from the HOH. All the information in the current paper came from the household and adult member survey.

Survey questions were adapted from the Ghana Demographic and Health Survey (Ghana Statistical Service and Ghana Health Service, 2009), the British Medical Research Council Questionnaire (MRCQ) on Respiratory Symptoms, and the American Thoracic Society's Epidemiology Standardization Project (Ferris, 1978). Participants were asked to give the total number of years in each mining activity (excavation, crushing/grinding, sifting, washing, amalgamation, and burning). A composite variable was created to capture the minimum number of years a participant performed the identified mining activities ("minimum years mining"). Minimum years mining were split into two sets of mining activities to distinguish activities likely to have higher dust exposure (excavation, crushing, and sifting) from activities with lower dust exposure (washing, amalgamation, and burning). Current miners were defined as having engaged in a mining activity within the previous three months. Ex-miners have engaged in mining activities, but not within the previous three months.