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Relationship between environmental factors and adverse birth outcomes in a rural high altitude community in East Africa

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Abstract: *Background*
Evidence emerging are suggesting associations between environmental exposures and adverse pregnancy outcomes.
Subject and methods: This was a prospective cohort study, carried out in year 2019, over a period of 12 months in Gitwe village, Rwanda. Mother-infant pairs were recruited consecutively, on first-come-first-serve basis from Gitwe district hospital. Newborns were classified based on their weight and gestational age, soon after birth. Healthy, singleton newborns, weighing ≥1.5kg were included in the study (n = 529).Very small, sick babies, and multiple gestation pregnancies were excluded from the study. Data on socio-demographics, environmental exposures and birth outcomes were obtained in the postnatal ward before discharge. Logistic regression models and Chi test were used to examine the relationships between environment exposures as independent variables and birth outcomes as dependent variables. The results were presented in p-values, Odds ratio and 95% confidence interval.
Results: Rates of antenatal exposures to charcoal fuel, unsafe water and potentially harmful social habits in the study were 96.2%, 67.1% and 12.5%, respectively. Overall, the prevalence of adverse birth outcomes [SGA, LBW, Preterm (according to WHO classification) and cesarean section births were 21.4%, 10.6%, 4.9% and 38.8%, respectively], was unusually high in this study. Exposures to unsafe water and charcoal fuel were the strongest environmental factors determining gestational age at birth. Unsafe water was strongly linked to pregnancies complicated with preterm, LBW and cesarean section births. Use of charcoal fuel for cooking and house heating was particularly associated with post-term (rather than preterm) and SGA births. Antenatal ingestion of or exposure to local herbs/alcohol/tobacco, which may have contained some unknown insulinogenic or sex selection compounds, led to increased risk of preterm, male, LGA and cesarean section births in the study.
Conclusion and Recommendations
The environmental factors that led to an unusually high prevalence of adverse birth outcomes in the study, could be modified by maternal counseling, rehabilitation and public education, upgrading access road to the health facilities, and improving WASH situation in the rural areas.

Key words: Environmental Factors, Childbirth outcomes, rural community

Résumé: *Contexte :* Les preuves émergentes suggèrent des associations entre les expositions environnementales et les issues défavorables de la grossesse.
Patientset méthode : Il s'agissait d'une étude prospective de suivi de cohorte, réalisée en 2019, sur une période de 12 mois dans le village de Gitwe, au Rwanda. Les couples mère-enfant ont été recrutés consécutivement, selon le principe du premier arrivé, premier servi, dans l'hôpital du district de Gitwe. Les nouveau-nés ont été classés en fonction de leur poids et de leur âge gestationnel, peu après la naissance. Les nouveau-nés uniques en bonne santé, pesant plus de 1,5

kg ont été inclus dans l'étude (n = 529). Les nouveau-nés de très petits poids et malades, et les grossesses multiples ont été exclus. Les données socio-démographiques, les expositions environnementales et les données sur l'issue de l'accouchement ont été obtenues dans le service avant la sortie. Le modèle de régression logistique et le test de Chi ont été utilisés pour examiner les relations entre les expositions environnementales en tant que variables indépendantes et l'issue de l'accouchement Les valeurs de p et l'intervalle de confiance à 95% ont été présentées.

Résultats: Les taux d'exposition prénatale au charbon de bois, à l'eau insalubre et aux habitudes sociales potentiellement nocives étaient respectivement de 96,2 %, 67,1 % et 12,5 %. Dans l'ensemble, la prévalence des issues défavorables à la naissance [Retards de croissances intra utérines (21,4 %), petit pois de naissance (10,6 %), prématurités-selon la classification de l'OMS (4,9 %) et les naissances par césarienne (38,8 %,) était fortement élevée. Les expositions à l'eau insalubre et au charbon de bois étaient les facteurs environnementaux les plus importants déterminant l'âge gestationnel à la naissance. L'eau insalubre était fortement liée aux grossesses compliquées de naissances prématurées, de faible poids de naissance et de césarienne. L'utilisation du charbon de bois pour la cuisine et le chauffage de la maison était particulièrement associée aux naissances post-terme (plutôt que prématurées) et aux retards de croissance pour l'âge gestationnel. L'ingestion prénatale ou l'exposition à des herbes/alcool/tabac locaux, susceptible de contenir des composés in connusinsulinogènes ou de sélection du sexe, ont entraîné un risque accru de naissances prématurées, de naissance de sexe masculin, de macrosome et d'accouchement par césarienne.

Conclusion et recommandations: Les facteurs environnementaux qui ont conduit à une prévalence anormalement élevée d'issues défavorables à la naissance pourraient être modifiés par le conseil maternel, la réhabilitation et l'éducation du public, l'amélioration de la route d'accès aux établissements de santé et l'amélioration de la situation de l'eau, de l'assainissement et d'hygiène dans les zones rurales.

Mots clés: Facteurs environnementaux, issue de l'accouchement, zone rural.

Introduction

Emerging mixed evidences are suggesting associations between modifiable environmental exposures such as high altitude, air pollution, environmental tobacco smoke, water contaminants and adverse pregnancy outcomes such as pregnancy loss, stillbirth, fetal growth, preterm birth and congenital anomalies.[1]

Among the harmful social habits common amongst pregnant mothers in developing countries, are alcohol, herbal, hard drug consumption and snuff or tobacco smoking. Although, globally, cultural and ethnical relevant factors have kept the proportion of women, who smoked during pregnancy low, the prevalence of domestic environmental tobacco smoke (ETS) exposure during pregnancy still remain high.[2] In developed countries, about 15%, and in developing countries, approximately 8% of women smoke cigarettes. ETS is a risk factor for low birth weight and preterm delivery[1] respiratory problems, antepartum and intrapartum still birth, perinatal death as well as long-term morbidity in offspring, sudden unexpected infant death[3] neurodevelopmental and behavioral problems, obesity, hypertension, type 2 diabetes, impaired lung function, asthma and wheezing.[4] Exposure of nonsmoking pregnant women (second hand smoke exposure) to ETS, for at least two hours per day could result in a mean birth weight reduction of 85 g and a twofold increased risk of LBW among the infants of nonsmokers.[5,6] Tobacco smoke toxins (nicotine, carbon monoxide) damage the placenta resulting in maternal tachycardia and vasoconstriction effects, premature rupture of the membranes through mechanical stress disrupting membrane integrity, placental abruption, abortion or placenta praevia and then premature delivery.[7] Carbon monoxide binds to maternal and fetal hemoglobin with an affinity that is more than 200-times that of oxygen.[8] The carbon monoxide displaces oxygen in the circulation, reducing the amount of oxygen available to the fetus and impairing fetal growth.[9]

Maternal alcohol consumption also increases the risk of preterm birth and low birth weight.[10] Use of local herbal concoctions during pregnancy for several social and medical reasons is prevalent among pregnant mothers globally and can be as high as 71.8% among Bangladesh mothers[11] and 80% among African women.[12] The components of these herbs are often times unknown, but may contain ginger, garlic, green teas, sex steroids etc, and therefore using them in the first or second trimester or at any time during pregnancy may be unsafe for the fetus.[11] Jahan et al. Observed significantly higher rates of cesarean section, preterm and low birth weights births and medically complicated babies among mothers using traditional herbal medicines in Bangladesh.[11] Some insulinogenic local herbs used to treat gestational diabetes may result in LGA births.[13]

Charcoal fuel appears to be the cheapest source of energy for home cooking in most families in developing countries. Weber et al.[14] reported that 33% of pregnant mothers use polluting cooking fuels, such as wood and charcoal, and this was significantly, associated with perinatal mortality and low Apgar score at 5 minutes in the urban city of Accra, Ghana. The products of these small polluting fuel combustion (carbon monoxide and particulate matters-PM2.5) may cross the placental barrier, bind to fetal hemoglobin and compromise fetal oxygenation. In addition, the PM2.5, either acting

systemically or via placental deposition, may cause oxidative stress and an inflammatory response, further impacting fetal growth and development.[14] Moreover, the overly physical exertion (e.g. collecting firewood to make charcoal, firing-up the charcoal) can lead to poor pregnancy outcomes.[15]

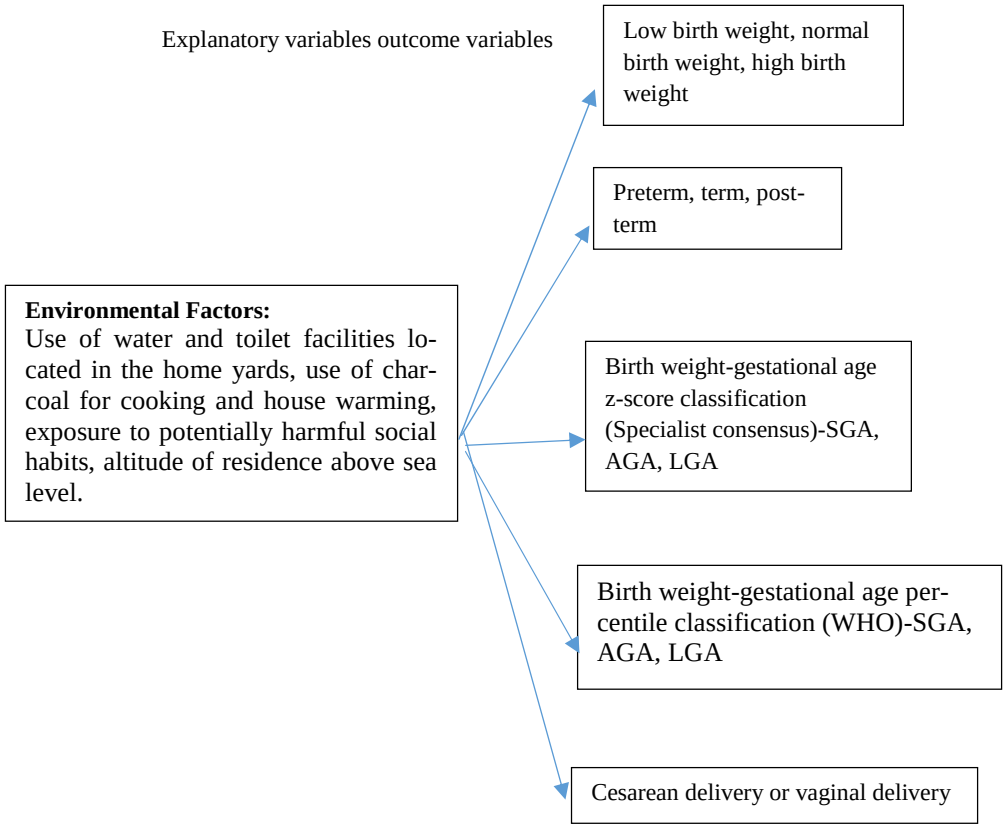
High-altitude pregnancies, as a result of chronic exposure to environmental hypobaric hypoxia,[16] often results in fetuses that are lighter in weight,[17] with reduced body length and gestation.[18] Especially, residence at altitudes >2500 mabove sea level is accompanied by some physiological adaptation in pregnancy and that includes reduction in uterine artery diameter[19] and blood flow by about 30%, and consequent reduced exchange of oxygen and nutrients at the chorionic villito the fetus.[20] Metabolic changes also occur within a high-altitude placenta that prioritize glycolysis to preserve oxygen for fetal metabolism[21] and modifications in fetal oxygen consumption.[22] These adaptations may ensure fetal survival at the expense of fetal growth.[16] The numbers of highaltitude pregnancies are increasing, globally, as a result of low-altitude areas becoming more heavily populated, and more people are pushed to live at higher elevations worldwide, with climate change likely to perpetuate this trend.[23] Baye et al. from Ethiopia, reported that children, who are born at higher altitudes > 1,500m above sea level, are more at risk of being smaller at birth and have a stunted growth compared to their counterparts born at lower altitudes. According to these authors' findings, for every 1000-m above sea level increase in altitude, there was associated 0.163-unit decrease in height-for-age z-score.[24] Strong evidences exist to support the claims that poor WASH adversely influences maternal and perinatal health outcomes to the extent that it should be considered in global strategies and national policies.[25]

The effects of these environmental factors on birth outcomes have not been extensively studied in resource-limited settings, especially in the rural areas. Data from Gitwe village (study site) have not featured in any of the RDHS survey publications. This current study in Rwanda, contributed to this knowledge gap and will assist decision and policy makers to develop tailored guidelines, policies and interventions to curtail the effects of these environmental exposures and improve newborn survival, growth and well being. Hence, the objectives of this study, were to determine the prevalences of the different categories of antenatal environmental exposures and adverse birth outcomes; and investigate the relationships between these outcomes and the exposures in a rural, poorly researched, high altitude community in Rwanda.

Concept of the study

Figure 1, shows the antenatal environmental determinants (use of water and toilet facilities located in the home yards, use of charcoal for cooking and house heating, exposure to potentially harmful social habits, altitude of residence above sea level) and birth outcomes (birth size, gestationalage and mode of delivery), that were investigated in this study.

Fig 1: Concept of the study



Materials and methods

The methods employed in carrying out this study is discussed in this section.

Study setting

Rwanda is a low-income, agricultural and landlocked country with approximately 11 million people living in five provinces, covering an area of 26,338 km^2. It is called the home of a '1000 hills'.[26,27,28] The limited area of flat land available in most part of Rwanda is a hindrance to farming, animal rearing and construction of standard residential houses, among others and this has forced some families to migrate uphill. For example, the recommended minimum of 50 feet distance between source of household water and sewage tank in residential yards are often compromised during construction, leading to contamination of water source. There are two peak raining seasons in the country: April to June and September to November. Majority of the families in the rural areas use charcoal fuel for cooking and house heating as the cost of electricity is beyond their reach.

Rwanda has an average of 4.4 persons per household[26] and a gross domestic product per capita of US $780.80.[26] About half (48%) of its population is under 19 years of age and 39% live below the poverty line with a life expectancy at birth of 71.1 years for women and an adult literacy rate of 80% among 15–49 years old women. In addition, 87.3% of the population have health insurance and access to health services; spending an average of 47.4 min to reach a health center.[27] Non-availability of regular supplies of clean and safe water, has been a longstanding problem in Rwanda, as a whole, probably because of its landlocked and hilly terrains, making construction and supply of piped water, a major challenge. The public piped water flow infrequently and the taps and pipes may be rusted and breached in some places, especially in the rural areas, further leading to contamination of household water. Many families store rain water in big tanks for use in their homes and this may become polluted (in the writer's opinion) because of difficulties of cleaning these storage tanks. A few non-profit organizations, such as USAID and Water-for-life have sunk bore holes in strategic locations in a few number of villages in the country, with the aim of alleviating this water problem.[26,27]

Gitwe village is located at a high altitude of 1,674 meters above sea level, in the southern province, 240km from Kigali, which is the capital city of Rwanda. Gitwe general hospital began in 1995, immediately after the genocide, for the purposes of providing medical services and later training to this isolated community. The hospital currently has 100% government support, since year 2020. The maximum number of deliveries at the hospital per month was about 200. Some of the challenges in the hospital include poor specialist coverage and few trained health workers, poor supply of equipment, water, electricity, laboratory services and medicines. Challenging cases are referred to the university of Rwanda teaching hospital in Butare or Kigali. Gitwe village was selected for this study, because there was no published birth data from this poorly researched, remote community. In 2019, socio demographic, birth, feeding and growth data on 529 healthy mother-singleton newborn pairs were compiled in this village, over a period of 12months. This study was carried out in the delivery and postnatal wards of Gitwe general hospital and at its annex, the maternal and child health clinic.

Data source and sample

This was a prospective cohort study design. Mother-newborn pairs were recruited consecutively, on first-come-first-serve basis. Very small and sick babies, and multiple gestation pregnancies were excluded from the study, because they needed immediate resuscitation and transport to a more specialized neonatal centre before anthropometry could be done. Maternal file review and newborn anthropometry [weight (kg), length (cm) and head circumference (cm) measurements, recorded to the nearest decimals] were carried out, soon after birth. Maternal sociodemographic and environmental data were obtained using questionnaires, which were read to the mothers and filled by the research assistants. Four approaches were used to classify the newborn: gestational age, birth weight, birth weight-gestational age percentile (WHO), birthweight-gestational age z-score (Specialists consensus). Newborn gestational age was determined using the maternal last menstrual period (LMP), fetal ultrasound gestational age dating (preferably done at first trimester) and/or expanded new Ballard criteria and were classified into preterm, term and post-term. Birth weight regardless of gestational age, with cut-off points of 2.5-3.9kg for normal birth weight. Birth weight-gestational age newborn classification (globally recommended) into small-for-gestational age (SGA), appropriate-for-gestational age (AGA) and large-for-gestational age (LGA) was done: according to WHO using 10^{th}-90^{th} percentiles cut-off points for AGA and according to Specialists consensus using ±2 z-score cut-off points for AGA. It is worth noting that newborn classification is rarely done routinely in the study site.

To ensure the quality of data collected, two registered nurses were trained as research assistants at Gitwe Hospital for two days on the over-all procedure of mother and newborn anthropometry and data collection by the investigator. The questionnaires were pre-tested before the actual data collection period, on 10mother-infant pair participants (2% of the total sample). The investigator closely followed the day-to-day data collection process and ensured completeness and consistency of the questionnaires administered each day, before data entry.

Statistical analysis

Data clean up, cross-checking and coding were done

before analysis. These data were entered into Microsoft Excel statistical software for storage and then exported to SPSS version-26 for further analysis. Both descriptive and analytical statistical procedures were utilized. Participants' categorical characteristics were summarized in frequencies and percentages. A multivariate, multinomial and binary logistic regression models and Chi test were created to examine the relationships between the antenatal environmental independent variables (use of water and toilet facilities located in the home yard, use of charcoal for cooking and house heating, exposure to potentially harmful social habits) and dependent variables [gestational age, birthweight classification, birthweight-gestational age z-score classification (Specialists' consensus), birthweight-gestational age percentile classification (WHO), mode of delivery] and to generate the odds ratio. Factors with p-values <0.1 were included in the regression models. Odds ratio (OR), with a 95% confidence interval (CI) were computed to assess the strength of association between independent and dependent variables. Significant environmental factors determining birth outcomes were cross-tabulated. For all, statistical significance was declared at p-value < 0.05.The rates of the different adverse birth outcomes in the study site, were compared with those of a similar high altitude country. The reporting in this study were guided by the STROBE guidelines for observational studies.[29]

Ethics

Ethical approval from the Health Sciences Research Ethics Committee of the University of the Free State in South Africa (Ethical Clearance Number: UFS-HSD2018/1493/2901) was obtained. Written permission to collect data was obtained from the Director of Gitwe Hospital and the eligible mothers gave their informed consent before enrolment. The participants were given research identity numbers and the principal investigator was responsible for the safe keeping of the completed questionnaires and collected data, to ensure anonymity and confidentiality of the participants.

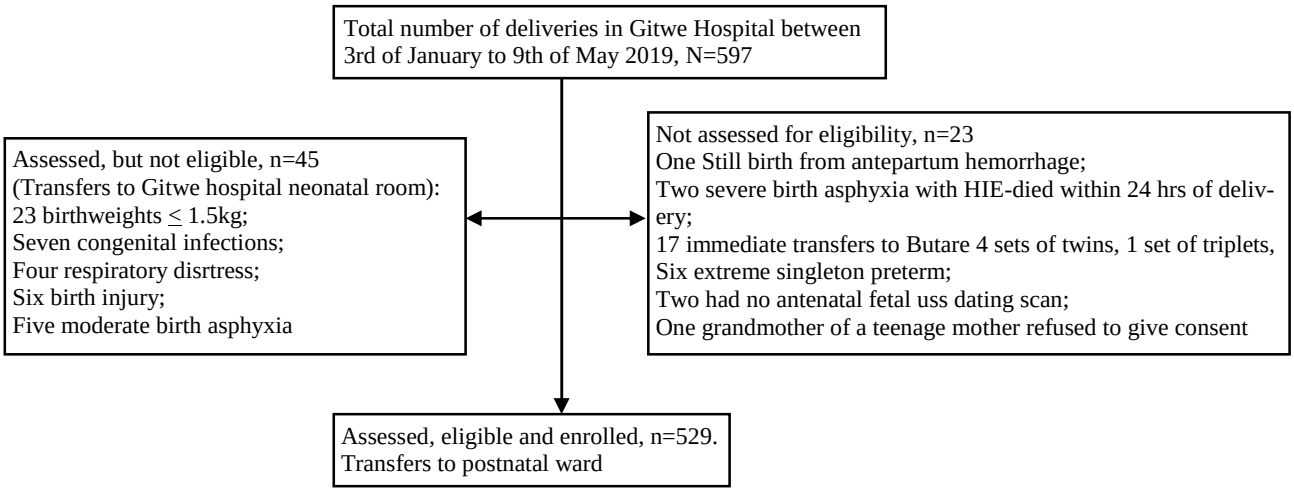
Results

The following are the results obtained from the study.

Participants

Five hundred and ninety-seven (597) babies were delivered at Gitwe Hospital, Rwanda, between 3rd January and 9th May 2019, out of which, eligible 529 mother-newborn pairs were enrolled into the study, Figure 2.

Fig 2: Flow of participants from admission to recruitment into study



HIE-hjpoxic ischemic encephalopathy; uss-utrasonography

Newborn characteristics

Prevalences of small for gestational age (SGA), appropriate for gestational age (AGA) and large for gestational age (LGA), were 21.4%, 71.6% and 7.0%, respectively, according to WHO percentile classification, Table 1.According to Specialists consensus z-score classification, there were SGA (5.3%), AGA (91.5%) and LGA (3.2%). Spearman rho correlation coefficient between the two classifications was fairly strong at 0.539. The majority were male (53.5%) and term babies (57.5%).

Table 1: Newborn characteristics in the study

Characteristics	Frequency	Percent
Weight-for-gestational age (WHO, 1995)		
Small-for-gestational age (<10thpercentile)	113	21.4
Appropriate-for-gestational age (10th - 90thpercentile)	379	71.6
Large-for-gestational age (>90th percentile)	37	7.0
Weight-for-gestational age (Specialist consensus, 2007)		
Small-for-gestational age (<2 z-score)	28	5.3
Appropriate-for-gestational age (±2 z-score)	484	91.5
Large-for-gestational age (>2 z-score)	17	3.2
Birth weight (grams)		
Low birthweight (<2500)	56	10.6
Normal birthweight (2500-3999)	461	87.1
High birthweight (>3999)	12	2.1
Gender		
Female	246	46.5
Male	283	53.5
Gestational age		
Preterm	26	4.9
Term	304	57.5
Post-term	199	37.6
Total	529	100.0

Maternal characteristics

The highest percentage of the mothers in the study, were young in age (43.9%), of primary school education (65.8%), unemployed/unskilled (58.8%), married (90.7%), christians (97.5%), middle class (75.0%), moderate parity (51.4%). Three (0.6%) mothers did not attend antenatal care clinic, and the majority (56.9%) had insufficient ANC visits (1-3). HIV positivity rate amongst the mothers was 5.1% and cesarean section delivery rate was 38.8%. Two babies (0.4%) were not delivered in any health facility, Table 2.

Sixty-six mothers (12.5%) were exposed to potentially harmful habits during pregnancy. Fifty-one (77.3%) out of the 66 mothers that were exposed to potentially harmful social habits during pregnancy, ingested herbs (content of herbs were unknown), 9 (13.6%) ingested alcohol (amount unknown), 13 (19.7%) were exposed to tobacco smokes from relatives living in the same house. Five (7.6%) were exposed to both herbs and alcohol, while 2 (3.0%) were exposed to both herbs and tobacco. Majority of the mothers had good BMI (99.2%), use charcoal as fuel (96.2%), did not have water (67.1%) nor toilet (59.2%) facilities in their home yards, Table 2.

Table 2: Categorical characteristics of mothers and their households in the study (n=529)

Characteristics	Frequency	Percent
Age (completed years)		
≤18 (Teenage mother)	23	4.3
19-25 (Very young mother)	195	36.9
26-35 (Young mother)	232	43.9
>35 (Elderly mother)	79	14.9
Education		
None/Informal	26	4.9
Primary	348	65.8
'O' level secondary	105	19.8
'A' level secondary/College	32	6.0
University	18	3.4
HIV status		
Positive	27	5.1
Negative	502	94.9
Occupation		
Unemployed/Unskilled	311	58.8
Semi-skilled/Skilled technician	195	36.9
Shop owner	13	2.5
Professional	10	1.9
Marital status		
Not married (single/separated)	49	9.3
Married	480	90.7
Religion		
Islam	13	2.5
Christian	516	97.5
Parity		
Primiparous (1)	196	37.1
Moderate parity (2-4)	272	51.4
Multiparous (≥5)	61	11.5
Mode of delivery		
Cesarean section	205	38.8
Vaginal delivery	324	61.2
Place of delivery		
Outside health facility	2	0.4
Inside health facility	527	99.6
Socioeconomic status		
Destitute/Poor	115	21.8
Middle	397	75.0
Rich	17	3.2
Exposure to potentially harmful social habits		
Yes	66	12.5
No	463	87.5
Availability of water source in household yard		
No	355	67.1
Yes	174	32.9
Availability of toilet facility in household yard		
No	313	59.2
Yes	216	40.8
Use of charcoal for cooking and house warming		
Yes	509	96.2
No	20	3.8
Frequency of visits for antenatal care		
0 to <4	301	56.9
≥4	228	43.1
Total	529	100.0

Multivariatelogistic regression analysis of environmental factors predicting birth outcomes

According to the Wilks' Lambda's test in the multivariate logistic regression analysis; whether or not the mother, used water (p=0.032) or toilet (p<0.00) facilities located in household yard; exposed to potentially harmful social habits (p=0.002), used both water and toilet facilities located in household yard (p=0.003); used toilet facilities located in household yard and is also exposed to potentially harmful social habits (p=0.024); exposed to potentially harmful social habits and used charcoal for house cooking and warming (p<0.000) during pregnancy were significant factors predicting birth outcomes. Of note the birthweight-gestational age percentile (WHO) classification was not significantly affected by any of the environmental factors tested in this study.

The tests of between-subjects effects: post-hoc multivariate logistic regression analysis

The tests of between-subjects effects in the multivariate logistic regression post-hoc analysis, revealed that gestational age of baby at birth was significantly determined by whether or not the mother used water facilities located in household yard (p=0.011); used water facilities located in household yard and also used charcoal for house cooking and heating (p=0.044); was exposed to potentially harmful social habits and used charcoal for house cooking and warming (p=0.031) during pregnancy.

Mode of delivery was significantly determined by whether or not the mother used toilet facilities (p=0.009) or used water facilities located in household yard and was exposed to potentially harmful social habits (p=0.037); was exposed to potentially harmful social habits and used toilet facilities located in household yard (p=0.049) during pregnancy.

Class of birthweight, in which baby belonged to at birth was significantly determined by whether or not the mother used toilet facilities located in household yard (p=0.015) or used both water and toilet facilities located in household yard (p=0.008).

Birthweight z-score class in which baby belonged to at birth was significantly determined by whether or not the mother used toilet facilities located in household yard (p=0.004) or used both water and toilet facilities located in household yard (p=0.001); was exposed to potentially harmful social habits and used charcoal for house cooking and warming (p=0.003) or was exposed to potentially harmful social habits (p=0.017) or used charcoal for house cooking and warming (p=0.034). This analysis also revealed factor-factor interactions.

Multinomial and Binary Logistic regression analysis of significant environmental factors predicting birth outcomes

Multinomial logistic regression analysis was carried out to determine the strength and direction of relationship between significant environmental factors identified during multivariate logistic regression analysis, predicting the various newborn classifications studied. The strongest two factors that determined preterm birth were water (wald 12.21) and charcoal (wald 10.93). Preterm birth was less likely, if mother used charcoal for home cooking and heating (p=0.001; OR=0.08; 95%CI=0.02, 0.36) compared to post-term birth. Term baby birth was less likely, if mother has no water facility (p<0.000; OR=0.43; 95%CI=0.27, 0.69) at home compared to post -term birth.

With regards to birthweight outcome, water again had the strongest effect (wald 4.0). Normal birth weight was less likely, if mother had no water facility at home (p=0.045; OR=7.47; 95%CI=1.04, 53.63), compared to high birth weight.

With regards to newborn birthweight-z-score classification, charcoal had the strongest effect (wald=5.07). Those who used charcoal (p=0.024; OR=4.69; 95% CI=2.2, 17.99), were more likely to deliver AGA babies, compared to LGA.

Binary logistic regression analysis was also carried out to assess the relationships between significant factors and mode of delivery. With regards to mode of delivery, water again was the strongest factor (wald 70.04), mothers who had water facilities (p<0.000, OR=11.54, 95% CI 6.51, 20.47) at home were more likely to deliver by cesarean section compared to those who did not have.

This sort of mixed findings could be as a result of overlapping environmental factors or interruptions from maternal factors in the study. The effects of maternal factors influencing birth outcomes are covered elsewhere in another study.

Cross-tabulation of significant environmental factors and birth outcomes

Table 3 shows that a higher percentage of mothers, who drank from water facilities located in their households (13, 7.5%), who were exposed to potentially harmful social habits (7, 10.6%, p=0.068) delivered preterm babies, compared to those who did not. A higher percentage of mothers who used charcoal for household cooking and heating (195, 38.3%) gave birth to post-term babies, compared to those who did not.

A higher percentage of mothers, who drank from water facilities located in their household yards gave birth by cesarean section (128, 73.6%), to LBW (20, 11.5%) or HBW (9, 5.2%)or LGA (14, 8.0%) babies, p<0.05. A higher percentage of mothers, who used charcoal for household cooking or warming (27, 5.3%) or did not have water (20, 5.6%) or toilet facilities in their household yards(17, 7.9%)delivered SGA babies. A higher percentage of mothers, who were exposed to potentially harmful social habits gave birth by cesarean section (42, 63.6%)or to LGA babies (5, 7.6%). A higher percentage of mothers, who had toilet facilities at home gave birth by cesarean section (156, 49.8%). A higher percentage of mothers, who were exposed to potentially harmful habits at home gave birth to male babies (43; 65.2%; p=0.042; OR=1.72; 95% CI 1.01, 2.94).

Table 3: Crosstabulation of significant environmental factors and birth outcomes,n=529

Crosstabulation

			Gestational age, p<0.000			Total
			Preterm	Term	Post-term	
Water	No	Count (%)	13 (3.7)	189 (53.2)	153 (43.1)	355 (100.0)
	Yes	Count (%)	13 (7.5)	115 (66.1)	46 (26.4)	174 (100.0)
Total	Count (%)		26 (4.9)	304 (57.5)	199 (37.6)	529 (100.0)

			Gestational age, p<0.000			Total
			Preterm	Term	Post-term	
Charcoal	Yes	Count (%)	20 (3.9)	294 (57.8)	195 (38.3)	509(100.0)
	No	Count (%)	6(30.0)	10 (50.0)	4 (20.0)	20 (100.0)
Total	Count (%)		26 (4.9)	304 (57.5)	199 (37.6)	529 (100.0)

			Gestational age, p=0.068			Total
			Preterm	Term	Post-term	
Habits	Yes	Count (%)	7 (10.6)	37 (56.1)	22 (33.3)	66 (100.0)
	No	Count (%)	19 (4.1)	267 (57.7)	177 (38.2)	463 (100.0)
Total	Count (%)		26 (4.9)	304 (57.5)	199 (37.6)	529 (100.0)

			Birthweight classification, p=0.198			Total
			Low	Normal	High	
Toilet	No	Count (%)	25 (11.6)	189 (87.5)	2 (0.9)	216 (100.0)
	Yes	Count (%)	31 (9.9)	272 (86.9)	10 (3.2)	313 (100.0)
Total	Count (%)		56 (10.6)	461(87.1)	12 (2.3)	529 (100.0)

			Birthweight classification, p=0.006			Total
			Low	Normal	High	
Water	No	Count (%)	36 (10.1)	316 (89.0)	3 (0.8)	355 (100.0)
	Yes	Count (%)	20 (11.5)	145 (83.3)	9 (5.2)	174 (100.0)
Total	Count (%)		56 (10.6)	461 (87.1)	12 (2.3)	529 (100.0)

			Birthweight z-score classification, p<0.000			Total
			SGA	AGA	LGA	
Water	No	Count (%)	20 (5.6)	332 (93.5)	3 (0.8)	355 (100.0)
	Yes	Count (%)	8 (4.6)	152 (87.4)	14 (8.0)	174 (100.0)
Total	Count (%)		28 (5.3)	484 (91.5)	17 (3.2)	529 (100.0)

			Birthweight z-score classification, p=0.001			Total
			SGA	AGA	LGA	
Toilet	No	Count (%)	17 (7.9)	198 (91.7)	1 (0.5)	216 (100.0)
	Yes	Count (%)	11 (3.5)	286 (91.4)	16 (5.1)	313 (100.0)
Total	Count (%)		28 (5.3)	484 (91.5)	17 (3.2)	529 (100.0)

			Birthweight z-score classification, p<0.000			Total
			SGA	AGA	LGA	
Charcoal	Yes	Count (%)	27 (5.3)	469 (92.1)	13 (2.6)	509 (100.0)
	No	Count(%)	1 (5.0)	15 (75.0)	4 (20.0)	20 (100.0)
Total	Count (%)		28 (5.3)	484 (91.5)	17 (3.2)	529 (100.0)

			Birthweight z-score classification, p=0.098			Total
			SGA	AGA	LGA	
Habit	Yes	Count (%)	3 (4.5)	58 (87.9)	5 (7.6)	66 (100.0)
	No	Count (%)	25 (5.4)	426 (92.0)	12 (2.6)	463 (100.0)
Total	Count (%)		28 (5.3)	484 (91.5)	17 (3.2)	529 (100.0)

			Mode of delivery, p<0.000		Total
			Cesarean delivery	Vaginal delivery	
Water	No	Count (%)	77 (21.7)	278 (78.3)	355 (100.0)
	Yes	Count (%)	128 (73.6%)	46 (26.4)	174 (100.0)
Total	Count (%)		205 (38.8)	324 (61.2)	529 (100.0)

			Mode of delivery, p<0.000		Total
			Cesarean delivery	Vaginal delivery	
Toilet	No	Count (%)	49 (22.7)	167 (77.3)	216 (100.0)
	Yes	Count (%)	156 (49.8)	157 (50.2)	313 (100.0)
Total	Count (%)		205 (38.8)	324 (61.2)	529 (100.0)

			Mode of delivery, p<0.000		Total
			Cesarean delivery		Vaginal delivery
Habits		Yes	Count (%)	42 (63.6)	24 (36.4)
		No	Count (%)	163 (35.2)	300 (64.8)
Total	Count (%)		205 (38.8)		324 (61.2)

			Gender, p=0.042, OR =0.58		Total
			Female	Male	
Habits	Yes	Count (%)	23 (34.8)	43 (65.2)	66 (100.0)
	No	Count (%)	223 (48.2)	240 (51.8)	463 (100.0)
Total	Count (%)		246 (46.5)	283 (53.5)	529 (100.0)

Discussion

This study examined the prevalence of the different birth outcomes and investigated the relationship between these birth outcomes and existing environmental factors in a rural high altitude community in Rwanda, East Africa. Prenatal exposures to charcoal fuel, unsafe water and potentially harmful social habits in the study were 96.2%, 67.1% and 12.5%, respectively. The prevalence of SGA, LBW, Preterm (according to WHO classification) and cesarean section births were 21.4%, 10.6%, 4.9% and 38.8%, respectively, in this study. These figures are consistent with existing literature that stipulate that the prevalence of SGA births is approximately double the prevalence of low-birthweight birth.[30] However, these study rates could have been higher, if the very small, sick and multiple gestation babies were included in the study.

The altitude of our study site is 1674m (highest peak in Rwanda is 4507m) above sea level. Ethiopia has an average elevation of 1330m (highest peak of 4533m) above sea level and its SGA rate, as at 2017 was 21.4%, similar to this study rate. Ethiopia was then, considered as one of the top 10 countries with the highest rate of SGA among the LMICs in the world.[31] The study LBW rate was higher than the average rate of 9.76% in SSA, 2021.[32]The study preterm rate was slightly lower than the average 5.33% in SSA (2021).[33, 34] This is consistent with literature that associated SGA, rather than preterm births to high altitude residence.[34]
The study cesarean section rate was higher than the WHO safety limits of 10-15%, than the average rural and national rates in the country and several other countries in SSA.[35] These unusually high rates of poor birth outcomes in this rural village, cannot be attributed solely to the high elevation location. This situation could have been influenced by other factors.

As expected, exposures to possibly contaminated water, unhygienic WASH situation in the home yards, charcoal cooking fuel particles and potentially harmful social habits such as alcohol drinking, tobacco smoking (active or passive), ingestion of local herbs during pregnancy were significantly associated with adverse birth outcomes. In spite of the fact that, the SGA rate, according to WHO percentile criteria, was higher at 21.4% than the 5.3% captured by the Specialist consensus z-score criteria, there was fairly strong agreement between the two classifications. The WHO newborn classification was relatively resistant to all the tested environmental variables. This suggests that the Specialist consensus z-score cut-off point of ±2, identified higher proportion of babies with morbidity, compared to the WHO 10^{th}-90^{th} centile cut-off points. These results support the ongoing worldwide debate to replace the 1995 WHO percentile criteria for the definition of SGA, with the 2007 Specialist consensus z-score criteria.[36]
Unsafe water and charcoal were the strongest environmental factors determining gestational age at birth in this study. Ingestion of water from possibly unsafe sources in the household yards could have resulted in complicated pregnancies with preterm, LBW or HBW or LGA and cesarean section births. Those, who had no water or toilet facilities in their home yards were prone to deliver SGA babies, possibly due to a combination of physical exertion involved in going outside the home to fetch water and the unhygienic environment at home. Those who had toilet facilities at home, were prone to cesarean births, probably because of poorly constructed toilet facilities in their home yards and suboptimal WASH environment.

Use of charcoal as cooking and house heating fuel was particularly associated with post-term and SGA births. Charcoal is preferred as a domestic fuel in the rural areas, because it is about the cheapest source of energy for home cooking and heating, it produces less smoke while burning, has a higher energy content per unit mass, can be easily transported and stored, and reused when left over after cooking.[37] However, it takes longer to light up charcoal than gas or electricity, hence, requires more physical exertion. Unlike the observations of Weber et al.[14] and that of Hussein,[38] both in Ghana, this Rwanda study linked prenatal charcoal exposure with post-term birth, rather than preterm birth. The charcoal-postterm delivery association in this Rwanda study, however, was similar to a China study by Tang et al. (2008), who documented mean gestational age closer to term/ postterm at 277.3 ± 11.3 (224–294) days, (rather than preterm) at delivery in 110 babies with similar prenatal exposures. The reason for this inconsistent findings is unclear.[39]

Exposure to potentially harmful social habits was strongly associated with preterm, LGA, male and cesarean births in this study, and this was consistent with existing literature. The LGA birth suggests that some of the herbs ingested in unquantified amount, may contain some insulinogenic substances, which are anabolic in nature, and hence result in excessive increase in fetal size.[13] The traditional preference for male children in developing countries may be a motive behind ingesting local or traditional herbs during pregnancy, in some instances. Various means to have a son include going through multiple pregnancies till a son is born, sex selective abortions, pre-conceptional techniques, post-conceptional intake of drugs or local herbs, consumption of special diet before and after conception, timing and dating of sexual intercourse. These local herbs or medications are called sex selection drugs and are known to contain sex steroids such as testosterone and phytoestrogen, taken usually in the first trimester (during the most critical period of embryonic development) and could result in congenital malformations in the fetus. These practices have resulted in female feticide and poor health attention for the living girls.[40] The mechanism behind ingestion of local herbs and fetal sex determination is unclear.

The exclusion of very small (<1.5kg), still births, major

anomalies, other very sick babies and multiple gestation pregnancies, from the study, as resuscitation and transfer were prioritized in these babies, could have weakened the study results and therefore is considered a limitation. Small numbers of preterm and post-term babies and some subcategories of mothers, such as the highly educated, professionals, entrepreneurs, mothers who did not use charcoal, mothers who did not attend ANC clinic, challenged our statistical analysis, thereby necessitating merging of some sub categories in some cases, during the analysis.

The strength of the study include its prospective cohort design, which is a more expensive, time consuming, less encountered design in literature and leads to a stronger establishment of causality than other observational studies. Standard neonatal anthropometry and classification were carried out in this study for better management of these babies, which was not a routine practice in this non-specialised hospital. In addition, the study contributed to the ongoing global debate on the possible revision of the newborn classification, leaning toward the replacement of the current percentile criteria with that of the z-score criteria.

Conclusion and Recommendations

From the observations made in this study, prevalence of adverse birth outcomes is unusually high in this rural high-altitude community and some modifiable environmental factors have been implicated. Antenatal centers may address the exposures to charcoal, local herbs/ alcohol/tobacco and their associated risks of adverse pregnancy, during their counseling sessions. Local herbs ingested in the study during pregnancy, may contain some unknown insulinogenic or sex selection agents leading to increased risk of male, LGA and cesarean section births. Interventions such as upgrading access road to the health facilities, maternal and public education and rehabilitation, could improve antenatal clinic visits, curtail the prenatal exposures to these harmful social habits and their consequences. The suboptimal WASH situation in the rural areas require further investigation and improvement. Newborn birthweight-gestational age classification using the z-score criteria, with cut-off points at ±2 for normal (appropriate for gestational age) is recommended.

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Author Contributions

The corresponding author (Dr Ogah Adenike Oluwakemi) conceived and designed the study, collected data and conducted data analysis, interpreted the results, and drafted the manuscript.

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