Regular antenatal care visits were associated with low risk of low birth weight among newborns in Rwanda: Evidence from the 2014/2015 Rwanda Demographic Health Survey (RDHS) Data [version 2; peer review: 1 approved, 2 approved with reservations]

Emmanuel Biracyaza1,2, Samuel Habimana3, Donat Rusengamihigo4, Heather Evans5

1Department of Community Health, University of Rwanda, Kigali, Rwanda
2Sociotherapy Program, Prison Fellowship Rwanda (PFR), Kigali, Rwanda
3Executive Director, Rwanda Resilience and Grounding Organization (RRGO), Kigali, Rwanda
4Department of Clinical Psychology, University of Picardy Jules Verne, Amiens, France
5Evans Counseling Services, Coopersburg, USA

Abstract

Background: Low birth weight (LBW) remains the global unfinished agenda in most countries of the world especially in low- and middle-income countries. LBW subsequently has harmful effects on the lifestyle, psychosocial and physiological development of the child. Although it is known that antenatal care (ANC) visits are important interventions contributing to prediction of newborn birth weight, little has been conducted on effect of ANC visits on birth weight in Rwanda. This study aimed at determining the association between regular ANC visits and risk of LBW among newborns in Rwanda.

Methods: A cross-sectional study design was conducted to analyse the effects of ANC on LBW using the 2014/2015 Rwanda Demographic Health Survey. Associations of socio-demographic, socio-economic, and individual factors of the mother with LBW newborns were performed using bivariate and multiple logistic regression analyses.

Results: Prevalence of LBW and macrosomia were 5.8% and 17.6%, respectively. Newborns delivered from mothers attending fewer than four ANC visits were at almost three-times greater risk of having LBW [aOR=2.8; 95%CI (1.5–5.4), p=0.002] compared to those whose mothers attending four or more ANC visits. Residing in a rural area for pregnant women was significantly associated with LBW [aOR=1.1; 95%CI (0.7–1.6), p=0.008]. Maternal characteristics, such as anemia, predicted an increase in LBW [aOR=3.5; 95%CI (1.5–5.4), p<0.001].
Those who received no nutritional counseling [aOR=2.5; 95%CI (2–8.5), p<0.001] and who were not told about maternal complications [aOR=3.3; 95%CI (1.5–6.6), p=0.003] were more prone to deliver newborns with LBW than those who received them. Pregnant women who received iron and folic acid were less likely to have LBW newborns [aOR=0.5; 95%CI (0.3–0.9), p=0.015].

**Conclusion:** ANC visits significantly contributed to reducing the incidence of LBW. This study underscores the need for early, comprehensive, and high-quality ANC services to prevent LBW in Rwanda.

**Keywords**
Antenatal care; Birth weight; newborn; Maternal factors; Sustainable Development Goals; Pregnancy
Introduction

Antenatal care (ANC) globally is an important health strategy that has been considered as an essential intervention to contribute to the health of newborns and their mothers. This health intervention reduces low birth weight (LBW) which is a foremost public health burden that weakens the development of families and nations due to its harmful effects on quality of life. LBW is defined when a baby weighs less than 2.5 kilograms at birth. This health burden particularly, in low- and middle-income countries (LMICs) may cause multiple effects, such as birth asphyxia, amniotic fluid aspiration, hypoglycemia and hyponatremia. The estimate of 15.5% to 15.9% of LBW worldwide was reported and the high prevalence (95.6%) of LBW newborns occurred in LMICs. ANC visits were found to play a great role in the health promotion of mothers and children before, during and after delivery. It specifically contributes to the reduction of morbidity and mortality of mothers and children. Epidemiological studies have shown that the children weighing less than 2.5 kilograms are nearly 20-times more likely to die than those who weigh 2.5 kilograms and more. Other studies have stated that newborns with LBW were 5–10-times more likely to die than those who weighed 2.5 kilograms and more. Prior studies have indicated that the newborn may die if LBW is more than 2.5 kilograms. These newborns are considered to have an excessive birth weight. Its prevalence varies globally between 3 and 15% depending on the region, due to various factors where it remains higher in the developing world.

Prior studies indicated that maternal and environmental factors are major factors with regard to LBW. The number of ANC visits attended by the pregnant women and the amount of recommended packages of the interventions provided during ANC are the main factors contributing to LBW. A low socio-economic status and limited access to qualified health services related to pregnancy are risk factors for LBW. Multiple studies established that accessibility to poor food consumption behaviors, problems of health status for pregnant women, low caloric intake, hypertension, urinary infections, smoking behaviors, genital infections and psychological distress were found to be risk factors of LBW. Earlier studies conveyed that consumption of iron, birth order, and calcium supplementation reduces the risk to develop LBW.

ANC refers to the routine health management of presumed healthy pregnant women without the symptomatology or screening so as to diagnose and detect the diseases or complicating symptoms. The World Health Organization (WHO) recommended pregnant women attend a minimum of four ANC visits for obtaining the basic health education and interventions that promote health of babies. The more they attend ANC services, the more they receive the maximum health package that plays a crucial role in their health and the health of their newborn. Prior studies have documented that two-thirds of all pregnant women worldwide attended at least one ANC service during pregnancy. They also documented that ANC is the significant predictor of birth weight where attending the required ANC increases the probability of achieving full life-saving potential and having a newborn with more than 2,500 grams. In ANC visits, pregnant women are offered health education, such as adequate nutrients to be consumed during and after delivery, vitamin intake, proper vaccination, changing risk behaviors such as smoking, and place of delivery. The package provided to pregnant women consists of many interventions like the identification and management of the obstetric complications including pre-eclampsia, tetanus toxoid immunization, de-worming, iron and folic acid. The fundamental rudiments of a focused approach to ANC are surveillance of health issues among pregnant woman and their babies, management of complications occurring in the pregnancy period, such as hypertension, treatment of underlying or concurrent illness, screening for health conditions and diseases, mental health problems and intra-partner violence or domestic violence. ANC visits are obviously the opportunities for promoting the use of skilled attendance at birth, injury prevention, adherence support for preventive interventions, healthy lifestyle safety, and healthy behaviors such as breastfeeding, early postnatal, and planning for the optimal pregnancy spacing. Pregnant women are provided supplementary nutrients for enhancing the baby’s and mother’s health, screening for genetic and congenital disorders, and offered folic acid supplementation to reduce the risk of neural tube defects.

Earlier researchers documented that through ANC services, pregnant women and their newborns develop physiologically and psychosocial wellbeing. It also reduces risk to have a LBW newborn. ANC visits contributed to development of healthy behaviors and compromise of the emergency preparedness plan to intensify the maternal awareness, improving the newborn needs and self-care. Other studies indicated that ANC visits contribute to weight gain and weight regulation of women. They confirmed that ANC services increase the weight of pregnant women and contribute to the growth of the fetal and maternal tissues and fluids. This health intervention plays a great role in the provision of information about lifestyle, pregnancy, and delivery. They prevent the potential determinants associated with morbidity and mortality of mothers and children. ANC services not only contribute to pregnant women and their fetus, but also foster a virtuous social and family cohesion and resilience. It was found that more than 80% of pregnant women who attended at least four ANC visits reported...
showed effectively controlled pregnancy complications\textsuperscript{31,33,34}. ANC services contribute to preparing women for delivery and understanding warning signs during the pregnancy and childbirth\textsuperscript{16}. It was scientifically found that the ANC interventions attended early become the best opportunity for appropriate screening and medical testing for health problems in which pregnant women are exposed to have during and after pregnancy\textsuperscript{49}. ANC coverage was an important indicator for reducing the risks to neonatal, infant mortality, maternal mortality and stunting issues to the child\textsuperscript{41}.

Previous studies indicated that there is a substantial influence of ANC on increase of birth weight for the children and their development of a good life characterized by prevention and management of pregnancy-related or concurrent diseases and psychosocial development\textsuperscript{13,32}. Maternal health production function explained that early onset of ANC, prenatal care and have a minimum number of ANC and prenatal care visits\textsuperscript{38,39}.

The rationale of this study was to increase the accessibility to ANC services that were documented to be practiced, but there was no scientific evidence that was conducted to indicate its effect on neither LBW nor contributing determinants to the reduction of children and maternal morbidity and deaths in Rwanda. Through the findings from this research, the investigators indicated how pregnant women achieve the third goal of Sustainable Development Goal (SDG-III) related to the reduction of infant and maternal mortality and morbidity by completing four ANC visits and more. Although it is known that ANC visits are an important intervention that contributes to prediction of the newborn birth weight, little has been conducted on effect of ANC visits on birth weight in developing countries, including Rwanda. This research, therefore, aimed to determine the effect of antenatal care visits on the LBW of children in Rwanda using the secondary data analysis of Rwanda Demographic and Health Survey (RDHS) 2014–2015. We hypothesize that ANC visits result in reducing the high incidence of LBW among newborns of Rwanda.

**Methods**

**Data source**

The fifth RDHS 2015 was utilized as a nationally representative sample implemented by the National Institute of Statistics of Rwanda (NISR) and Ministry of Health of Rwanda.

**Study technique, participants and settings**

The study design was a secondary analysis of cross-sectional survey data from RDHS 2014/2015 that was retrospectively carried out for investigating the effects of antenatal care visits on birth weight of the newborn in Rwanda. The RDHS data collection fieldwork was conducted from November 9, 2014, to April 8, 2015. The data entry, editing, and cleaning was completed by May 15, 2015, and the final survey report was completed in March 2016. A total of 8,004 pregnant women who were to receive antenatal care interventions before delivery were recruited. The interviewed women were of reproductive age (15–49 years). This study was conducted in Rwanda, a small country located in the Central and Eastern Africa bordered by the Republic Democratic of Congo to the West, Uganda to the North, Tanzania to the East and Burundi to the South. This country lies a few degrees south of the equator and is landlocked. Concerning ANC visits, accessibility to ANC services is increasing due to the improvement of the health system and health financing\textsuperscript{1}. This health system contributes to the achievement of SDG-III those targets reducing morbidity and mortality of mothers and children worldwide specifically in LMICs. The total area of Rwanda is approximately 26,338 km\textsuperscript{2}, the Rwandan population density around 416 people per km\textsuperscript{2} and the total population is roughly 10.8 million. The majority (43\%) of the Rwandan population is aged 15 years or less. Women accounted for about 52.6\% of the population, 84\% of Rwandans resided in the rural setting, and 71\% participant in agricultural activities\textsuperscript{48}.

**Sampling design**

RDHS was a national survey conducted to assess the birth weight of newborns. To collect the data of this household-based survey, mothers who had the youngest children, age five years or less, were interviewed to provide data related to birth weight for their children. The data for this survey were collected using a two-stage sampling strategy for enrolling participants. These stages were cluster sampling design and the sampling frame. The sampling frame was composed of the list of the enumerators’ areas (EAs) that covered the entire country. All residents in selected households were eligible to be interviewed. At the first stage of this study, 492 clusters were randomly selected (113 in urban and 379 in rural areas). At the second stage of this study, the systematic sampling technique that focused on selecting the households was applied. Then, a fixed number of 26 households were selected randomly from each cluster and a total of 12,792 households were selected for the final sample for this study.

Additionally, the proportional sampling technique was used in the survey where the sample for each cluster was equal. The study included women aged 15–49 years who were permanent residents of the households or visitors who stayed in the recruited household the night before the survey. Instead, the mothers were interviewed about the size of their children at birth because this determinant was found to be a proxy for the weight of the newborn. Therefore, 8,004 mothers with 15–49 years of reproductive age were interviewed for reporting the actual weight in kilograms using the written information about birth weight or recalling the weight at birth for their newborns. But our study included 7381 women (92\%) whose their newborns were measured weight. Therefore, 8\% of the women whose newborns were not measured weight at birth were not enrolled in this study. Further, all records on birth weight, number of ANC visits and BMI were available in the RDHS.

**Research tools and data collection**

RDHS 2014/2015 collected data at the national level using household-based survey data on birth weight retrospectively collected from the mothers. The data collection was completed by trained data collectors who used face-to-face interviews, asking mothers eligible for this study to provide a detailed birth history for children born in the preceding five years. Recruitment included stratified sampling, two stages of cluster sampling design. The first stage was characterized by selecting the participants from the samples frame constructed from enumeration.
whereas the second stage involved the systematic sampling of the households. These were listed from each cluster to ensure that an adequate number of the completed individuals were obtained. Participants were interviewed based on the measurement of the DHS program. Birth weight was recorded in the RDHS using metric measurement (in kilograms) for all participants from the entire stratum of the country. Data from mothers with stillbirths were excluded from this study.

**Study bias**

Bias refers to any tendency or deviation from the truth in study design, data collection, recruiting participants, data analysis, and results interpretation. Generally, bias may occur at any stage of the research. To manage the bias for the data from RDHS, the authors systematically did data cleaning and removed the missing variables. All authors checked several times the selected variables to include in the analysis for minimizing all possible systematic errors that could occur in the study.

**Study variables**

**Dependent variable.** The outcome variable of the current study was birth weight of the newborns. As per World Health Organization (WHO), newborns weighing <2,500 grams were categorized as LBW while newborns weigh >2,500 grams were categorized as not having LBW.

**Independent variables.** Based on the literature review and the structure of the RDHS 2014/2015 dataset, the independent variables were found. The main independent variable was the number of the ANC visits for the pregnant women. Although we expected to use a cut-off of 8 ANC visits as recommended by the WHO, a low prevalence (1%) of utilising performing 8 recommended ANC visits did not allow to use this appropriate recommendation. Thus, we considered a cut of 4 ANC visits and considered that the pregnant women who attended less than 4 ANC visits and those who attended 4 and above ANC visits were inadequate and adequate respectively. As recommended by WHO in 2010, the pregnant women who attended 4 ANC visits were considered to have obtained extremely adequate healthcare that effectively contributes to the health of the mother and unborn. This study used different covariate variables selected based on the previous epidemiological studies, reviewing the suitable published studies and the available information provided in the demographic health survey (DHS) datasets with the consideration of the potential confounders. Based on the insights from the literature and availability in the datasets, such factors are socio-demographic data such as maternal maternal age, residence, educational attainment, household wealth status, place of delivery, marital status, maternal occupation, gender of the child, sex of household head. In addition to independent variables, we also had linear variables that compromise the variables such as body mass index (BMI), anemia and nutritional supplements including tetanus injection during the pregnancy, iron folic supplementation, and nutritional counseling during pregnancy.

**Statistical analyses**

Before analysis, the observations with missing data were dropped. Statistical analysis was performed using descriptive (such as frequency, percentage) and analytical analyses. In the analytical analysis, bivariate logistic regression analyses were performed and all significant explanatory variables at p<0.25 were included in the multivariate logistic regression models based on the odd ratios to determine the associated factors of LBW, presenting adjusted odd ratios with a consideration of 95% for the confidence intervals. Further, all determinants in the multivariate logistic regression models were assessed for collinearity, which was considered present if the study variables had a variance inflation factor (VIF) higher than 3. Therefore, we adjusted sampling based on the RDHS data that were widely used and consistent data for assessing maternal and child health statistics at the national level using STATA software version 13 (RRID:SCR_012763). In this cross-sectional study design, we respected the guidelines outlined in the Strengthening the Reporting of Observational Studies in Epidemiology statement in writing the manuscript.

**Ethical consideration**

Data used were electronically accessed. To get full access, the first registration was completed on the DHS website. The permission to use the 2014/2015 RDHS data was granted by DHS using its website and the prior approval was maintained. In the prior approval, the women of reproductive age who were age 18–49 years provided oral and written informed consent forms to take part in the survey. In the cases on the minor participants (those women aged 15–17 years); the assent form was obtained from them while written informed consent were simultaneously provided by their guardians or parents who were adults.

**Results**

**Socio-demographic and economic status of mothers during pregnancy**

Our of 7381 women, the majority (61.3%) of pregnant women were aged 35–39 years and 82.1% were married or lived with the cohabitants. Our results showed that the majority (46.1%) were Catholics and 55.2% presented normal BMI (18.5–25.9 kg/m²). Regarding behaviors, 0.9% of them were smokers. About 73.1% studies primary schools and majority of them (82.3%) were from rural areas. Concerning nutritional status, 80.5% received tetanus injection, 79.9% received iron and folic acid supplementations, however, 24.1% had anaemia. Further, a majority (66.3%) experienced ≥37 weeks, 64.1% were from the families hed by the females and 55.9% delivered females. Indeed, 89% of the women were informed about pregnancy complications and 70.7% provided nutritional counseling during the pregnancy (Table 1).

In the bivariate logistic regression, we indicated how low birth weight is associated with ANC services, socio-demographic characteristics, maternal influences and behaviors. Therefore, we found that LBW was significantly associated with the ANC visits, BMI, residence, place of delivery, sex of child, HWI, maternal parity, maternal, anemia for pregnant women, family size, age, maternal education, provision of tetanus injection during the pregnancy, health education about pregnant complications and provided of nutritional counseling during pregnancy (Table 2).
### Table 1. Descriptive analysis for socio-demographic, nutritional, maternal and economic factors (N=7381).

| Variables                              | Number | Percent |
|----------------------------------------|--------|---------|
| **Maternal age (years)**               |        |         |
| 15–19                                  | 529    | 4       |
| 20–34                                  | 5664   | 74.9    |
| 35–49                                  | 1188   | 21.1    |
| **Sex of newborns**                    |        |         |
| Males                                  | 3254   | 44.1    |
| Females                                | 4127   | 55.9    |
| **Marital status**                     |        |         |
| Single                                 | 790    | 10.7    |
| Married/cohabiting                     | 6059   | 82.1    |
| Widowed/separated/divorced             | 532    | 7.2     |
| **Maternal education**                 |        |         |
| Illiterate                             | 1002   | 13.6    |
| Primary                                | 5397   | 73.1    |
| Secondary/higher                      | 982    | 13.3    |
| **Religion**                           |        |         |
| Protestants                            | 3183   | 43.1    |
| Catholics                             | 3402   | 46.1    |
| Adventists                             | 513    | 7       |
| Others                                 | 283    | 3.8     |
| **Smoking**                            |        |         |
| Smokers                                | 63     | 0.9     |
| Non-smokers                            | 7318   | 99.1    |
| **Residence**                          |        |         |
| Urban                                  | 1307   | 17.7    |
| Rural                                  | 6074   | 82.3    |
| **Household wealth index**             |        |         |
| Poor                                   | 4178   | 56.6    |
| Middle/rich                            | 3203   | 43.4    |
| **Family size (persons)**              |        |         |
| Less than 4                            | 1425   | 19.3    |
| 4 to 7                                 | 4273   | 57.9    |
| More than 7                            | 1683   | 22.8    |
| **Birth weight**                       |        |         |
| <2,500 grams (LBW)                     | 436    | 5.8     |
| 2,500–4,000 grams (normal)             | 5646   | 76.6    |
| >4000 grams (macrosomia)               | 1299   | 17.6    |
| **Parity**                             |        |         |
| 1–2                                    | 163    | 2.2     |
| 3–4                                    | 1734   | 23.5    |
| **Body Mass index (BMI)**              |        |         |
| ≤18.5 kg/m²                            | 2293   | 31.1    |
| 18.5–25.9 kg/m²                        | 4076   | 55.2    |
| ≥25 kg/m²                              | 1012   | 13.7    |
| **Gestational age**                    |        |         |
| <37 weeks                              | 2485   | 33.7    |
| ≥37 weeks                              | 4896   | 66.3    |
| **Received tetanus injections**        |        |         |
| No                                     | 1439   | 19.5    |
| Yes                                    | 5941   | 80.5    |
| **During pregnancy, was given iron tablet** | | |
| No                                     | 1484   | 20.1    |
| Yes                                    | 5897   | 79.9    |
| **Sex of household head**              |        |         |
| Male                                   | 2651   | 35.9    |
| Female                                 | 4730   | 64.1    |
| **Places of ANC**                      |        |         |
| Homes                                  | 589    | 8       |
| Provincial/district hospital            | 2166   | 26.3    |
| Health center                          | 4363   | 59.1    |
| Privates and other health facilities   | 263    | 3.6     |
| **Number ANC visits**                  |        |         |
| Attended 4 or less ANC visits          | 4133   | 56      |
| Attended ≥4 ANC visits                 | 3248   | 44      |
| **Heard about nutrients from CHWs**    |        |         |
| No                                     | 3100   | 42      |
| Yes                                    | 4281   | 58      |
| **Desired children**                   |        |         |
| Both want same                         | 4378   | 59.3    |
| Husband wants more                     | 1349   | 18.3    |
| Husband wants fewer                    | 1281   | 17.3    |
| Unaware                                | 373    | 5       |
| **Maternal anemia**                    |        |         |
| No anemic                              | 5599   | 75.9    |
| Anemic                                 | 1982   | 24.1    |
| **Told about pregnancy complications** |        |         |
| No                                     | 797    | 10.8    |
| Yes                                    | 6584   | 89.2    |
| **Nutritional counseling during pregnancy** |        |         |
| No                                     | 2163   | 29.3    |
| Yes                                    | 5218   | 70.7    |
Table 2. Bivariate logistic regression for analysing the association between the independent variables and LBW.

| Characteristics                          | LBW, n (%) | Odds ratio | 95% CI     | p-value  |
|------------------------------------------|------------|------------|------------|----------|
| **Type of residence**                    |            |            |            |          |
| Urban                                    | 75(16.4)   | 1          |            |          |
| Rural                                    | 383(83.6)  | 1.3        | 1.1-1.7    | 0.031*   |
| **Body Mass index (BMI)**                |            |            |            |          |
| ≤18.5 kg/m²                               | 367(80.2)  | 1          |            |          |
| 18.5–25.9 kg/m²                           | 60(13.1)   | 0.4        | 0.1-1.1    | 0.02*    |
| ≥25 kg/m²                                 | 31(6.7)    | 0.83       | 0.73-0.94  | 0.03*    |
| **Parity**                                |            |            |            |          |
| 1-2                                       | 49(10.7)   | 1          |            |          |
| 3-4                                       | 338(73.8)  | 1.9        | 1.1-3.7    | 0.030*   |
| ≥5                                        | 71(15.5)   | 2.8        | 1.1-7.2    | 0.041*   |
| **Sex of newborn**                        |            |            |            |          |
| Male                                      | 203(44.3)  | 1          |            |          |
| Female                                    | 255(55.7)  | 0.8        | 0.6-0.9    | 0.014*   |
| **Household Wealth index**                |            |            |            |          |
| Poor                                      | 236(51.5)  | 1          |            |          |
| Richer/middle                             | 222(48.5)  | 0.5        | 0.1-0.7    | <0.001** |
| **Marital status**                        |            |            |            |          |
| Single                                    | 129(28.2)  | 1          |            |          |
| Married/cohabited                         | 263(57.4)  | 0.2        | 1.7-2.9    | <0.001** |
| Widowed/separated/divorced                | 66(14.4)   | 0.1        | 0.1-0.2    | <0.001** |
| **Wanted pregnancy when became pregnant** |            |            |            |          |
| Wanted then                               | 290(63.3)  | 1          |            |          |
| Wanted later                              | 114(24.9)  | 1.8        | 0.8-1.3    | 0.673    |
| Wanted no more                            | 54(11.8)   | 1.1        | 0.8-1.5    | 0.405    |
| **Husband's desire children**             |            |            |            |          |
| Both want same                            | 279(61)    | 1          |            |          |
| Husband wants more                        | 49(10.8)   | 0.8        | 0.6-1.1    | 0.211    |
| Husband wants fewer                       | 92(20.1)   | 1.1        | 0.8-1.4    | 0.610    |
| Unaware                                   | 37(8.1)    | 0.9        | 0.8-1.2    | 0.956    |
| **Place of delivery**                     |            |            |            |          |
| Homes                                     | 16(3.5)    | 1          |            |          |
| Provincial/district hospital               | 176(38.4)  | 1.3        | 0.3-5.8    | 0.071    |
| Health center                             | 257(56.1)  | 0.6        | 0.1-3.2    | 0.061    |
| Privates and other health facilities      | 9(2)       | 0.2        | 0.1-0.4    | 0.051    |
| **Gestational age**                       |            |            |            |          |
| <37 weeks                                 | 187(40.8)  | 1          |            |          |
| ≥37 weeks                                 | 271(59.2)  | 0.7        | 0.6-0.8    | <0.01**  |
| Characteristics               | LBW, n (%) | Odds ratio | 95% CI | p-value |
|------------------------------|------------|------------|--------|---------|
| Maternal age                 |            |            |        |         |
| 15–19                        | 12(2.6)    | 1          |        | <0.001**|
| 20–34                        | 342(74.7)  | 2.7        | 1.5-4.9| <0.001**|
| 35–49                        | 104(22.7)  | 14.6       | 7.9-27.1| <0.001**|
| Family size                  |            |            |        |         |
| Less than 6                  | 297(64.8)  | 1          |        |         |
| 6 members and more           | 161(35.2)  | 0.5        | 0.4-0.6| <0.001**|
| Smoking for pregnant women   |            |            |        |         |
| No smokers                   | 395(86.2)  | 1          |        |         |
| Smokers                      | 63(13.8)   | 1.6        | 1.2-2.1| 0.02    |
| Household head               |            |            |        |         |
| Male                         | 213(46.6)  | 1          |        |         |
| Female                       | 245(53.4)  | 1.2        | 0.7-1.02| 0.074  |
| Anemia                       |            |            |        |         |
| Not anemic                   | 201(43.9)  | 1          |        |         |
| Anemic                       | 257(56.1)  | 4.7        | 2.5-9.2| <0.001**|
| Maternal education           |            |            |        |         |
| Illiterate                    | 69(15.1)   | 1          |        |         |
| Post-primary/vocational      | 335(73.1)  | 0.5        | 0.3-1.3| 0.105   |
| Secondary and above          | 54(11.8)   | 0.3        | 0.1-0.9| 0.036   |
| Utilization of Antenatal care services during pregnancy | | | | |
| ≥ 4 ANC visits               | 158(34.5)  | 1          |        |         |
| Less than 4 ANC visit        | 300(65.5)  | 1.5        | 1.2-1.9| <0.001* |
| Taken Tetanus and diphtheria pregnancy | | | | |
| No                           | 49(10.7)   | 1          |        |         |
| Yes                          | 409(89.3)  | 0.3        | 0.1-0.2| <0.001* |
| Told about pregnancy complications | | | | |
| No                           | 87(18.9)   | 1          |        |         |
| Yes                          | 371(81.1)  | 0.9        | 0.4-2.7| 0.001** |
| Iron and folic acid during pregnancy | | | | |
| No                           | 95(20.8)   | 1          |        |         |
| Yes                          | 363(79.2)  | 0.4        | 0.12-1.02| 0.001**|
| Provided nutritional counseling during pregnancy | | | | |
| Provided                     | 252(55)    | 1          |        |         |
| Not provided                 | 206(45)    | 6          | 3.5-10.7| <0.001**|
| Utilization of antenatal care services at health center | | | | |
| Not utilized                 | 14(3.1)    | 1          |        |         |
| Utilized                     | 444(96.9)  | 0.5        | 0.3-0.9| 0.02    |

**Notice:** (*) Indicates the statistical significance level at 0.05; (**) Estimates the statistical significance level at 0.01; Unmarked p-values were not found to be the significant risk factors of LBW in Rwanda.
Multiple logistic regression analyses of the effects of the explanatory variables on birth weight of the newborns in Rwanda

Before conducting multivariate logistic regressions, VIF was checked and then the variables including weight, blood sample taken during the pregnancy, urine sample taken during pregnancy, province of residence, provided anti-malaria drugs during pregnancy, wanted pregnancy when get pregnant, pressure taken during pregnancy, blood pressure taken and height inflected the LBW since they scored more than 3 while the remaining variables remained with scores near to 1. Then, we removed the inflated variables from the models. Therefore, VIF were reduced significantly and satisfactory. The model showed that babies from the mother who attended less than 4 ANC visits were almost three-times more likely to experience LBW [aOR=2.8; 95%CI (1.5-5.4), p=.002] compared to those whose mother attended 4 ANC visits. For marital status, being married and cohabiting pregnant women were significantly associated with an increase of the risk to have LBW babies [aOR=1.9; 95%CI (1.3-2.8), p=0.002], widow, divorced and separated from their husbands were significantly associated with an increase of having LBW babies [aOR=1.6 ; 95%CI (1.1-2.5), p=0.015] compared to single mothers during pregancy. Further, being provided maternal iron and folic acid supplements during pregnancy [aOR=0.5, 95%CI (0.3-0.9), p=0.015], having gestational age of ≥37 weeks [aOR=0.8, 95%CI (0.6-0.9), p<0.012], being informed about maternal complications of pregnancy [aOR=0.4, 95%CI (0.3-0.7), p=0.001] were associated with a decrease of LBW babies. Also, women with anemia [aOR=2.4, 95%CI (1.3-4.5), p<0.001] were positively associated with LBW. Through the number of the pregnant women who smoked during pregnancy, smoker birth weight is significantly associated with smoking, as pregnant women who did not smoke were less likely [aOR=0.3; 95%CI (0.1-0.6), p=0.002] to deliver LBW babies than their counterparts. Finally, the females babies were more likely to experience LBW [aOR=3.5, 95%CI (1.5-9.2), p=0.012] than the males babies (Table 3).

Table 3. Multivariate logistic regression for the risk factors associated with low birth weight.

| Characteristics                                      | Low birth weight Percent | Adjusted odds ratio | 95% CI    | p-value |
|------------------------------------------------------|--------------------------|---------------------|-----------|---------|
| **Type of residence**                                |                          |                     |           |         |
| Urban                                                | 16.4                     | 1                   |           |         |
| Rural                                                | 83.6                     | 1.1                 | 0.7-1.6   | 0.008*  |
| **Sex of newborn**                                   |                          |                     |           |         |
| Males                                                | 44.3                     | 1                   |           |         |
| Females                                              | 55.7                     | 3.5                 | 1.5-9.2   | <0.01** |
| **Maternal education**                               |                          |                     |           |         |
| Illiterate                                           | 15.1                     | 1                   |           |         |
| Primary/vocational                                   | 73.1                     | 1.01                | 0.7-1.5   | <0.001**|
| Secondary/higher                                     | 11.8                     | 0.99                | 0.6-1.8   | <0.001**|
| **Maternal age**                                     |                          |                     |           |         |
| 15–19                                                | 2.6                      | 1                   |           |         |
| 20–34                                                | 74.7                     | 0.8                 | 0.4-1.5   | 0.428   |
| 35–49                                                | 22.7                     | 0.8                 | 0.4-1.5   | 0.467   |
| **Provided Tetanus injection during pregnancy**       |                          |                     |           |         |
| No                                                   | 10.7                     | 1                   |           |         |
| Yes                                                  | 89.3                     | 0.3                 | 0.1-0.7   | 0.021*  |
| **Body Mass index (BMI)**                            |                          |                     |           |         |
| ≤18.5 kg/m²                                          | 80.2                     | 1                   |           |         |
| 18.5–25.9 kg/m²                                      | 13.1                     | 0.9                 | 0.4-2.3   | 0.008*  |
| ≥25.9 kg/m²                                          | 6.7                      | 0.5                 | 0.2-1.1   | 0.005*  |
| Characteristics                              | Low birth weight<br>Percent | Adjusted odds ratio | 95% CI   | p-value |
|---------------------------------------------|-----------------------------|---------------------|----------|---------|
| Gestational age                             |                             |                     |          |         |
| <37 weeks                                   | 40.8                        | 1                   |          |         |
| ≥37 weeks                                   | 59.1                        | 0.8                 | 0.6-0.9  | 0.012*  |
| Smoking during pregnancy                    |                             |                     |          |         |
| Yes                                         | 3                           | 1                   |          |         |
| No                                          | 97                          | 0.3                 | 0.1-0.6  | 0.002*  |
| Utilization of Antenatal care services      |                             |                     |          |         |
| 4 ANC and more                              | 34.5                        | 1                   |          |         |
| No and less than ANC                        | 65.5                        | 2.8                 | 1.5-5.4  | 0.002*  |
| Parity for pregnant women                   |                             |                     |          |         |
| 1-2                                         | 10.7                        | 1                   |          |         |
| 3-4                                         | 73.8                        | 2.7                 | 1.1-6.7  | 0.052   |
| ≥5                                          | 15.5                        | 2.3                 | 0.9-5.5  | 0.09    |
| Family size                                 |                             |                     |          |         |
| Less than 6                                 | 64.8                        | 1                   |          |         |
| 6 members and more                          | 35.2                        | 1.02                | 0.8-1.4  | 0.918   |
| Household Wealth Index                      |                             |                     |          |         |
| Poor                                        | 51.5                        | 1                   |          |         |
| Middle/rich                                 | 48.5                        | 0.9                 | 0.6-1.4  | 0.728   |
| Anemia                                      |                             |                     |          |         |
| Not anemic                                  | 43.9                        | 1                   |          |         |
| Anemic                                      | 56.1                        | 2.4                 | 1.3-4.51 | <.001*  |
| Marital status                              |                             |                     |          |         |
| Single                                      | 15.5                        | 1                   |          |         |
| Married/cohabited                           | 75.5                        | 1.9                 | 1.3-2.8  | 0.002*  |
| Widowed/separated/divorced                  | 9.0                         | 1.6                 | 1.1-2.5  | 0.015*  |
| During pregnancy, provided counseling about nutrients |                   |                     |          |         |
| Yes                                         | 55                          | 1                   |          |         |
| No                                          | 45                          | 1.7                 | 0.8-3.5  | <0.003* |
| Provided tetanus injection during pregnancy |                             |                     |          |         |
| No                                          | 10.7                        | 1                   |          |         |
| Yes                                         | 89.3                        | 0.3                 | 0.8-2    | 0.337   |
| Received Iron and folic acid supplements    |                             |                     |          |         |
| No                                          | 20.8                        | 1                   |          |         |
| Yes                                         | 79.2                        | 0.5                 | 0.3-0.9  | 0.015*  |
Discussion

Our study investigated the influence of ANC contacts on birthweight and their factors contributing to LBW babies in Rwanda using RDHS. Interestingly, our results revealed that babies from the women who attended four and more ANC visits were less likely to have LBW than the babies from the pregnant women who attended less than 4 ANC contacts; however, Rwanda reports a low prevalence of attending 8 recommended ANC contacts. These results were coincided with the previous studies that documented an improvement of ANC services contributing to birth weight of the newborns. Our results revealed a prevalence of 5.8% for LBW and 17.6% for macrosomia. The previous studies documented that the prevalence of LBW in Rwanda is low when compared with other countries in the same region such as Zambia, Uganda and Nigeria. This magnitude is also less than the prevalence of some countries in Asia such as in China where the accessibility to ANC visits remains challenging.

The present prevalence of LBW is less than the previous document which was 7.1% and low access of four recommended ANC visits was 35.4%. There is a significant reduction of the prevalence of LBW in Rwanda through the efforts made by the government when compared to the other developing countries that has a prevalence of 15.9%. Our results indicated that experiencing gestational age of more than 37 weeks reduced the risk for LBW babies. Further, non-smokers women and non-anemic women were at lower level to deliver LBW babies when compared to their counterparts. These results were relevant to prior studies conducted in central African counties that indicated that the attendance of ANC visits for pregnant women reduce the risk for delivering LBW babies. These findings are relevant to the previous studies that documented that smoking is a harmful behavior for the pregnant women that increase the risk for LBW babies. Further, gestational age of more than 37 weeks was significantly associated with a reduction of the LBW babies. These results agreed with the earlier studies. These results were similar to the previous studies that documented that children born to educated pregnant women and pregnant women with high wealth index who attend are less likely to weigh less than 2.5kg than other pregnant women. Prominently, in this research, the results are robust to adjustment for the socio-demographic characteristics of the recruited pregnant women. They revealed that marital status increased the odds of LBW. It was found that pregnant women who were married or living with the cohabitants as well as divorced and separated from their partner were more likely to deliver LBW newborns than the women who were single during pregnancy. These results challenged the previous studies that indicated being single was significantly associated with a greater risk of having LBW children than others.

Moreover, women who attended nutritional counseling were found to have a protective effect against LBW in this study, which is supported by previous studies. This is because nutritional counseling may have a positive impact on the improvement of feeding behaviors of pregnant women and their nutritional status which may significantly contribute to a decrease of the risk of delivering babies with LBW. Also, pregnant women who were fluently explained about pregnancy complications were less likely to deliver LBW babies when compared to their counterparts. These findings are consistent with the previous studies that indicated that ANC visits are significant contributor to birth weight, since it normalizes the birth weight of the child and their mother due to the prevention, intervention and health education that are effectively provided in each visit. Our results indicated that experiencing gestational age of more than 37 weeks reduced the risk for LBW babies. Further, non-smokers women and non-anemic women were at lower level to deliver LBW babies when compared to their counterparts. These results were relevant to prior studies conducted in central African counties that indicated that the attendance of ANC visits for pregnant women reduce the risk for delivering LBW babies. These findings are relevant to the previous studies that documented that smoking is a harmful behavior for the pregnant women that increase the risk for LBW babies. Further, gestational age of more than 37 weeks was significantly associated with a reduction of the LBW babies. These results agreed with the earlier studies. These results were similar to the previous studies that documented that children born to educated pregnant women and pregnant women with high wealth index who attend are less likely to weigh less than 2.5kg than other pregnant women.

Table 3. Characteristics of Babies and Associated Low Birth Weight and their Adjusted Odds Ratio

| Characteristics                  | Low birth weight | Adjusted odds ratio |
|---------------------------------|------------------|---------------------|
| Told about complications during pregnancy |                  |                     |
| No                              | 18.9             | 1                   |
| Yes                             | 81.1             | 0.4                 |
| Household head                  |                  |                     |
| Male                            | 46.6             | 1                   |
| Female                          | 53.4             | 1.1                 |

Notice: *Indicates statistical significance at p-value <0.05; **Indicates significance at 0.01, Unmarked p-values were not found to be the significant risk factors of LBW in Rwanda.
this supplement has a significant contribution to a decline in the prevalence of intrauterine growth retardation with folic acid supplementation as it was previously documented by the previous researchers\textsuperscript{39,65}.

Maternal anemia was identified as a risk factor, where we found that pregnant women with anemia had greater odds of delivering a newborn who weighed less than 2.5 kg than those who are not anemic. This is because moderate to severe anaemia for pregnant women could not only affect the mother but also impair oxygen delivery to the fetus and thus interfere with normal intrauterine growth. These results are similar to the findings from the previous studies that reported that micronutrients deficiency during pregnancy has harmful impact on the development of fetus and hence, birth weight. This result is in line with the prior studies conducted in Nigeria\textsuperscript{39,60}. Females babies were more likely than males. These findings were supported by previous study conducted in Ethiopia\textsuperscript{39}. Although several socio-demographic factors, nutritional factors, behavioral factors and ANC contacts including maternal age, parity, HWI and family size were not significantly associated with the LBW in our study; however, the previous studies conducted in sub-Saharan African countries peviosuly reported them as the risk factors of LBW\textsuperscript{39,66}.

Strengths, limitations and future directions
The present research has numerous prominent strengths. The first strength is that the RDHS 2014/2015 used the validated and standardized tools for interviewing the eligible participants. Second, the research data about birth weight that we used were obviously verified through records and recall bias was prevented. Another important strength is that the findings from this study have a primordial implication for preventing LBW and inform the policy makers to promote nutritional education or counseling, provision of the supplements namely iron-folic acid and prevention of anemia among the pregnant women. However, several limitations also warrant discussion. First, it was limited to a study design that did not actually explore for modifiable factors of ANC visits like HIV status of pregnant women, prenatal depression, receiving the supplementary vitamins (like vitamin A) during the pregnant, ultrasound, eclampsia, gestational diabetes, high blood glucose level during pregnancy, antiretroviral (ART) for HIV-positive women and reducing transmission of HIV from pregnant mother to child. Second, birth weight data was available for only babies whose weight was measured at birth. This limited us for estimating the real prevalence. Third, the selection bias resulted in the underestimation of the association between ANC and birth weight. This was because not all babies’ weight was measured. The other limitation was that the qualitative aspects data from the participants was not included for exploring some factors and to triangulate the findings of the quantitative methods used. Additionally, as the attendance of 8ANC visits required by 2016 WHO was very low (less than 1%), it was impossible to categorise the ANC visits as an outcome variables respecting such recommendation. Indeed, the qualitative nature of the risk factors captured in the RDHS, like iron intake and duration, nutrition intake, maternal anemia and malnutrition status, which influence the birth weight. Additionally, as the methods used for measuring birth weight were not validated by the survey team, the misclassification could occur in this research. As we do not know the exact timing of the birth weight measurement, this causes misclassification. Further, our study design could not determine causal relationship; so, further research on longitudinal study design are needed.

Conclusion
In conclusion, this study found several risk factors of LBW in Rwanda that remains a national public health concern. However, ANC services for pregnant women are a fundamental intervention for reducing LBW, the pregnant women of Rwanda are encouraged to attend all 8 recommended ANC visits for increasing the quality of their life and the life of the babies. This integral part of primary health care, ANC services, is the population-based intervention that reduces the risk to deliver the newborn with LBW. Therefore, there is a need of a multifaceted approach for addressing the factors of LBW through reinforcing ANC coverage and quality of ANC services for pregnant women. Information on anthropometric measurement and increased awareness of the importance of regular ANC visits is also desirable. Attending four or more ANC visits is a step toward improving maternal health by providing maximum required packages and this strategy reduces the risk to LBW. The policy makers and researchers should prioritize maternal education and families with low socio-economic status for preventing LBW in Rwanda. We recommend further research be conducted on the risk factors of macrosomia in Rwanda. Additionally, further study to explore the barriers to access ANC visits effectively for pregnant women from the rural settings is recommended. In the meantime, pregnant women in Rwanda are required to attend ANC visits appropriately and regularly for benefiting from the required packages that increase the probability to attenuate the LBW among the newborns. We recommend to measure birth weight immediately after birth for reducing the recall bias and misclassification.

Ethics and consent to participate
The present study was exempt from the ethical approval because the RDHS 2014/15 obtained the ethical approval from the Institutional Review Board (IRB) of the Rwanda National Ethics Committee (RNEC).

Data availability
Underlying data
Underlying data for ‘Regular antenatal care visits were associated with low risk of low birth weight among newborn in Rwanda: Evidence from the 2014/2015 Rwanda Demographic Health Survey (RDHS) Data was owned by the DHS program that can be obtained from https://dhsprogram.com/methodology/survey/survey-display-468.cfm.

The electronic data is available from the DHS program under its terms of use. Before downloading the data, the main author of this study registered as DHS user for reasons laid out on the DHS program website and dataset access was only granted for legitimate purpose of this research.
Authors’ contributions

EB conceptualized the study, did study design, formal analysis, wrote the protocol, requested the permission from the DHS website, drafted the manuscript and coordinated the study. SH contributed to data analysis, data curation and methodology. DR substantially contributed to the conceptualization. He also wrote the original draft preparation. HE reviewed and revised the manuscript, and searched the relevant journal to which the study is submitted. HE reviewed and edited the study. All investigators approved the final manuscript. They also agreed to take responsibility and be accountable for the content of the manuscript. All of them agreed on all versions of the manuscript before submitting it in the international journal. They also agreed on the final version accepted for publication.

Acknowledgments

We are thankful to DHS program for providing us for the permission to use the dataset. We sincerely acknowledge the substantial help of RDHS for provision of the datasets.

References

1. Ataguba JEO: A reassessment of global antenatal care coverage for improving maternal health using sub-Saharan Africa as a case study. PLoS One. 2018; 13(10): e0204822.
2. Mahumud RA, Sultana M, Sarker AR: Maternal factors contributing to low birth weight deliveries in Tshwane District, South Africa. PLoS One. 2014; 14(3): e0213558.
3. Gardner H, Green K, Gardner AS: Maternal iron and folic acid supplementation is associated with lower risk of low birth weight among mothers attending antenatal care from private clinics in Mekelle City, Northern Ethiopia: A facility based follow-up study. PLoS One. 2019; 14(3): e0212424.
4. Balarajan Y, Subramanian S, Fawzi W: Distribution and determinants of low birth weight in developing countries. J Prev Med Public Health. 2017; 50(1): 18-28.
5. Wagura P: Low Birth Weight Country, Regional and Global Estimates. World Health Organization; 2004.
6. Basinga P: Effect of antenatal care on low birth weight neonates: a hospital based case-control study in rural area of western maharashtra, India. Natl J Community Med. 2011; 2(3): 394-398.
7. Matin A, Azimul Sh, Matiar A, et al.: Maternal socioeconomic and nutritional determinants of low birth weight in urban area of Bangladesh. J Dhaka Med Coll. 2008; 17: 83-87.
8. Basinga P, Gertler PJ, Binagwaho A: Maternal factors contributing to low birth weight deliveries in Tshwane District, South Africa. PLoS One. 2014; 14(3): e0213558.
9. Hayat H, Khan P, Hayat G, et al.: A study of epidemiological factors affecting low birth weight. East J Med. 2014; 18(2013): 13-15.
10. Oulay L, Laohasiriwong W, Pajhan T, et al.: Effect of antenatal care on low birth weight prevention in Lao PDR: A case control study [version 1; peer review: 1 approved with reservations, 1 not approved]. F1000Res. 2018; 7: 1-12.
11. Hayat H, Khan P, Hayat G, et al.: Maternal factors contributing to low birth weight deliveries in Tshwane District, South Africa. PLoS One. 2014; 14(3): e0213558.
12. Mahumud RA, Sultana M, Sarker AR: Distribution and determinants of low birth weight in developing countries. J Prev Med Public Health. 2017; 50(1): 18-28.
13. Chukwuji NK, Nwokekwu HI, Adimora GN: Use of a Simple Anthropometric Measurement to Identify Low-Birth-Weight Infants in Enugu, Nigeria. Glob Pediatr Health. 2018; 5: 2331784818798174.
14. World Health Organization (WHO): Sustainable Development and Healthy Environments. International Statistics Classification of Diseases and Related Health Problems. 1999.
15. Henriksen T: The macrosomic fetus: a challenge in current obstetrics. Acta Obstet Gynecol Scand. 2008; 87(2): 134-135.
16. Muchie KF: Quality of antenatal care services and completion of four or more antenatal care visits in Ethiopia: A finding based on a demographic and health survey. BMC Pregnancy Childbirth. 2017; 17(1): 300.
17. Balarajan Y, Subramanian S, Fawzi W: Maternal iron and folic acid supplementation is associated with lower risk of low birth weight in India. J Nutr. 2013; 143(8): 1309-1315.
18. Balarajan Y, Subramanian S, Fawzi W: Maternal iron and folic acid supplementation is associated with lower risk of low birth weight in India. J Nutr. 2013; 143(8): 1309-1315.
19. Tuncapel O, Pena-Rosas J, Lawrie T, et al.: WHO recommendations on antenatal care for a positive pregnancy experience--going beyond survival. BJOG. 2017; 124(8): 860-862.
20. Tuncapel O, Pena-Rosas J, Lawrie T, et al.: WHO recommendations on antenatal care for a positive pregnancy experience--going beyond survival. BJOG. 2017; 124(8): 860-862.
21. Tuncapel O, Pena-Rosas J, Lawrie T, et al.: WHO recommendations on antenatal care for a positive pregnancy experience--going beyond survival. BJOG. 2017; 124(8): 860-862.
22. Haddad GS, Dejong J, Terreri N, et al.: Patterns and determinants of antenatal care utilization: analysis of national survey data in seven countenant countries. J Glob Health. 2016; 6(1): 010044.
23. Anthony J, Darnasceno A, Ojiji D: Hypertensive disorders of pregnancy: what the physician needs to know. Cardivasc J Afr. 2016; 27(2): 104-110.
24. Anthony J, Darnasceno A, Ojiji D: Hypertensive disorders of pregnancy: what the physician needs to know. Cardivasc J Afr. 2016; 27(2): 104-110.
25. Anthony J, Darnasceno A, Ojiji D: Hypertensive disorders of pregnancy: what the physician needs to know. Cardivasc J Afr. 2016; 27(2): 104-110.
26. Anthony J, Darnasceno A, Ojiji D: Hypertensive disorders of pregnancy: what the physician needs to know. Cardivasc J Afr. 2016; 27(2): 104-110.
during pregnancy on birthweight: Evidence from Zimbabwe. Food Nutr Bull. 2005; 26(4): 338-347
PubMed Abstract | Publisher Full Text | Free Full Text

31. Rooney CW. Maternal Health and Safe Motherhood Programme: Antenatal care and maternal health: how effective is it? a review of the evidence. by Cesene Rooney. Geneva: World Health Organization. Published online, 1992. Reference Source

32. Kanyangarara M, Munos MK, Walker N: Quality of antenatal care service provision in health facilities across sub-Saharan Africa: Evidence from nationally representative health facility assessments. J Glob Health. 2017; 7(2): 021101.
PubMed Abstract | Publisher Full Text | Free Full Text

33. Cumber SN, Dale DC, Stany EM, et al.: Importance of Antenatal Care Services to Pregnant Women at the Buea Regional Hospital Cameroon. J Fam Med Heal Care. 2016; 2(4): 23–29. Publisher Full Text

34. Olayi J, Lachasiriwo W, Phajan T, et al.: Effect of antenatal care on low birthweight prevention in Lao PDR: A case control study (version 1; peer review: 1 approved with reservations, 1 not approved). J0000res. 2018; 7(1138): 1138. Publisher Full Text

35. Kawungozi PC, Askibua D, Aleni C, et al.: Attendance and Utilization of Antenatal Care (ANC) Services: Multi-Center Study in Upcountry Areas of Uganda. Open J Prev Med. 2015; 5(3): 132–142. PubMed Abstract | Publisher Full Text | Free Full Text

36. Moller AB, Petzold M, Chou D, et al.: Early antenatal care visit: a systematic analysis of regional and local levels and trends of coverage from 1990 to 2013. Loncest Glob Health. 2017; 5(10): e977–e983. PubMed Abstract | Publisher Full Text | Free Full Text

37. Takashii K, Nomura M, Horuchi S, et al.: Global policy directions for maternal and child health in the SDG era SDGs Review. J Natl Inst Public Heal. 2017; 66(4): 401–395. Reference Source

38. Awiti JO: A multilevel analysis of prenatal care and birth weight in Kenya. Health Econ Rev. 2014; 4(1): 33. PubMed Abstract | Publisher Full Text | Free Full Text

39. Rosenzweig MR, Schultz TP: Estimating a household production function: Heterogeneity, the demand for health inputs, and their effects on birth weight. J Polit Econ. 1983: 91(5): 723–46. Publisher Full Text

40. NISR: Rwanda Demographic and Health Survey 2014-15: Final Report. National Institute of Statistics of Rwanda; 2015. Reference Source

41. Habimana S, Biracayza E: Risk Factors Of Stunting Among Children Under 5 Years Of Age In The Eastern And Western Provinces Of Rwanda: Analysis Of Rwanda Demographic And Health Survey 2014/2015. Pediatric Health Med Ther. 2019: 10: 115–130. PubMed Abstract | Publisher Full Text | Free Full Text

42. Hughes MM, Black RE, Katz J: 2500-g Low Birth Weight Cutoff: History and Implications for Future Research and Policy. Matern Child Health J. 2017; 21(2): 283–289. PubMed Abstract | Publisher Full Text | Free Full Text

43. Noh J, Kim YM, Lee LJ, et al.: Factors associated with the use of antenatal care in Sindh province, Pakistan: A population-based study. PLoS One. 2019; 14(4): e0213987. PubMed Abstract | Publisher Full Text | Free Full Text

44. Manari A, Nyirazinyoye L, Ntaganira J, et al.: Beyond coverage: improving the quality of antenatal care delivery through integrated mentorship and quality improvement at health centers in rural Rwanda. BMC Health Serv Res. 2018; 18(1): 136. PubMed Abstract | Publisher Full Text | Free Full Text

45. StataCorp: Stata Statistical Software: Release. StataCorp LP: College Station, 2014; 13.

46. Vandenbroucke JP, von Elm E, Altman DG, et al.: Strengthening the Reporting of Observational Studies in Epidemiology (STROBE): Explanation and elaboration. PLoS Med. 2007; 4(10): e297. PubMed Abstract | Publisher Full Text | Free Full Text

47. Chibwesha CJ, Zanolin A, Smid M, et al.: Predictors and outcomes of low birth weight in Lusaka, Zambia. Int J Gynaecol Obstet. 2016; 134(3): 309–314. PubMed Abstract | Publisher Full Text | Free Full Text

48. Oladeinde HB, Oladeinde OB, Omoregie R, et al.: Prevalence and determinants of low birth weight: the situation in a traditional birth home in Benin City, Nigeria. Afr J Health Sci. 2015; 13(4): 1123-1129. PubMed Abstract | Publisher Full Text | Free Full Text

49. Arondu MO, Agardh A, Asamoah BO: Survival of low birthweight neonates in Uganda: Analysis of progress between 1995 and 2011. BMC Pregnancy Childbirth. 2018; 18(1): 189. PubMed Abstract | Publisher Full Text | Free Full Text

50. Zhou H, Wang A, Huang X, et al.: Quality antenatal care protects against low birth weight in 42 poor counties of Western China. PLoS One. 2019; 14(1): e0213993. PubMed Abstract | Publisher Full Text | Free Full Text

51. NISR: Rwanda Demographic and Health Survey 2010. 2010. Reference Source

52. Rurangireva AA, Mogren I, Ntaganira J, et al.: Quality of antenatal care services in Rwanda: assessing practices of health care providers. BMC Health Serv Res. 2018; 18(1): 865. PubMed Abstract | Publisher Full Text | Free Full Text

53. Acharya D, Singh JK, Kadel R, et al.: Maternal Factors and Utilization of the Antenatal Care Services During Pregnancy Associated with Low Birth Weight in Rural Nepal: Analyses of the Antenatal Care and Birth Weight Records of the MATRI-SUMAN Trial. Int J Environ Res Public Health. 2018; 15(11): 2450. PubMed Abstract | Publisher Full Text | Free Full Text

54. Tekelab T, Chojenta C, Smith R, et al.: Factors affecting utilization of antenatal care in Ethiopia: A systematic review and meta-analysis. PLoS One. 2019; 14(4): e0214846. PubMed Abstract | Publisher Full Text | Free Full Text

55. Pawar A, Kumar D: Maternal factors associated with low birth weight: a case control study in rural Kerala. Int J Community Med Public Heal. 2017; 4(10): 3793-3795. Publisher Full Text

56. Mumbare S, Mbinda-Amon G, Darade R, et al.: Maternal risk factors associated with term low birth weight neonates: A matched-pair case control study. Indian Pediatr. 2012; 49(1): 25–28. PubMed Abstract | Publisher Full Text | Free Full Text

57. Chukwu SN: Low Birth Weight in Nigeria: Does Antenatal Care Matter? 2008. Reference Source

58. Gupta S, Yamada G, Mpembeni R, et al.: Factors Associated with Four or More Antenatal Care Visits and Its Decline among Pregnant Women in Tanzania between 1999 and 2010. PLoS One. 2014; 9(7): e101893. PubMed Abstract | Publisher Full Text | Free Full Text

59. Siza JE: Risk factors associated with low birth weight of neonates among pregnant women attending a referral hospital in northern Tanzania. Tanzan J Health Res. 2008; 10(1): 1–8. PubMed Abstract | Publisher Full Text | Free Full Text

60. Louis B, Steven B, Margret N, et al.: Prevalence and Factors Associated with Low Birth Weight among Teenage Mothers in New Mulago Hospital: A Cross Sectional Study. J Health Sci (El Monte). 2016; 4(04): 192-199. PubMed Abstract | Publisher Full Text | Free Full Text

61. Rode SJ: Effect of Complete Antenatal Care on Birth Weight of Children in India: Evidence from National Family Health Survey (NFHS) Data. J Women's Heal Care. 2018; 7(1): 1–12. PubMed Abstract | Publisher Full Text | Free Full Text

62. Sebayang SK, Dibley MJ, Kelly P, et al.: Determinants of low birthweight, small-for-gestational-age and preterm birth in Lombok, Indonesia: analyses of the birthweight cohort of the SUMMIT trial. Trop Med Int Health. 2012; 17(8): 938–950. PubMed Abstract | Publisher Full Text | Free Full Text

63. Louis B, Steven B, Margret N, et al.: Traffic and Transportation Improvement Plans for Trivandrum. Indian Highw. 2016; 14(2): 22–29. PubMed Abstract | Publisher Full Text | Free Full Text

64. Mvunta MH, Mboya IB, Msuya SE, et al.: Incidence and recurrence risk of low birth weight in Northern Tanzania: A registry based study. PLoS One. 2019; 14(4): e0215768. PubMed Abstract | Publisher Full Text | Free Full Text

65. Mengesha HG, Wuneh AD, Weldearegawi B: Low birth weight and macrosomia in Tigray, Northern Ethiopia: who are the mothers at risk? BMC Pediatr. 2017; 17(1): 144. PubMed Abstract | Publisher Full Text | Free Full Text
Open Peer Review

Current Peer Review Status: ✅ ❓ ❓

**Version 2**

Reviewer Report 07 November 2022

https://doi.org/10.5256/f1000research.139674.r154974

© 2022 Islam M. This is an open access peer review report distributed under the terms of the Creative Commons Attribution License, which permits unrestricted use, distribution, and reproduction in any medium, provided the original work is properly cited.

✅ M. Mazharul Islam

Department of Statistics, College of Science, Sultan Qaboos University, Muscat, Oman

No further comment.

**Competing Interests:** No competing interests were disclosed.

I confirm that I have read this submission and believe that I have an appropriate level of expertise to confirm that it is of an acceptable scientific standard.

**Version 1**

Reviewer Report 12 August 2022

https://doi.org/10.5256/f1000research.55185.r142748

© 2022 Mazumder S. This is an open access peer review report distributed under the terms of the Creative Commons Attribution License, which permits unrestricted use, distribution, and reproduction in any medium, provided the original work is properly cited.

❓ Sarmila Mazumder

Society for Applied Studies, New Delhi, India

This is an important domain and the paper reiterates the importance of antenatal care. However, this a rather simplistic view of a complex issue. Few points to consider:

1. The focus of the manuscript is on the number of ANC visits and not on the quality, content, examination, investigations, ultrasound, or respectful care, ability to identify/manage or refer high risk pregnancies, etc. The underlying assumption is that these are optimum at the the ANC sources. In that case, information on the same needs to be provided.
2. Additionally, just the number of ANC visits is not enough; gestational age when the pregnant women was first registered, the timeliness of the ANC visits going by the 4 ANC norm, that is, one in the first trimester, 1 in the second trimester and 2 in the third trimester, are equally important.

3. The ANC standard needs mention, there are women with 7 ANCs. Is the 2016 WHO ANC guideline being implemented at the study site? In that case is the rationale of 4 ANC as a cut-off based on minimum ANC visits? Need clarity.

4. Specific issues: How were the 8004 women selected? It is mentioned that that women who had documented birth weight were interviewed. The sampling method says 2 stage cluster sampling and random selection. In that case the selection of women seems purposive, this needs clarity.

5. This is a retrospective data collection, where women with youngest child less than 5 years were interviewed. It will be important to mention that all records on birth weight, number of ANC visits, measurement of BP, administration of antimalarial drug, height, weight and BMI, etc were available. Recall bias cannot be ruled out unless good documentation was available.

6. At which stage was BMI measured? Pre-pregnancy or early first trimester? This will be important to document.

7. Gestational weight gain is an essential component of ANC, this is not specified.

8. It is not clear why BP measurement and antimalarials are considered as confounders.

9. Tables do not have N (total number, denominators). Table 1 needs explanation. The sample size was 8004 women but in table 1, the numbers do not add up to 8004. it varies with each variable. There is no information on the number of births. It would be informative to know about preterms, SGA, AGA as well.

10. The information on availability of birth weight is a little confusing. 92% reported birth weight, were these documented on discharge reports or verbally reported. Additionally, the low birth weight does not seem to be a major issue, with only 5.8% low birth weight while 18% macrosomia.

11. Some information would be useful to present. 99% women attended ANC clinic but 44% had 4 ANCs. A qualitative component would have been helpful to understand the barriers to low utilization.

12. The discussion section needs strengthening, it is repetition of the previous section. Some of the findings could have been analyzed, for eg., explore further how was home delivery associated with LBW. The places of ANC, pros and cons, etc. have not been discussed.

13. Typographical error, table 2, 7th row, last column. 0.0.3.
14. The authors need to match the numbers in the tables and text.

Is the work clearly and accurately presented and does it cite the current literature?
Yes

Is the study design appropriate and is the work technically sound?
Partly

Are sufficient details of methods and analysis provided to allow replication by others?
Partly

If applicable, is the statistical analysis and its interpretation appropriate?
Partly

Are all the source data underlying the results available to ensure full reproducibility?
Yes

Are the conclusions drawn adequately supported by the results?
Partly

Competing Interests: No competing interests were disclosed.

Reviewer Expertise: Maternal and child health

I confirm that I have read this submission and believe that I have an appropriate level of expertise to confirm that it is of an acceptable scientific standard, however I have significant reservations, as outlined above.

Author Response 10 Oct 2022

Emmanuel Biracyaza, University of Rwanda, Kigali, Rwanda

This is an important domain, and the paper reiterates the importance of antenatal care. However, this a rather simplistic view of a complex issue. Few points to consider:
Response: Dear reviewer, thank you very much for these kind words and crucial suggestions and recommendations for improving our study that was submitted in the f1000research.com. All the point you raised so that we can improve our study have been relevant and they helped us to continue looking our further investigation.

Frankly, the ANC contacts remains at a very low level (less than 1%) which represents pregnant women who attended 8 ANC contacts. This is similar to the other countries of the same region (SSA) or LMICs.

The focus of the manuscript is on the number of ANC visits and not on the quality, content, examination, investigations, ultrasound, or respectful care, ability to identify/manage or refer high risk pregnancies, etc. The underlying assumption is that these are optimum at the ANC sources. In that case, information on the same needs to be provided.
Response: Thank you for the recommendations that are important. We totally agree
with you about the focus of this work. But these variables about ultrasound, respectful care and risk pregnancies etc. were not found in the RDHS and we cannot change the dataset. But we recommend that the further studies can investigate and include such variables. In our data analysis, we included socio-demographic, nutritional variables, maternal and individual variables. But we did not find that the information about ultrasound or respectful care etc., however, we know how they are important in the ANC contacts.

Additionally, just the number of ANC visits is not enough, gestational age when the pregnant women was first registered, the timeliness of the ANC visits going by the 4 ANC norm, that is, one in the first trimester, 1 in the second trimester and 2 in the third trimester, are equally important.

**Responses:** We thank you for this essential observation and suggestion. We have checked and corrected according to the suggestions provided. Variables such as gestational age were added. But about the ANC visits, we found that majority of the attended 4-7 ANCs while only 1% attended 8 recommended ANC contacts by the 2016 WHO but we have recommended the decision makers to encourage the pregnant women to attend the ANC visits as recommended by WHO. The main challenge was that the utilisation of 8 ANC visits is at low level and this could limit us in the data analysis.

The ANC standard needs mention, there are women with 7 ANCs. Is the 2016 WHO ANC guideline being implemented at the study site? In that case is the rationale of 4 ANC as a cut-off based on minimum ANC visits? Need clarity.

**Responses:** The cut-off of used is the 4 ANC visits as recommended by the WHO due to the evidence provided above. We wrote an unintentional in our previous version and this created the mismatch in the first version. We notice that the attendance of the ANC as required remains a public health concern in Rwanda as one of SSA countries which remain with such concern that has to be solved through multidisciplinary team.

Specific issues: How were the 8004 women selected? It is mentioned that that women who had documented birth weight were interviewed. The sampling method says 2 stage cluster sampling and random selection. In that case the selection of women seems purposive, this needs clarity.

**Responses:** Thank you as the study used secondary study (dataset from DHS), we did not conduct the data collection with direct contact with the women. But the RDHS indicates that the women were interviewed. The sample size was clearly indicated (7381 women who fit the inclusion criteria). We only included the women who provided information about the birth weight (they were only 7381) while 8004 was for the women who gave birth. Of course, if we take 8004-7381, we directly find the number of those who did not provide birth weight for their babies.

This is a retrospective data collection, where women with youngest child less than 5 years were interviewed. It will be important to mention that all records on birth weight, number of ANC visits, measurement of BP, administration of antimalarial drug, height, weight and BMI, etc were available. Recall bias cannot be ruled out unless good documentation was available.
Response: Thank you for this recommendation that has helped us to improve our study. We included your recommendations and clarified the above-mentioned part.

At which stage was BMI measured? Pre-pregnancy or early first trimester? This will be important to document.
Response: This was documented in the study. BMI as an important anthropometric indicator for pregnant women and can have a crucial effect on weight of child was measured at early first trimester (when the pregnant women attended the 1st ANC contact).

Gestational weight gain is an essential component of ANC, this is not specified.
Responses: Thank you. The gestational age was added in the analysis; however, gestational diabetes was not included because of having several missing information.

It is not clear why BP measurement and antimalarials are considered as confounders.
Responses: We have corrected according to your recommendations. By analysing the multicollinerality, we found that the variables such as variables related to malaria and BP inflected with the birth weight. As results, we removed them from the analysis and we remained with the good variables that presented the variables, which seemed to be equal (near to 1). But the removed ones had more than 3 values of VIF.

Tables do not have N (total number, denominators). Table 1 needs explanation. The sample size was 8004 women but in table 1, the numbers do not add up to 8004. It varies with each variable. There is no information on the number of births. It would be informative to know about preterms, SGA, AGA as well.
Responses: All the tables were appropriately corrected. The mismatching was because we shared the wrong table. This impact in the interpretations. About the above variables such as AGA, preterms, and SGA; they had several missing variables. So, that is why we did not include them in the analysis.

The information on availability of birth weight is a little confusing. 92% reported birth weight, were these documented on discharge reports or verbally reported. Additionally, the low birth weight does not seem to be a major issue, with only 5.8% low birth weight while 18% macrosomia.
Responses: Thank you very much for this but for the developing country like Rwanda, the prevalence of about 6% for LBW may be a public health burden if the further strategies to promote health for the pregnant woman and the newborns.

Some information would be useful to present. 99% women attended ANC clinic but 44% had 4 ANCs. A qualitative component would have been helpful to understand the barriers to low utilization.
Responses: Thank you for these important recommendations. The qualitative study design was recommended based on our results. This can be found in the strengths and further directions.

The discussion section needs strengthening, it is repetition of the previous section. Some of the findings could have been analyzed, for e.g., explore further how was home delivery
associated with LBW. The places of ANC, pros and cons, etc. have not been discussed.  

Responses: The discussion was also modified and of course improved due to your recommendations.

Typographical error, table 2, 7th row, last column. 0.0.3.  

Responses: This typo error and grammatical errors were corrected.

The authors need to match the numbers in the tables and text.  

Responses: We kindly thank you for these recommendations. We have matched the results from the tables and texts.

Thank you very much.

Competing Interests: No conflict of interest

Manoja Kumar Das
The INCLEN Trust International, New Delhi, Delhi, India

The article presents the prevalence of LBW and the risk factors for the same in Rwanda using the RDHS 2014/15 data.

The manuscript needs attention in some sections:
1. Methods
1.1 Macrosomia definitions should be mentioned

2. Results
2.1 The following statements need review and clarification.  
"For marital status, married and cohabiting pregnant women were 1.86-times at greater risk to have LBW children [aOR=1.9; 95%CI (1.3–2.8), p=0.002] compared with single pregnant women."  
"The results indicated that the widowed, separated and divorced pregnant women had 1.7-times greater risk of having LBW babies [aOR=1.7; 95%CI (1.1–2.5), p=0.015] than women who were single during pregnancy."  
The two statements are in conflict. Please check.

2.2. The statement "Results found that being provided maternal iron and folic acid supplementation during pregnancy [aOR=0.5, 95%CI (0.3–0.9), p=0.015], not being given nutrients during pregnancy [aOR=2.5, 95%CI (2-8.4), p<0.001], being told about maternal complications
during pregnancy [aOR=0.7...."
How was the nutrient given assessed?

3. Discussion
3.1. Please check the statements and discuss
"They revealed that marital status increased the odds of LBW. It was found that pregnant women who were married or living with the cohabitants were 1.9-times likely to have LBW compared with pregnant women who were single. They also revealed that the pregnant women who divorced or separated had 1.7-greater risks to have new-borns who weigh less than 2.5 kg."
This statement needs to be examined carefully, whether the factor responsible was crowding, low SES and undernutrition or hunger.

4. Limitations
4.1 The limitations should mention the qualitative nature of the risk factors captured in the RDHS, like iron intake and duration, nutrition intake, maternal anemia and malnutrition status, which influence the birth weight.

Is the work clearly and accurately presented and does it cite the current literature?
Yes

Is the study design appropriate and is the work technically sound?
Yes

Are sufficient details of methods and analysis provided to allow replication by others?
Yes

If applicable, is the statistical analysis and its interpretation appropriate?
Yes

Are all the source data underlying the results available to ensure full reproducibility?
Partly

Are the conclusions drawn adequately supported by the results?
Partly

Competing Interests: No competing interests were disclosed.

Reviewer Expertise: Child health, public health

I confirm that I have read this submission and believe that I have an appropriate level of expertise to confirm that it is of an acceptable scientific standard, however I have significant reservations, as outlined above.

Author Response 10 Oct 2022
Emmanuel Biracyaza, University of Rwanda, Kigali, Rwanda
First of all, I thank you for the valuable points you raised for us. They have of course and prominently helped us to strengthen our study.

The article presents the prevalence of LBW and the risk factors for the same in Rwanda using the RDHS 2014/15 data.

Response: Thank you very much for this appreciation.

The manuscript needs attention in some sections:

1. Methods
1.1 Macrosomia definitions should be mentioned

Responses: Thank you very much for the recommendations. The concept macrosomia was also defined in the first paragraph of the background of the study. It was defined as when a baby is born with more than 4 kilograms (or 4000 grams).

2. Results
2.1 The following statements need review and clarification.
"For marital status, married and cohabiting pregnant women were 1.86-times at greater risk to have LBW children [aOR=1.9; 95%CI (1.3–2.8), p=0.002] compared with single pregnant women."

Response: This sentence was rephrased and improved.

"The results indicated that the widowed, separated and divorced pregnant women had 1.7-times greater risk of having LBW babies [aOR=1.7; 95%CI (1.1–2.5), p=0.015] than women who were single during pregnancy."

The two statements are in conflict. Please check.

Responses: This sentence was rephrased and improved.

2.2. The statement "Results found that being provided maternal iron and folic acid supplementation during pregnancy [aOR=0.5, 95%CI (0.3–0.9), p=0.015], not being given nutrients during pregnancy [aOR=2.5, 95%CI (2.8–4), p<0.001], being told about maternal complications during pregnancy [aOR=0.7...."

How was the nutrient given assessed?

Responses: This statement was also improved after adjusting some analyses due to the required analysis from the other reviewers.

3. Discussion
3.1. Please check the statements and discuss
"They revealed that marital status increased the odds of LBW. It was found that pregnant women who were married or living with the cohabitants were 1.9-times likely to have LBW compared with pregnant women who were single. They also revealed that the pregnant women who divorced or separated had 1.7-greater risks to have new-borns who weigh less than 2.5 kg."

Responses: In discussion section, we improved this part, and we changed the statement as recommended by the reviewer.

This statement needs to be examined carefully, whether the factor responsible was crowding, low SES and undernutrition or hunger.

Responses: Thank you very much the factors such as SES and undernutrition (based on wasting, underweight, stunting and obesity) were also explored.

4. Limitations
4.1 The limitations should mention the qualitative nature of the risk factors captured in the
RDHS, like iron intake and duration, nutrition intake, maternal anemia and malnutrition status, which influence the birth weight.

Responses: Thank you very much for these recommendations; and we included the recommendation that further studies could also be conducted using qualitative methods for exploring the perspectives from the pregnant women about the factors that influence their attendance of ANC and the benefits from attending ANC services on child weight at birth. So, we believe that the women can be experts in this qualitative exploration.

Thank you very much for your prominent recommendations that have helped us to improve our study.

Competing Interests: No competing interest.
3. The authors should provide clear information about the total number of births considered in the study, of whom birth weights were available for how many or what proportion of births. Among the children with birth weights, what proportion of birth weights was obtained from mothers' recall and what proportion from written information. What was meant by written information? Is it birth certificates or health cards?

4. The most important information which is missing in this study is the total sample size of the study population. In one place, the authors mentioned about 8,004 mothers of reproductive age, but the distribution of the mothers provided in column 2 of Table 1 does not reflect that. What are these numbers in column 2 of Table 1 and why there is a wide variation in number across the variables?

5. In page 6, under the Results section of Multiple logistic regression analysis: There are a lot of mistakes. Most of the aORs and the 95% CIs given within parenthesis do not correspond with the results presented in Table 3.

6. The discussion section has been written very poorly, as it is mostly a repetition of the description of the findings without providing any explanations or possible implications of their findings. To validate their results, the authors just wrote “the results are consistent or similar or corroborate with findings of other study” without providing any numerical evidence how their findings are consistent with other studies.

7. There is a methodological problem in the application of multiple logistic regression analysis to the real data considered in this study. One of the basic assumptions of the regression model is that the explanatory variables are independent. However, in this study, all the selected explanatory variables are not independent. For example, maternal height and weight are linearly dependent, and they are also related to body mass index (BMI) because $\text{BMI} = \text{weight}/\text{height}^2$. Violation of the assumption of independence creates a serious problem in statistical analysis, which is known as multicollinearity problem, resulting in biased results. While applying regression model, the researchers should be careful about multicollinearity problem. The authors did not provide any information about the goodness of fit of the model and adequacy of the fitted model. The author should redo the multiple regression analysis by removing the suspected inter-correlated variables.

Is the work clearly and accurately presented and does it cite the current literature?
Yes

Is the study design appropriate and is the work technically sound?
Partly

Are sufficient details of methods and analysis provided to allow replication by others?
Yes

If applicable, is the statistical analysis and its interpretation appropriate?
Partly

Are all the source data underlying the results available to ensure full reproducibility?
Yes

Are the conclusions drawn adequately supported by the results?
Partly

**Competing Interests:** No competing interests were disclosed.

I confirm that I have read this submission and believe that I have an appropriate level of expertise to confirm that it is of an acceptable scientific standard, however I have significant reservations, as outlined above.

Author Response 10 Oct 2022

**Emmanuel Biracyaza**, University of Rwanda, Kigali, Rwanda

The paper addressed a very important issue of public health. The findings of the paper are likely to contribute in literature of the impact of antenatal care on birth weight. However, I have some observations, which are given below.

In the Introduction section, page 3, the authors stated that WHO recommended four or more ANC visits during pregnancy, which is a dated recommendation. Perhaps, the authors are referencing 2001 WHO recommended schedule of 4 ANC visits (Villar et al., 2001). However, in 2016 WHO revised its recommendation and prescribed 8 or more visit schedules (see WHO (2016). WHO recommendations on antenatal care for a positive pregnancy experience. [https://apps.who.int/iris/bitstream/handle/10665/250796/9789241549912-eng.pdf](https://apps.who.int/iris/bitstream/handle/10665/250796/9789241549912-eng.pdf)).

**Responses:** Thank you very much; we found that there was a typing error since in our study, we used expected to use the recent recommendations of the WHO that recommend 8 ANC visits for the pregnant women. But when we realised that it could not be possible to assess it because the prevalence of using 8 recommended ANC contacts was low in Rwanda (less than 1%). So, in the study limitations and conclusions we tried to mention it and then recommend the policy makers to encourage pregnant women to respect the respected ANC contacts.

The authors defined the main explanatory variable (no or less than 4 ANC and ≥ 4 ANC) based on the old schedule of ANC. Considering the low average frequency of ANC visits in Rwanda, I am not claiming that the analysis is wrong, but not mentioning the latest development is a clear oversight. The authors should discuss the compliance of 8 or more ANC visits in Rwanda.

**Responses:** Thank you very much. As indicated in the work, we considered the 8 ANC visits as recommended by 2016 WHO. So, the problem was in the first table where we shared the wrong table, but we effectively corrected it and then provided the appropriate table.

**Notice.** For the case of 2016 WHO recommendations, you can also refer to the following publications to indicate you how the ANC remains very low:

1. Sserwanja, Q., Nuwabaine, L., Gatasi, G. *et al*. Factors associated with utilization of quality antenatal care: a secondary data analysis of Rwandan Demographic Health Survey 2020.
Under sampling design, page 4, the authors wrote: “current birth weights were not available for the most children”, which contradicts the last line of the paragraph stating that “It was found that 92% of newborns had a birth weight reported while 8% did not.”

Responses: We edited the sentence after noticing that what you have observed. We decided to remove it because we found it was not necessary. Thus, the last line of the paragraph was really enough.

The authors should provide clear information about the total number of births considered in the study, of whom birth weights were available for how many or what proportion of births. Among the children with birth weights, what proportion of birth weights was obtained from mothers' recall and what proportion from written information. What was meant by written information? Is it birth certificates or health cards?

Responses: We thank you very much for this suggestion. Normally, after we recheck our dataset and remove missing variables, we also tried to indicate the corrected number of the births and pregnant women. Please, note that we only used the data of the women who provided the number weight of their newborns at birth. the women who were of out of this major inclusion criteria were removed from the analyses (therefore, our study was conducted among 7381 women).

The most important information, which is missing in this study, is the total sample size of the study population. In one place, the authors mentioned about 8,004 mothers of reproductive age, but the distribution of the mothers provided in column 2 of Table 1 does not reflect that. What are these numbers in column 2 of Table 1 and why there is a wide variation in number across the variables?

Responses: Thank you very much for this observation about mismatching of the totals for the table 1. We included the corrected table. In addition to that, the sample size was 7381 women who provided the weight of their babies. They were recruited from 8004 women who delivered and 30058 individuals for the participants of this dataset in which we used. In page 6, under the Results section of Multiple logistic regression analysis: There are a lot of mistakes. Most of the aORs and the 95%CIs given within parenthesis do not correspond with the results presented in Table 3.

Responses: We thank you or this observation. We have corrected the interpretations since the information provided in the table was correct. Improved interpretations of the results were also made.

The discussion section has been written very poorly, as it is mostly a repetition of the description of the findings without providing any explanations or possible implications of their findings. To validate their results, the authors just wrote “the results are consistent or similar or corroborate with findings of other study” without providing any numerical evidence how their findings are consistent with other studies.

Responses: Regarding the discussion, we have importantly made the revisions and changes based on the major results from the section results.
There is a methodological problem in the application of multiple logistic regression analysis to the real data considered in this study. One of the basic assumptions of the regression model is that the explanatory variables are independent. However, in this study, all the selected explanatory variables are not independent. For example, maternal height and weight are linearly dependent, and they are also related to body mass index (BMI) because \( \text{BMI} = \frac{\text{weight}}{\text{height}^2} \). Violation of the assumption of independence creates a serious problem in statistical analysis, which is known as multicollinearity problem, resulting in biased results. While applying regression model, the researchers should be careful about multicollinearity problem. The authors did not provide any information about the goodness of fit of the model and adequacy of the fitted model. The author should redo the multiple regression analysis by removing the suspected inter-correlated variables.

Responses: Thank you for these recommendations. To manage the issues of methods, we did again the analysis part and we found the new results with some differences. So, we really have computed the goodness of fit for the multivariate logistical model. Multicollinearity was assessed using VIF and as a result several variables that inflacted were directly removed from models for avoiding overestimation or underestimations. We really found that the removed variables negatively impacted some variables because some of the remaining variables became significantly associated while others were not. But we observed crucial improvements.

**Competing Interests:** No competing interests were disclosed.