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How seasonality and weather affect perinatal health: comparing the experiences of Indigenous and non-Indigenous mothers in Kanungu District, Uganda

Abstract

Maternal and newborn health disparities and the health impacts of climate change present grand challenges for global health equity, and there remain knowledge gaps in our understanding of how these challenges intersect. This study examines the pathways through which mothers are affected by seasonal and meteorological factors in sub-Saharan Africa in general, and Kanungu District (Uganda), in particular. We conducted a community-based study consisting of focus group discussions with mothers and interviews with health care workers in Kanungu District. Using *a priori* and *a posteriori* coding, we found a diversity of perspectives on the impacts of seasonal and weather exposures, with reporting of more food available in the rainy season. The rainy season was also identified as the period in which women performed physical labour for longer time periods, while work conditions in the dry season were reported to be more difficult due to heat. The causal pathways through which weather and seasonality may be affecting size at birth as reported by Kanungu mothers were consistent with those most frequently reported in the literature elsewhere, including maternal energy balance (nutritional intake and physical exertion output) and seasonal illness. While both Indigenous and non-Indigenous mothers described similar pathways, however, the *severity* of these experiences differed. Non-Indigenous mothers frequently relied on livestock assets or opportunities for less taxing physical work than Indigenous women, who had fewer options when facing food shortages or transport costs. Findings point to specific entry points for intervention including increased nutritional support in dry season periods of food scarcity, increased diversification of wage labour opportunities, and increased access to contraception. Interventions

should be particularly targeted towards Indigenous mothers as they face greater food insecurity, may have fewer sources of income, and face greater overall deprivation than non-Indigenous mothers.

Keywords: Uganda; perinatal health; climate change; weather; season; Indigenous health

1 Introduction

Climate change will have substantial impacts for populations worldwide (Watts et al. 2015, Smith et al. 2014). In response, research investigating climate impacts on health has grown rapidly in the past two decades. Research has, however, primarily focused on health outcomes with relatively direct or proximal relationships with climate (e.g., infectious disease, heat-related illness, mortality due to extreme events (Smith et al. 2014)). Less attention has been paid to health outcomes with more indirect or distal links to climate or weather, despite predictions that most climate impacts are mediated through indirect social and ecological factors (Watts et al. 2015). Research has shown, for example, an empirical relationship between weather and/or season and size at birth in multiple regions and contexts (Strand, Barnett and Tong 2011, Laaidi et al. 2011, Beltran, Wu and Laurent 2014).

While the effects of climate change will have health impacts worldwide (Costello et al. 2009, Few 2007, Haines and Patz 2004, McMichael, Woodruff and Hales 2006, Watts et al. 2015, Smith et al. 2014), Indigenous populations will face a disproportionate burden of these negative impacts due to their traditional reliance on biophysical resources and existing health inequalities. (Ford 2012). The holistic definition of health in many Indigenous populations means environmental and individual health are seen as inextricably linked, thus the effects of climate change on the environmental are also felt at a personal level in such communities (Berry et al. 2010). Connectedness to the land (both physical and spiritual) is seen as one of the essential components to Indigenous health, and therefore a critical consideration in the planning of health adaptations to

climate change in these communities (Green and Minchin 2014). Much of the literature on Indigenous health comes from North America, Australia, and New Zealand, and to a lesser extent, South and Central America. There is a limited body of literature regarding the health of Indigenous populations in Africa, where the existing burden of ill-health is high and investigation of differential vulnerability between ethnic groups has been negligible (Ohenjo et al. 2006).

The burden of climate change on maternal and infant health will be inequitably distributed. The groups already facing the greatest vulnerability—women, the poor, and Indigenous populations—have been identified as being particularly at risk for adverse health impacts due to climate change (Watts et al. 2015, McMichael et al. 2006, Smith et al. 2014). As Busby et al. (2013) write, ethnicity may prove a key determinant in differential vulnerability to climate change. Already, Indigenous mothers in remote areas often face inequities in perinatal health and are at risk of poorer perinatal outcomes than non-Indigenous mothers (Graham et al. 2007, Gracey and King 2009); poor women in both industrialized and low-resource settings tend to face disparities when compared to their wealthier counterparts (Kramer et al. 2000, Lawn et al. 2009). There is a double-burden of maternal and infant health inequity in populations reliant on subsistence agriculture: subsistence-based Indigenous women are among the most vulnerable populations in the world due to persistent health inequality and reliance on fluctuating food sources.

In both developed and developing settings, low birth weight is considered an important determinant of infant mortality (Kramer 1987, Lawn, Cousens and Zupan 2005, McCormick 1985). More than 80% of neonatal deaths in sub-Saharan Africa and south Asia occur in small babies as a result of both preterm births and intrauterine growth restriction (IUGR) (Lawn et al. 2014). The effects of being born small can persist throughout infancy and childhood (Lawn et al. 2014, Paneth 1995). A number of studies indicate that IUGR may increase risk of a range of adult-onset conditions (Botero and Lifshitz 1999, Barker et al. 2002, Harding 2001, Kajantie et al. 2005, Low et

al. 1992). A combination of birth weight, gestational age, and Apgar scores are the recommended predictors for infant mortality (Ma and Finch 2010), and are often the outcomes of interest when examining in utero exposures (Chou et al. 2014, Porpora et al. 2013).

Maternal energy balance (i.e., food intake versus physical activity output) and seasonal patterns in infectious disease (particularly malaria) are theorized in the literature as the predominant pathways through which season and weather affect pregnant women in low-income country settings (Rayco-Solon, Fulford and Prentice 2005, Laaidi et al. 2011, Beltran et al. 2014). For populations reliant on subsistence agriculture, seasonal food shortages and seasonal trends in agricultural labour activities are affected by weather and seasonality. Though research is mixed, most literature has reported that increased incidence of lower birth weights coincides with periods of increased energy expenditure, particularly when these periods coincide with food shortages. Variation in patterns of malaria and other infectious diseases have also been associated with both weather and birth outcomes, with malaria believed to be a key pathway for low birth weights resulting from preterm births (Kinabo 1993; Rayco-Solon et al. 2005). Grace et al. (2015) investigate the role of weather on birth outcomes across Africa, characterizing the variation in the relationships between weather and birth weight across different livelihood zones . What remains unclear, however, is the extent to which these aggregated results mask heterogeneity in the effect of weather on birth outcomes in different countries, contexts, and *within* livelihood zones.

Climate, agricultural practices (Grace et al. 2015), birthing and pregnancy cultures (Brighton et al. 2013, Magadi, Madise and Rodrigues 2000), and malaria transmission patterns (Noor et al. 2014) differ regionally, and the direction, magnitude, and nature of weather and/or climatic determinants of infant health vary in diverse contexts (Strand et al. 2011, Laaidi et al. 2011, Beltran et al. 2014, Carolan-Olah and Frankowska 2014, Chodick et al. 2009). Further, inequities in maternal and infant health are multifactorial in origin, and arise based on different factors in different

96 contexts (Wirth et al. 2006). This regional diversity necessitates local studies characterizing the place-
97 specific experience of weather and season during pregnancy. Where regional differences do exist,
98 we do not yet have a complete picture as to how and why they differ—do the pathways through
99 which weather and pregnancy experiences may be linked differ in different regions? To date, there
100 has been limited qualitative investigation characterizing the pathways linking weather to birth
101 outcomes, and whether these are heterogeneous across and within populations. With the exception
102 of one paper among nomadic Turkana pastoralists (Pike 2000), we are aware of no studies exploring
103 the pathways by which weather influences perinatal health using empirical results from fieldwork
104 and qualitative analysis.

105 We address this research gap by bringing a qualitative lens to a problem that has primarily
106 benefitted from quantitative examination. This paper contributes to our understanding of how and
107 why season and weather influence pregnant mothers and newborns in a rural east African setting,
108 specifically among Indigenous and non-Indigenous subsistence-based populations in rural Uganda
109 where we have previously identified associations between *in utero* rainfall and temperature exposures
110 and birth weight [Anonymous Under review A]. Despite significant progress through Millennium
111 Development Goals initiatives, maternal mortality in Uganda remains 325 per 100 000 (Kassebaum
112 et al. 2014) and infant mortality 22 per 1000 live births (United Nations Inter-agency for Child
113 Mortality Estimation (UN IGME) 2014). We focus on some of the most vulnerable mothers within
114 this context (Indigenous women whose babies are born on average 295.5 g smaller than the general
115 population) [Anonymous under review A (on request)], and identify the most pressing needs of
116 these mothers and develop initiatives to enhance maternal resilience. The unique context in
117 Kanungu, a region in which Indigenous and non-Indigenous populations live in the same
118 environment with the same health services, permits study of the social modifiers of women's
119 experiences during pregnancy. In this context, study objectives were to: 1) qualitatively characterize

how mothers and health care worker key informants perceive seasonal and weather exposures to influence pregnancy and birth in Kanungu District, Uganda, and 2) assess compare the experiences of these pathways between Indigenous and non-Indigenous mothers.

2 Methods

2.1 Theoretical approach

This study is grounded in the theories and methods of health geography, and is guided by the integral consideration within health geography of *place* and *space* as important predictors of health (Jones and Moon 1993, Macintyre, Ellaway and Cummins 2002). By situating this research as a geographic inquiry, there is a freedom to not only assess whether or not a relationship exists between environmental conditions and birth outcomes, but also to investigate *how* and *why* it exists. One of the key elements in the shift from medical geography to health geography is the emphasis on the use of critical theory to understand health disparities as a product of larger-scale forces and systematic inequities (Cutchin 2007). Our inquiry is driven by the vulnerability approach (Adger 2006) which recognizes that climate vulnerability will manifest through existing social gradients. We tackle the question of environmental impacts on pregnancy from a critical realist perspective (Yeung 1997), an approach focused on translating this knowledge into social change (Ng and Muntaner 2014) and emphasizing the policy relevance of findings (Fletcher 2017).

2.2 Study population

Kanungu District is located in southwestern Uganda, bordered by the Democratic Republic of the Congo to the west and by protected park lands to the north (Kigezi Game Reserve) and south (Bwindi Impenetrable National Park). In addition to subsistence agricultural activities, there is considerable influence from the tourism industry in the region. Industrial tea and coffee production also play a role in local livelihoods. The adult literacy rate in the region is comparable (71.9%)

(Kanungu District Local Government 2013) to the national rate (73%) (UNICEF 2014). The region experiences bimodal seasonality, with rainy seasons from October to December and again from March to May, and low average temperatures relative to the rest of Uganda (typically below 20°C) (McSweeney, New and Lizcano 2010). Climate change projections indicate that the region will likely experience increases in annual mean temperature and frequency of heavy rain events (Anyah and Qiu 2012, Christensen et al. 2013).

[INSERT FIGURE 1 HERE]

Figure 1. Map of Kanungu District

The Bakiga ethnic group, a traditionally agrarian society, make up the majority of the population of Kanungu District. One percent of the population (approximately 800 inhabitants) are members of the Indigenous Batwa ethnic group. The Batwa [Anonymous 2012] and Bakiga [Anonymous 2015 A] have both been identified as being highly vulnerable to the health impacts of climate change. Perinatal health indicators for the region are also below national averages—only about 40% of births occur in health facilities (Uganda Bureau of Statistics (UBOS) and ICF International Inc 2012) as opposed to 57% nation-wide (UNICEF 2014). Though 59% of Ugandan infants are delivered by a skilled provider, skilled providers are only present at 42% of births in the Southwest Region (Uganda Bureau of Statistics (UBOS) and ICF International Inc 2012). In a sample of newborns delivered at Bwindi Community hospital, the prevalence of low birth weight births (<2500g) was 7.2% and the prevalence of preterm births was 8.1% [Anonymous Under review A].

The Batwa ethnic group are a subgroup of the Central African Pygmy population and the Indigenous residents of the Bwindi Impenetrable Forest [Anonymous 2012]. The Batwa have faced historic oppression and marginalization, not unlike other Indigenous populations worldwide, and they face a greater burden of climate change vulnerability [Anonymous 2012, Anonymous 2016 B,

Anonymous Under review B]. Evicted from their homes when conservationists created the National Park in the early 1990s, the Batwa were forcibly resettled in agrarian communities despite their history as traditional hunter-gatherers (Ohenjo et al. 2006, Jackson 2006) [Anonymous 2012].

There are deep health disparities between the Batwa and both the Ugandan population at large and the neighbouring Bakiga ethnic group (which has historically existed in settled agriculture-based communities), despite the fact that both groups live in the same biophysical environment with identical health services [Anonymous 2012]. The Batwa have a higher prevalence of malaria (9.4% compared to 4.5% in the Bakiga population [Anonymous 2016 A]) and acute gastrointestinal illness (compared to East Africa [Anonymous 2015 B]). The Batwa also face extreme food insecurity [Anonymous Under review B]. The prevalence of HIV among the Batwa population is lower than that in the Bakiga population (Birungi 2010). The two ethnic groups have some interaction, primarily when Batwa women perform wage labour for Bakiga farmers.

Table 1. Indicators of socioeconomic status among Batwa and Bakiga communities. (Adapted from [Anonymous Under review A])

Measure (variable descriptor)	Batwa (proportion of the population)	Bakiga (proportion of the sample)	Source
Moderate acute malnutrition among adult women (classified as moderately malnourished according to Uganda Ministry of Health Integrated Management of Acute Malnutrition Guidelines)	45.86%	0.42%	[Anonymous 2017]
Household mosquito net use (did not have nets)	70.99%	53.56%	[Anonymous 2016 A] (by request)
Assets (did not have any assets)	62.12%	19.01%	[Anonymous 2016 A] (by request)
Access to handwashing facilities (did not have access to handwashing)	73.85%	56.40%	[Anonymous 2016 A] (by request)
Access to soap (did not have access to soap)**	75.38%	62.06%	[Anonymous 2016 A] (by request)

**Only asked of people that had access to hand washing facility, for example for the Batwa, 32 or 94% of the households that had access to handwashing had access to soap

In 2003, the Bwindi Community Hospital (BCH) was established by American medical missionaries as an outreach clinic for the Batwa. It has since expanded to an inpatient hospital with a catchment area population of 100 000 (BCH n.d.). BCH's antenatal clinic sees approximately 250 mothers per month and over 1000 deliveries are performed at the hospital annually (BCH 2014). The hospital also operates a Waiting Mothers Hostel, where women who live far away can stay during the weeks leading up to their deliveries (BCH 2009), and Village Health Teams from the hospital provide outreach to both Indigenous and non-Indigenous communities through the region on a monthly basis (Haven Nahabwe, Public Health Officer, Bwindi Community Hospital, 2015, conversation). All of the healthcare workers at the hospital are non-Indigenous.

2.3 Indigeneity and birth weight in Kanungu

Defining Indigeneity remains a global and domestic challenge, and there is no universal consensus on its definition and criteria (Stephens et al. 2006). The question of what it means to be Indigenous in Africa is particularly contentious, and while there is little formal recognition of Indigenous peoples by national governments, it is estimated that there are 14.2 million self-identifying Indigenous people in Africa (Ohenjo et al. 2006). The Pygmy peoples of Central Africa, of which the Batwa are a subgroup, number an estimated 920 000, a small proportion of whom live in Uganda (Olivero et al. 2016). Though Indigeneity is often presumed to be a function of being tied to specific geography, self-identification and the relationship of the group to a dominant state body have become more salient qualifiers of Indigeneity (Maybury-Lewis 2002). In the case of the Batwa, their historic marginalization and discrimination relative to the non-Indigenous ethnic majority have translated into existing and persistent health and socioeconomic inequities (Table 1). Despite contested definitions, the Batwa history (Jackson 2003) and current experiences [Anonymous 2012] are consistent with most constructs of Indigeneity, including long-standing reliance on existing lands and resources (Stephens et al. 2006, Shaw, Herman and Dobbs 2006), dispossession from traditional

208 resources, local stigmatization as 'other' compared to neighbouring populations, ongoing
209 discrimination and inequity based on their ethnicity (Maybury-Lewis 2002), and importantly, self-
210 identification as 'Indigenous' (Martinez Cobo 1981).

211 We sought to characterize how the pathways identified in existing literature linking weather
212 to birth outcomes were applicable to, manifested within, and differed between Indigenous Batwa
213 and non-Indigenous neighbouring Bakiga. A quantitative relationship between meteorological
214 factors and birth outcomes has already been established among Batwa and Bakiga, finding that there
215 is not only a difference in *magnitude* of the effect of weather on birth weight by ethnicity (effect
216 modification), but that the high-risk period of gestation and the meteorological variables of
217 significance differ as well [Anonymous Under review A]. This prior work revealed a significant
218 relationship between exposure to more days of precipitation and higher average temperatures in the
219 third trimester and birth weight. This relationship was different for the two ethnic groups: in the
220 non-Indigenous population, only exposures in the third trimester were associated with birth weight,
221 while the birth weights among infants from the Indigenous Batwa ethnic group were associated with
222 average temperature exposure throughout pregnancy. In this paper, we thus sought to qualitatively
223 characterize the pathways underpinning these previously established relationships, herein conducting
224 a qualitative, community-based study with Batwa and Bakiga mothers and health care workers in the
225 region.

226 **2.4 Data collection**

227 The research was guided by a community-based participatory research approach (Wallerstein and
228 Duran 2006, O'Fallon and Dearry 2002), building on existing partnerships with both Batwa and
229 Bakiga communities, the Bwindi Community Hospital, and the Batwa Development Program. The
230 research is underpinned by a phenomenological philosophy that is used to understand the
231 "common or shared experiences of a phenomenon" of several individuals (Creswell 2013, 81). We

sought to understand the individual and group perspectives of how mothers experienced the effects of weather and season during their pregnancies. The study was conducted from June-August 2015 in Kanungu District, Uganda. Qualitative data collection took two forms: focus group discussions (FGDs) in both Batwa and Bakiga communities (n=16 FGDs, 8 Batwa and 8 Bakiga), and key informant interviews (KIIs) with community members and hospital employees (8 KIIs, total n=10 individuals).

We sought permission from the village chairperson in advance of each focus group and held each gathering at a designated communal gathering area within each settlement. Each group consisted of five female participants, selected from all village women available on the day of the focus group. A diverse range of ages was selected for each discussion to invite historical perspectives from elder community members. Focus groups included both primagravidae and multigravidae mothers. Discussions were conducted in Rukiga, the local language, with translation through two local research assistants known to the communities. One research assistant facilitated the discussions and provided translation after each response, while the other assisted with the logistics of gathering the women and provided simultaneous translation as needed (Esposito 2001). This early stage translation approach (Santos, Black and Sandelowski 2015) offered flexibility to English-speaking researchers to redirect lines of questioning as appropriate and to better gage participant engagement (MacKenzie 2016, Esposito 2001). The discussion guide was designed to elicit storytelling and open-ended responses, and was structured around three topic areas: personal background, pregnancy experiences and childbirth experiences. Questions around environmental exposures during pregnancy were open-ended, but included specific questions around diet, physical work, and patterns of illness based on the three primary exposure pathways we had observed in the literature. The total recorded focus group discussion time was 661 minutes and the average length per

255 discussion was 41 minutes. All participants were remunerated in a manner determined in
256 consultation with local partners (with community lunches or gifts of soap for individual mothers).
257 Semi-structured interviews were conducted with key informants (Brown and Durrheim 2009,
258 Fylan 2005) according to the interview guide included in our Supplemental Materials. All informants
259 were given the choice of language of interview; with the exception of one key informant, all
260 interviews were conducted in English (the official common language of Uganda). All key informants
261 were staff affiliated with the Bwindi Community Hospital except for one community informant. All
262 participants received a modest token of appreciation (e.g., pen, key chain) but no monetary
263 compensation from the researchers, as per hospital policy. The total recorded interview time with
264 key informants was 344 minutes, with an average interview length of 43 minutes.
265 The research team conducting focus groups included two outside female researchers
266 ([removed for blind review]) with unmistakable identifiers of privilege (both being white North
267 American researchers). The history of unethical research conducted on Indigenous and other
268 vulnerable populations (Smith 1999) was a constant consideration as we tried to minimize power
269 imbalances and create an environment where women felt safe discussing personal experiences of
270 pregnancy and childbirth. Confidentiality was stressed in each interview and focus group facilitators
271 explained that there were no 'right' or 'wrong' answers. Despite measures taken to ensure that
272 participants felt safe and comfortable sharing information with researchers, participants were
273 sometimes reluctant to divulge information about the things they perceived as frowned upon by
274 healthcare workers (e.g., use of traditional medicines). We acknowledge the unequal power
275 relationships that persist in spite of our efforts to balance power differentials in focus group and
276 interview settings (Nunkoosing 2005).
277 We obtained ethics approval for this research protocol from the [institution names removed
278 for blinded review] University Research Ethics Board, as well as from the Bwindi Community

Hospital administration. Informed consent was obtained prior to all research activities, and participants were informed that they could end the interview at any time. To protect confidentiality outside of the group and beyond the focus group, no demographic information was sought from focus group participants apart from the number of children they had and the number of pregnancies they had experienced. Key informants were offered the choice of being named or anonymous in research notes and any subsequent publications.

2.5 Data analysis

All interviews were audio recorded with consent from participants. The recordings were subsequently transcribed and verified for accuracy 1-2 times prior to coding. The recordings of all focus groups conducted in Rukiga were translated by a translator who was present at all focus groups but was not the discussion facilitator. This meant that the research team had a second opportunity to verify the translations that were recorded in the initial discussions, allowing us to seek clarification on any terms or cultural concepts that were unfamiliar.

As with data collection, data analysis was guided by a phenomenological approach. In this study, the phenomenon of interest was how women experienced seasonal and weather exposures during pregnancy and the health effects they attributed to these exposures. Throughout the data collection process, memoing (Birks, Chapman and Francis 2008) was used to capture our initial impressions during the interview and focus group processes. Through memoing, we generated a list of significant statements that were later used to guide the coding process (Creswell 2013). We drew on the dominant pathways identified in the systematic literature review to guide *a priori* deductive coding (Crabtree and Miller 1999) while also examining transcripts for any *a posteriori* inductive themes that could emerge (Pope, Ziebland and Mays 2000, Fereday and Muir-Cochrane 2006). The framework of the interview guides allowed researchers to hone in on topics relevant to the analysis

of pathways through which seasonal or weather exposures may be affecting perinatal health, and to code any mentions of concepts related to maternal nutrition, physical labour, or infectious disease.

3 Results

3.1 Lived experience of pregnancy and seasonality

A nine-month gestation means that all mothers experience the effects of both rainy and dry seasons at various points in their pregnancies. Mothers and key informants reported that they observed seasonal differences in the experiences of pregnancy. Respondents identified seasonal variation in food supply and strenuous labour, as well as seasonal patterns in illness, as the primary ways they were affected by season or weather during pregnancy. Focus group participants connected these factors to the health of their babies: stated ways to have big healthy babies included "*not working so hard*," "*having peace,*" and "*not becoming sick, and even eating well*" *(Batwa FGD 7B)*. The dry season was identified as the period of greatest food scarcity, though many also reported environmental challenges during the rainy season as well. Many women highlighted maternal nutrition as the most important factor affecting the health of their infants, and associated lack of food with the most severe outcomes, stating: "*we don't have those foods [in the dry season], that's why we produce smaller babies,*" *(Batwa FGD 6B)* and "*that's the reason why our babies die in our stomach, because we don't have food*" *(Batwa FGD 7A)*. These statements reinforce prior research demonstrating high levels of food insecurity in the region, particularly among the Batwa [Anonymous Under review B].

Few FGD participants perceived a difference in the health and size of their babies based on the season of their birth. One focus group participant stated: "*dry season, or rainy season, the babies are all the same*" *(Batwa FGD 2A)*. Individual mothers did not associate seasonal effects on birth outcomes when considered in the broader context of their livelihoods and other health and prenatal stressors. In contrast, a local traditional birth attendant working in the area for over forty years, who has

experienced the birth of a large number of babies, reported that "*the baby of the rainy season is always big. It's because of eating well*" (*KII 6).*

Both mothers and hospital key informants emphasized access to health services as one of the predominant challenges faced by pregnant women in the region. Respondents expressed that it was difficult for mothers to leave seasonal work opportunities that sustained their families and to leave other children at home to attend antenatal care or to come to the hospital for delivery. Transport to health services was a critical barrier, both financially in times when paid labour was scarce, and physically in the rainy season when road conditions worsened:

> *And also it would become the dry season, where you find most of the jobs… these mothers… they have no money… most of them go work for others, to get some little money, get some food... So [in the] dry season, where are most of the [mothers coming to the hospital]? (KII 4)*

However, especially when it came to their desire for what they considered to be a "*good*" *or* "*safer*" *(Batwa FGD 2B)* delivery at a health care facility, many women shared an attitude of resilience, explaining that you find a way to the hospital however you can (e.g., by taxi, motorcycle, or walking up to ten hours) because delivering at home is too great a risk to take—as one participant described, if she cannot make it to the hospital, "*I have to deliver [from home] and wait to die.*" *(Batwa FGD 1B).*

3.2 Reported pathways between meteorological conditions and birth outcomes

3.2.1 Maternal nutrition

Eating well was identified in nearly all focus groups (n=15) as a crucial determinant of a healthy pregnancy and healthy baby. Mothers also identified this as a factor that varied seasonally, with all but one focus group confirming that there was less food available in the dry season:

> *In the rainy season, you find you go to dig somewhere and you get food. You eat, and the baby inside is receiving that food. And you find that you even got some vitamins for the baby. But in the*

dry season, you find you have no energy, you stay home, you have not gone to look for food, even the baby inside will not have energy. (Batwa FGD 6A)

Key informants also reported the dry season as the period of greater food scarcity. A traditional birth attendant explained, *"In the rainy season, that is when the food is available, like greens and some other foods. So you find the woman is healthy in the rainy season" (KII 6).* She explained the effects of this lack of healthy food on the babies of malnourished mothers, stating that "*the babies [born in] the rainy season are not the same as the dry season. The baby of the rainy season is produced healthy and the one of the dry season is not healthy*" *(KII 6).* Cost of food increases in the dry season as a result of scarcity: "*in the dry season, their food is expensive… in the rainy season it's in the harvesting time, and their food is available. But in the dry season, there is no food*" (*Bakiga FGD 8A*). Quality of food available in the dry season was also of concern: "*in dry season, the greens are very few,"* stated one focus group participant (*Bakiga FGD 4B).* One key informant who had expressed concern at how the seasonal trends in food insecurity affected mothers also highlighted that changes in weather patterns have begun to affect agriculture in the region:

Sometimes, you may expect rainfall in a certain season… you may find... it's time for rainy season, winter, but [the sun] is shining heavily, every day. When it should be dry season, it's raining. So maybe you go and plant crops expecting rain and then the rain ceases for a month, then you make a loss, so this is difficult. Or, you have planted crops, and because you get a lot of rainfall, then they can't grow, or it's erosion, you find all of the crops planted, they are swept off by moving water. (KII 9)

3.2.2 Physical labour

Energy expended through physical work was described by participants as being season-dependent. Participants described physical labour as being stratified across different livelihood activities. Rainy season work included weeding, planting, mulching, and digging in the gardens. These activities were

described as being more difficult than most dry season work: harvesting, preparing the gardens, drying crops, and weaving mats and baskets. Though digging was one of the predominant activities in both seasons, participants stated that they spent longer hours digging in the rainy season than in the dry. As one key informant described it:

> *We usually have a lot of work in the rainy season because most of the activities are being done, compared to the dry season; in the dry season, there is harvesting of some crops and preparation of crops…when it rains, you have to prepare and wait for rain... then you start growing crops, planting crops. (KII 9)*

Several women stated that being pregnant in the dry season was advantageous because it meant they would have already planted their crops and would not need to go back to the gardens to dig. The heat and hardness of the soil in the dry season were listed as intensifying strenuous work during the dry periods. Women were aware of the potential for adverse outcomes due to overexerting themselves with physical work during pregnancy: "*[there are] some challenges, like digging, and you dig a lot and you find you have some abdominal pain and you even can end up getting some abortion or miscarriages*" *(Batwa FGD 7B).* However, their experiences of physical work during pregnancy varied. Some women described working up until the time of delivery (even to the extent of needing to deliver in the garden), while others stopped working as early as the first trimester if they were feeling ill.

The ability to choose not to work was not available to all mothers. Some were motivated to work by cravings for more expensive foods ("*When my heart wants meat, I have to go and dig for the money, then I buy meat." – Batwa FGD 2B*). Others worked to ensure the immediate survival of their families. Stories from key informants highlighted the high levels of poverty among the population:

> *Mothers work a lot in their pregnancy. Not only to earn money to attend the facility, but also because they are the basic unit of the household's survival, so, to some mothers, it is the least of their worries: money that will take them to the facility. Because they are still at day-to-day*

survival. That is shown in how those mothers who present to us... She presents with mud on the feet, meaning that labour started when she was in the field. … (KII 1)

3.2.3 Seasonal illness

Mothers told us that illness strikes in all seasons, but that there were seasonal differences in the types of illnesses prevalent in the area. Focus group participants stated that in the rainy season "*there is a lot of malaria and coldness, compared to the dry season" (Batwa FGD 7A).* Women were acutely aware of the dangers of contracting malaria during pregnancy, associating it with pregnancies ending in miscarriage. Mothers were well informed of prophylactic interventions providing protection from malaria during pregnancy and many reported use of malarial prophylactics in prior pregnancies. In the dry season, focus group participants identified hunger and fatigue as the primary threats to their wellbeing. Feeling a lack of energy in the dry season was expressed by many mothers and confirmed by a traditional birth attendant key informant, who stated *"In the rainy season they [pregnant mothers] have energy, but in the dry season they have no energy*" *(KII 6).*

Maternal nutritional status plays an important role in seasonal variation in anemia, a phenomenon highlighted by both participants and key informants alike. A participant stated: "*during the dry season, we find we have no energy and there is a lot of sweating. We find there are no greens for eating. When we go to the hospital, we are told that we are lacking blood in our bodies*" *(Batwa FGD 1B).* One key informant expressed that cases of severe anemia in pregnancy were somewhat rare, since pregnant women would prioritize their own nutritional needs and sell assets if needed to safeguard the health of their foetus. However, the risks remain high, as several stated that the reason a woman might miscarry is because she lacks the good foods (especially green leafy vegetables) that will help prevent anemia. One key informant linked anemia to meteorological factors:

…in the past, like half a year, we had a very dry period from December through January, up to… end of March, that's when a bit of rain started coming. And in that period, we had two pregnant mothers coming in with very severe anemia. (KII 1)

Mothers expressed concern at the effects of anemia on their infants: "*The way you are in the dry season, that is how the baby will be when it is produced. When you are low on energy in the dry season, the baby produced, will also have low energy and low strength.*" *(Batwa FGD 1A).*

3.3 Comparing experiences of Batwa and Bakiga mothers

When asked if there were differences between the challenges faced by Batwa and Bakiga mothers, a hospital administrator key informant stated, "*the challenges faced by Batwa and Bakiga mothers, they're the same challenges. They face the same challenges. They live in the same environment... so they face the same issues*" *(KII 10).* Batwa and Bakiga mothers reported similar experiences of seasonal and weather exposures during pregnancy, however, the extent or *magnitude* to which these exposures influence their health differed. Bakiga mothers spoke of selling off livestock to pay for transport to access health services but no Batwa women mentioned such an option. Batwa mothers consistently reported that they were unable to earn enough money for transport, and would deliver from home. Bakiga women were more likely to report stopping physical work when such work became untenable with their pregnancy. Batwa mothers rarely reporting reducing physical work. One Batwa mother stated: "*If I sit at home, who will go and dig for me? So I have to go*" *(Batwa FGD 6B).* A key informant who has worked among the Batwa for five years described the differences in the challenges facing Batwa and Bakiga mothers:

All those challenges… for the Batwa, it's much, much, much, much worse. …it's very hard, it's cost of food… they don't have food at all. I may call it severe. (KII 9)

Last year we lost one Mutwa [Batwa singular], and their total population is fewer than a thousand. And for women of reproductive age… when you lose one woman out of 200, you feel it. (KII 2)

Older Batwa mothers recalled the foods they would eat in the forest prior to eviction, expressing frustration with being restricted from accessing the forest herbs that were used for medicinal purposes. Some Batwa women stated that they had larger babies when living in the forest: "*Because we used to eat honey, and used to get fish from the water, that's the reason why we used to produce healthy babies*" *(Batwa FGD 6B)*. Despite these losses following their eviction from the forest, many Batwa women praised the positive impact the hospital has had on their health during pregnancy, mentioning in particular the availability of antenatal care that allows them to monitor the health of their babies throughout pregnancy. Some of the older Batwa mothers reported that rates of infant mortality were higher when they lived in the forest due to harsher living conditions and lack of formal healthcare *(Batwa FGD 1A)*.

4 Discussion

Prentice et al. (1987) were among the first to examine the effects of seasonality on birth weight and posited that this relationship manifested through malaria morbidity, food shortages, and hard physical work experienced during pregnancy. These same drivers were identified and validated by the mothers and key informants we spoke to in Uganda.

Mothers generally stated that the babies were the same regardless of their season of birth but expressed differing opinions as to whether they had found pregnancy more challenging in the rainy season or in the dry season. This finding may indicate that there is not a clearly defined risk period, but rather that pathways of risk differ under different seasonal conditions. Key informants offered breadth of experience balancing the depth of individual perspectives, with many describing the increased availability of food in the rainy season. This finding is consistent with our other work [Anonymous Under review A], which found that exposure to more days of precipitation in the third trimester was associated with increased birth weight (3.1g increase in birth weight per additional day

of exposure). Several prior studies from other parts of sub-Saharan Africa also identified the dry season as a period in which food shortages and/or increases in physical labour occurred and lower birth weights were recorded (Neufeld, Pelletier and Haas 1999, Onyiriuka 2006, Enquoselassie 2000, Friis et al. 2004). Mothers expressed concern about sickness during both seasons, but malaria and cold-related illness were of greater concern during the rainy season. Difficulties in accessing the hospital and antenatal care services during the rainy season were mentioned by several mothers and key informants. These access issues appeared to be driven by a lack of resources to pay for transport to service providers and being unable to sacrifice time off work or to find child care to attend appointments. The difference in the nature of the concerns by season may indicate that mothers experience the effects of weather through different pathways in different seasons, with implications for seasonally-sensitive interventions based on a woman's gestational stage.

Interviews and focus groups revealed that while both Batwa and Bakiga mothers experienced the effects of weather and seasons via the same pathways, the extent of their vulnerability differed. Batwa mothers had fewer assets to sell to pay for transport to the hospital, and did not have the same level of flexibility in choosing when to stop doing strenuous work during their pregnancies. Other prior research in the region has shown that Bakiga are considerably better equipped to cope with shocks threatening food security, often by selling off livestock [Anonymous 2016 B]. Existing disparities in social determinants of health between Batwa and Bakiga mothers appear to leave Batwa mothers more vulnerable to the effects of weather and seasonal variation, magnifying the adverse effects of these exposures on their pregnancies and on the health of their newborns.

This study sought to understand the pathways through which weather and season may affect birth outcomes in low-resource settings. It is these pathways that might be modifiable to help improve birth outcomes. Studies conducted in more developed settings where food security is a less acute concern, where physical work may not vary seasonally, and where seasonal infectious diseases

491 are less common suggest different pathways through which meteorological factors may affect birth
492 weight (e.g. vitamin D exposure) (McGrath, Burne and Eyles 2005), and highlight interaction effects
493 with air pollution (Beltran et al. 2014, Chodick et al. 2009, Laaidi et al. 2011)). These pathways may
494 also be at work in Kanungu District, but the magnitude of their effects is likely to be marginal when
495 compared to the dominant pathways proposed in this paper (Strand et al. 2011). Consideration of
496 black carbon and other air pollutants—for which data were not available for this study—would also
497 be appropriate in this context given the extensive use of biofuels such as wood for cooking.
498 In the 5th Assessment Report of the Intergovernmental Panel on Climate Change, Smith et
499 al. (2014, 741) note that "[g]iven the increase globally in life expectancies, many babies born this
500 decade will be alive at the end of the century, and will be personally affected by the climate that is in
501 place in 2100". However, climate change will begin affecting these babies far sooner than 2100—
502 unpredictable and intensified effects of season and weather will begin to affect their health in utero
503 (Rylander, Odland and Sandanger 2013, Grace et al. 2015). As climate change intensifies, the effects
504 of season and weather on birth outcomes will likely be amplified (Grace et al. 2015, Rylander et al.
505 2013). Understanding the new dimension climate change adds to existing disparities in perinatal
506 health should help illuminate interventions aimed at eliminating these inequities. Understanding the
507 context-dependent pathways means that we have intervention points around the prevention of
508 predictable food shortages, protecting women from excess physical exertion and ensuing best
509 practices for infectious disease prevention. The health effects of climate change and maternal and
510 newborn health disparities will be magnified by existing social gradients. Interventions supporting
511 those at the lower end of these social gradients have the potential for double benefit by addressing
512 two grand challenges in global health: maternal/child health and climate change adaptation.
513 Our findings suggest focused adaptation strategies targeting the pathways through which
514 mothers and developing foetuses are exposed to the effects of weather and season: maternal energy

515 balance and risk of seasonal illness. These pathways are relatively consistent across and within
516 populations, meaning they could be entry points to interventions in other subsistence agriculture-
517 based contexts. However, further place-based qualitative inquiry characterizing the nature and extent
518 of these pathways is warranted, particularly in communities where alternative livelihoods
519 predominate. These findings are of use to collaborators at Bwindi Community Hospital and the
520 Ugandan Ministry of Health as they develop strategies specific to the regional needs of the women
521 of Kanungu District. BCH has made it a priority in their strategic plan to reduce maternal and child
522 mortality by 25% by 2019, and the results of this study suggest placing a particular emphasis on
523 supporting Batwa mothers as a vulnerable population group to reach this goal. Hospital and ministry
524 planners may also take into consideration the need for more nutritional interventions in the dry
525 season and continued education around climate change and agriculture, as well as education
526 initiatives geared towards other income-generating activities. The need for better access to transport
527 in the rainy season (Caulfield et al. 2016) and opportunities to leverage the knowledge and access of
528 traditional birth attendants might also be considered in policy development (Rishworth et al. 2016,
529 Sarker et al. 2016). Promotion of family planning to time births according to the most optimal
530 seasonal conditions for pregnancy might also be also be considered as an initiative to enhance
531 perinatal health in the region.
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[Anonymous 2012] Details omitted for double-blind reviewing.
[Anonymous 2015 A] Details omitted for double-blind reviewing.
[Anonymous 2015 B] Details omitted for double-blind reviewing.
[Anonymous 2016 A] Details omitted for double-blind reviewing.
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