Global Health Journal 7 (2023) 167–174

Contents lists available at ScienceDirect

Global Health Journal

journal homepage: https://www.keaipublishing.com/en/journals/global-health-journal/

RESEARCH ARTICLE

Assessing the influence of digital technologies on antenatal care visits in Zimbabwe: insights from 2019 Zimbabwe Multiple Indicator Cluster Survey

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ARTICLE INFO

Article history:
Received 12 September 2022
Received in revised form 26 April 2023
Accepted 10 July 2023
Available online 28 July 2023

Keywords:
Digital technologies
Maternal and child health
Africa
Child mortality
Maternal mortality
Prenatal care

ABSTRACT

Background and objective: To provide good health and well-being as established by the Sustainable Development Goal (SDG) 3, access to digital technologies can act as conduits to achieve such progress in a population. As guided by the World Health Organization, antenatal care (ANC) attendance is one of the measures promoted to curtail the global health burden of maternal and infant mortality. ANC services are seldom utilized to their full potential in Zimbabwe. This study explores if any of the women's digital technology characteristics were associated with antenatal care visits.

Methods: The study analyzed population-based cross-sectional data with a subsample of 1 932 women aged 15–49 years from the 2019 Zimbabwe Multiple Indicator Cluster Survey. Test of associations with chi-square test, bivariate, and multivariate multinomial logistic regression analyses were used to examine the predictors of adequate (4–7) and optimal (≥ 8) ANC visits relative to undesirable (1–3) antenatal care visits among women who had given births 2 years before the survey.

Results: The results indicate that 64.5% (1246/1 932) of the women attained adequate ANC while about 9.8% (189/1 932) attained optimal ANC. Reading a newspaper/magazine at least once a week (odds ratio [OR] 1.73, $\beta' = 0.551$, $t = 2.030$, $P = 0.043$) and watching television at least once a week (OR 1.72, $\beta' = 0.545$, $t = 2.454$, $P = 0.015$), listening to the radio less than once a week (OR 1.28, $\beta' = 0.247$, $t = 1.750$, $P = 0.080$), and owning a mobile phone (OR 1.48, $\beta' = 0.394$, $t = 3.020$, $P = 0.003$) were positively associated with adequate ANC. Optimal ANC was significantly associated with women being able to read a newspaper at least once a week (OR 2.93, $\beta' = 1.074$, $t = 3.120$, $P = 0.002$), listen to the radio less than once a week (OR 2.07, $\beta' = 0.73$, $t = 2.700$, $P = 0.007$) and have ownership of a mobile phone (OR 1.88, $\beta' = 0.631$, $t = 2.620$, $P = 0.009$).

Conclusion: Access to a newspaper, radio, television, and mobile phone were important predictors of a woman's ability to achieve her ANC attendance. Policies to improve the knowledge of ANC packages can be facilitated using digital technology to achieve adequate and preferably optimal ANC in Zimbabwe. It is important to improve digital infrastructure to support digital technologies in providing ANC services.

1. Background

Improving antenatal care (ANC) services is one of the most important interventions for reducing maternal mortality in many sub-Saharan African (SSA) countries. Antenatal care refers to the routine care delivered to expectant mothers by skilled healthcare professionals, from conception to the onset of labor.[1] Several strategies including the World Health Organization (WHO)-focused ANC framework and safe motherhood initiatives have been launched to provide adequate ANC services and promote and establish good health during pregnancy and the early postpartum period.[2-3] These initiatives seek to promote good health and well-being of pregnant mothers to improve health outcomes, deliver health promotion, and preventive services,[4] as established in the sustainable development goal (SDG) 3. Thus, the WHO recommended at least eight ANC visits for uncomplicated pregnancies to reduce maternal morbidity and improve newborns' health.[5] However, there is slower progress in attaining the minimum ANC visits in the majority of SSA countries as per WHO's recommendations,[3] exacerbating maternal mortality and newborn deaths. For instance, approximately 295 000 women died globally during and following pregnancy and childbirth in 2017,

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https://doi.org/10.1016/j.glohj.2023.07.003

94% of deaths occurred in low-resource settings, and most could have been prevented.[6] SSA accounted for 196 000 maternal deaths. Most of these maternal deaths are preventable by providing quality and adequate antenatal care services and establishing communication between healthcare professionals and pregnant mothers.[6] A study conducted in Bangladesh revealed that ANC services including health promotion, screening and diagnosis, and disease prevention can reduce maternal mortality by 20%,[6] given the good quality and regular attendance. These services are developed to maximize good health outcomes, such as lowering maternal deaths, reducing complications during pregnancy and neonatal mortality,[3] low postpartum anemia, and ensuring appropriate birth weight.[7]

However, most maternal deaths are preventable, but they have been increasing in Zimbabwe.[8] Integrating digital technologies such as mobile health applications,[9] radio, television, and digital billboards into the existing interventions can assist to create awareness, sending reminders for healthcare appointments,[10] promoting ANC services, and intensifying health promotion to curtail the global health burden of maternal and infant mortality. For instance, improving access to maternal information through mass media platforms such as radio and television can increase the utilization of ANC.[2] A study conducted in Zanzibar, Tanzania that developed a mobile phone ANC intervention using short messaging services to provide two-way communication between healthcare professionals and expectant mothers revealed improvement in ANC attendance.[10] Interestingly, delivering ANC services through digital technologies is still nascent and seldom, consequently leading to the underutilization of emerging technologies to their full potential in Zimbabwe. Apparently, about 89% of pregnant women attended ANC services at least 4 times, but only 39% of women had their first ANC visit in the first trimester in Zimbabwe.[11] Determining feasible digital technologies that can be utilized to promote ANC services in Zimbabwe can assist policymakers to develop low-cost mobile interventions[12] for pregnant mothers. Such mobile health interventions can be used to establish two-way communication between pregnant mothers and health workers,[13] make appointments, send reminders and monitor ANC visits adherence among others. Therefore, this study explores the influence of various digital technologies and their association with ANC visits in Zimbabwe.

2. Methods

2.1. Data source, sampling method, and sample size

The 2019 Zimbabwe Multiple Indicator Cluster Survey (ZMICS) was used for this study. The ZMICS is a cross-sectional nationwide survey study to assess the situation of households and individuals including women aged 15–49 years of reproductive age. The ZMICS was conducted by the Zimbabwe National Statistics Agency (ZIMSTAT) with funding and technical support from the United Nations Children's Fund (UNICEF), the Government of Zimbabwe Ministerial departments, and other stakeholders or donors.[14]

In the 2019 ZMICS, each sample was stratified by region (province) and area (urban-rural) of residence. In a two-stage sampling method, a selection of enumeration areas (cluster) was done using a probability proportionate to the size. Within each cluster, households were drawn using a systematic sampling approach resulting in 462 clusters and 12 012 households. In each household, all women aged 15–49 years were interviewed. In the 2019 ZMICS data of 10 703 women aged 15–49 years a total of 2 338 women who had given birth 2 years prior to the data collection were included in this study. From this, a subsample of 1 932 women was extracted. Using the Stata complex survey function, all the sociodemographic variables had complete data while missing cases were observed for the outcome (antenatal care visits) and digital technology variables: newspaper and internet use. The missing cases were not retained in the analysis obtained from the joint distribution of all the variables.

2.2. Measures

2.2.1. Outcome variable

Based on WHO recommendations, ANC visits were categorized into a three-scale response format: "1–3 visits", "4–7 visits", and "≥ 8 visits", representing undesirable, adequate, and optimal visits, respectively. In the 2019 ZMICS, the question on the frequency of ANC attendance was asked to women who had given a live birth 2 years before the date of the interview.

2.2.2. Explanatory variables

Six digital technology explanatory variables were identified as of main interest: Three variables frequency of reading a newspaper/magazine, listening to the radio, and watching television had the following responses each: not at all, less than once a week, at least once a week combined with every day; The participants were also asked three questions on whether they ever used the internet, a computer or own a mobile phone. The answers were categorized as yes or no.

The study controlled for other sociodemographic variables based on their reported significance to ANC attendance in previous studies.[15-18] Age: 15–24 years, 25–34 years, 35–49 years; health insurance coverage: yes, no; parity: primiparous, double, multiparous; marital status: never married, currently married (in union/living with a man), formerly married; household wealth: poor (first two quintiles), middle, rich (fourth and fifth quintiles combined); education: primary or less, secondary, higher education; urban-rural residence.

2.2.3. Ethical approval and data availability

This study was based on an analysis of a public domain population-based dataset from the UNICEF MICS initiative and ZIMSTAT available upon request. The original survey data was approved by the Ethical Review Board of Zimbabwe. Informed consent and voluntary participation from all respondents were sought before data collection and confidentiality and anonymity of information were guaranteed to all participants. The final data was delinked from unique identifiers of names and locations to ensure privacy.

2.2.4. Statistical analysis

Data analyses were carried out in Stata 15 using the complex survey command for stratification, clustering, and sample weighting. The women's characteristics were obtained using frequencies and percentages of all the variables; cross-tabulations were done with a chi-square test to examine the association between ANC visits and the explanatory variables of interest.

Multinomial logistic regression explored whether any of the digital technological participant characteristics were associated with ANC visits. There were two models used in the study. The unadjusted bivariate multinomial regression was first performed for associations of the six independent digital technology variables and ANC. In the final multivariate regression, all the explanatory variables were simultaneously included irrespective of their statistical significance. To predict ANC visits, the six digital technology variables were entered independently controlling for potential confounding variables. Thus, the final model was adjusted for the eight sociodemographic characteristics reported in the study. Adequate visits and optimal visits were compared separately with undesirable visits. Relative risk ratio (*RRR*) along with 95% confidence interval (*CI*) described the associations. Statistical significance was set at $P < 0.05$ in all analyses. Multicollinearity was tested using the variance inflation factor (VIF). The VIF for the independent variables ranged between 1.04 and 3.03, suggesting no multicollinearity (VIF < 10). Collinearity testing with a cut-off of 0.7 to detect interdependence between variables showed no variables from the correlation matrix were removed from the model.

3. Results

3.1. Sociodemographic characteristics of respondents

Out of 1 932 women aged 15–49 years in 2019 who had given birth 2 years before the survey, 40.9% (791/1 932) and 41.2% (795/1 932) were 15–24, and 25–34 years old, respectively. The mean age was (27.3 ± 6.7) years. The majority 94.4% (1824/1 932) of the mothers had no access to health insurance, 85.8% (1 657/1 932) were currently in union/living together, 83.7% (1 617/1 932) had not had a child death, 73.8% (1 427/1 932) had secondary education, 70.1% (1 355/1 932) resided in urban areas and 49.3% (953/1 932) were multiparous or had at least 3 children ever born, as shown in Table 1.

Table 1
Descriptive statistics of participants in the 2019 Zimbabwe multiple indicator cluster survey (n = 1 932).

Characteristic	Data [n (%)]
Age	
15–24 years	791 (40.9)
> 24–34 years	795 (41.2)
> 34–49 years	345 (17.9)
Health insurance	
No	1 824 (94.4)
Yes	108 (5.6)
Parity	
Primiparous	504 (26.1)
Double	476 (24.6)
Multiparous	953 (49.3)
Child loss	
No	1 617 (83.7)
Yes	315 (16.3)
Marital status	
Never married	110 (5.7)
Currently married	1 657 (85.8)
Formerly married	165 (8.5)
Household wealth	
Poor	859 (44.5)
Middle	372 (19.2)
Rich	701 (36.3)
Education	
Primary/less	427 (22.1)
Secondary	1 427 (73.9)
Higher	78 (4)
Residence	
Urban	1 355 (70.1)
Rural	577 (29.9)

3.2. Digital technologies

The results in Table 2 suggest that 67.8% (1 310/1 932) of women own a mobile phone and 58.3% (1 126/1 932) listen to the radio but 71.9% (1 390/1 932) were not reading a newspaper/magazine, 66.0% (1 276/1 932) were not watching television, 74.0% (1 430/1 932) were not using the internet and also 81% (1 565/1 932) were not using a computer or tablet.

3.3. Digital technologies as correlates of antenatal care visits

Most respondents, 64.5% (1 246/1 932) had adequate (4–7) ANC visits. Almost a quarter of respondents, 25.7% (497/1 932) had undesirable (1–3) ANC visits while about 9.8% (189/1 932) had optimal (≥ 8) ANC visits (see Table 2). In the chi-square test, all the digital technology variables (newspaper, radio, internet, computer, and mobile phone), except television were significantly associated with ANC visits (see Table 2). Among controls, except for age and parity, health insurance, child loss experience, marital status, household wealth, education, and urban-rural residence were significantly associated with ANC. The undesirable (1–3) ANC visits were 27.0% (377/1 390) higher among women who had never read a newspaper/magazine. Adequate (4–7) and optimal (≥ 8) ANC visits were highest among women who read a newspaper at least once or every day with 64.6% (102/158) and 19% (30/158), respectively.

Overall, for all significant digital technology variables, the percentage of those with undesirable (1–3) ANC visits was highest among women who had no access to a newspaper 27% (377/1 390), radio 29.5% (238/806), internet 26.7% (381/1 430), computer/tablet 26.7% (417/1 565) and mobile phone 29.8% (185/622). Optimal (≥ 8) ANC visits were significantly higher among women who had access to a newspaper 11.1% (43/384) and 19.0% (30/158), radio 12.1% (33/272) and 10.5% (89/584)), internet 14.4% (72/502), computer/tablet 14.6% (54/367) and mobile phone 11.1% (146/1 310) than their counterparts with no access at all. Similarly, adequate (4–7) ANC visits were higher among those who had access to a mobile phone 65.0% (852/1 310),

Table 2
Cross-tabulation between ANC visits and digital technology study variables in the 2019 Zimbabwe multiple indicator cluster survey [n (%)].

Characteristic	All ANC visits	Undesirable ANC visits†	Adequate ANC visits‡	Optimal ANC visits⁑	P
Total	1 932 (100)	497 (25.7)	1246 (64.5)	189 (9.8)	
Frequency of reading newspaper/magazine					< 0.001*
Not at all	1 390 (71.9)	377 (27.1)	898 (64.6)	115 (8.3)	
Less than once a week	384 (19.9)	96 (25.0)	245 (63.9)	43 (11.1)	
At least once a week	158 (8.2)	25(16.2)	102 (64.6)	30 (19.0)	
Frequency of listening to radio					0.039*
Not at all	806 (41.7)	238 (29.5)	502 (62.3)	66 (8.2)	
Less than once a week	272 (14.1)	59 (21.7)	180 (66.2)	33 (12.1)	
At least once a week	854 (44.2)	200 (23.4)	565 (66.1)	89 (10.5)	
Frequency of watching television					0.073
Not at all	1 276 (66.0)	332 (26.0)	837 (65.6)	107 (8.4)	
Less than once a week	113 (5.8)	35 (30.5)	68 (60.5)	10 (9.0)	
At least once a week	543 (28.1)	132 (24.2)	341 (62.7)	71 (13.0)	
Internet use					0.003*
No	1 430 (74.0)	381 (26.7)	932 (65.2)	117 (8.2)	
Yes	502 (26.0)	116 (23.1)	314 (62.5)	72 (14.4)	
Computer use					0.004*
No	1565 (81.0)	417 (26.7)	1012 (64.7)	136 (8.6)	
Yes	367 (19.0)	80 (21.8)	233 (63.6)	54 (14.6)	
Own a mobile phone					0.005*
No	622 (32.2)	185 (29.8)	394 (63.3)	43 (6.9)	
Yes	1 310 (67.8)	312 (23.8)	852 (65.0)	146 (11.1)	

†1–3 ANC visits; ‡4–7 ANC visits; ⁑≥ 8 ANC visits; *P < 0.05. ANC: Antenatal care.

Table 3
Unadjusted multinomial logistic model showing correlates of ANC visits in the 2019 Zimbabwe Multiple Indicator Cluster Survey.

Characteristic	Base†	Adequate vs. Undesirable ANC visit				Optimal vs Undesirable ANC visit			
		u*RRR* (95% *CI*)	*β'*	*t*	*P*	u*RRR* (95% *CI*)	*β'*	*t*	*P*
Frequency of reading newspaper/magazine									
Not at all	1		REF				REF		
Less than once a week	1	1.07 (0.76 to 1.52)	0.068	0.38	0.702	1.44 (0.87 to 2.40)	0.367	1.42	0.157
At least once a week	1	1.67 (1.03 to 2.72)	0.515	2.09	0.038*	3.81 (2.08 to 6.98)	1.337	4.34	< 0.001*
Frequency of listening to radio									
Not at all	1		REF				REF		
Less than once a week	1	1.45 (1.01 to 2.06)	0.368	2.04	0.042*	2.00 (1.17 to 3.42)	0.691	2.53	0.012*
At least once a week	1	1.34 (1.02 to 1.76)	0.291	2.10	0.036*	1.60 (1.04 to 2.47)	0.470	2.14	0.033*
Frequency of watching television									
Not at all	1		REF				REF		
Less than once a week	1	0.78 (0.47 to 1.31)	−0.243	−0.93	0.354	0.91 (0.42 to 1.95)	−0.097	−0.25	0.804
At least once a week	1	1.03 (0.77 to 1.37)	0.025	0.17	0.864	1.66 (1.12 to 2.45)	0.505	2.55	0.011*
Internet use									
No	1		REF				REF		
Yes	1	1.10 (0.80 to 1.52)	0.100	0.62	0.539	2.03 (1.33 to 3.10)	0.709	3.31	< 0.001*
Computer use									
No	1		REF				REF		
Yes	1	1.20 (0.87 to 1.66)	0.185	1.12	0.263	2.07 (1.37 to 3.14)	0.729	3.46	< 0.001*
Own a mobile phone									
No	1		REF				REF		
Yes	1	1.28 (1.00 to 1.65)	0.248	1.95	0.052	2.01 (1.29 to 3.14)	0.700	3.11	0.002*

†Undesirable ANC visit; *$P < 0.05$. *β'*: Coefficient; REF: Reference category; ANC: Antenatal care.

the internet 62.5% (313/502), listen to the radio less than once a week 66.2% (180/272), listen to the radio at least once a week 66.1% (564/854) and read a newspaper/magazine at least once a week 64.8% (102/158) compared to those who did not have access. Unexpectedly, women who never used a computer 64.7% (1012/1 565) had a slightly higher proportion of adequate ANC than those who had used a computer 63.6% (233/367), as shown in Table 2.

Generally, across women's sociodemographic variables, marked disparities in undesirable, adequate, and optimal ANC visits were observed. Table 3 represents unadjusted multinomial logistic regression results showing the digital technology correlates of ANC visits in Zimbabwe in 2019. The results show that all the digital technology variables are statistically significant predictors of ANC visits in agreement with chi-square test results with the exclusion of the television variable. Generally, women who read a newspaper/magazine listened to the radio, watched television, used the internet, used a computer, and had a mobile phone had higher optimal ANC than their counterparts who did not have access to any of these respective digital technologies.

Compared to women with no access at all to a newspaper/magazine, women who read a newspaper/magazine at least once a week were 3.8 times more likely to have optimal ANC than undesirable ANC (unadjusted relative risk ratio [u*RRR*] = 3.81, $\beta' = 1.337$, $t = 4.34$, $P < 0.001$). With not listening to the radio as the reference, women who listen to the radio less than once a week (u*RRR* = 1.45, $\beta' = 0.368$, $t = 2.04$, $P < 0.05$) or listen at least once a week (u*RRR* = 1.34, $\beta' = 0.291$, $t = 2.10$, $P < 0.05$) were 1.5 and 1.3 times more likely to have adequate ANC. Similarly, listening to the radio less than once a week (u*RRR* = 2.00, $\beta' = 0.691$, $t = 2.53$, $P < 0.05$) or listening to the radio at least once a week (u*RRR* = 1.60, $\beta' = 0.470$, $t = 2.14$, $P < 0.05$) increases the likelihood of achieving optimal ANC when compared to those who did not listen to the radio. Women who had watched television at least once a week were more likely to have attained optimal ANC compared to those who did not watch by 66% (u*RRR* = 1.66, $\beta' = 0.505$, $t = 2.55$, $P < 0.05$). Women who had ever used the internet, a computer, and owned a mobile phone were more likely to have optimal ANC compared to those who did not use, with increased odds of about 2 times (u*RRR* = 2.03, $\beta' = 0.709$, $t = 3.31$, $P < 0.001$; u*RRR* = 2.07, $\beta' = 0.729$, $t = 3.46$, $P < 0.001$; u*RRR* = 2.01, $\beta' = 0.700$, $t = 3.11$, $P < 0.01$, respectively).

The results of the adjusted multinomial logistic regression model are presented in Table 4. All explanatory digit variables except for internet and computer use were statistically significantly associated with ANC attendance after adjusting for other confounders. Controlling for all other explanatory variables, women who read a newspaper/magazine at least once a week were more likely to have adequate and/or optimal ANC than women who did not all read (adjusted relative risk ratio [a*RRR*] = 1.73, $\beta' = 0.55$, $t = 2.03$, $P < 0.05$ and a*RRR* = 2.93, $\beta' = 1.074$, $t = 3.12$, $P < 0.01$, respectively). Those who listened to the radio less than once a week had 1.6 and 2.1 times higher odds of having adequate and optimal ANC, respectively, compared to those who did not (a*RRR* = 1.58, $\beta' = 0.457$, $t = 2.46$, $P < 0.05$ and a*RRR* = 2.07, $\beta' = 0.73$, $t = 2.7$, $P < 0.01$). Women who watch television at least once per week were more likely to attain adequate ANC than those who did not watch at all (a*RRR* = 1.72, $\beta' = 0.545$, $t = 2.45$, $P < 0.05$). Women who had ownership of a mobile phone were likely to attain adequate ANC (a*RRR* = 1.48, $\beta' = 0.394$, $t = 3.02$, $P < 0.01$) and 1.9 times more likely to have optimal ANC (a*RRR* = 1.88, $\beta' = 0.631$, $t = 2.62$; $P < 0.01$) than those who did not own a mobile phone.

Table 4 results reveal the significant effect of sociodemographic characteristics on the relationship between digital technologies and ANC visits in Zimbabwe. Women with health insurance coverage were 4.5 times more likely to get optimal ANC compared to those without health insurance (a*RRR* = 4.47, $\beta' = 1.498$, $t = 3.46$, $P < 0.001$). With being never married as the reference, women currently married (a*RRR* = 2.93, $\beta' = 1.075$, $t = 4.38$, $P < 0.001$) or previously married (a*RRR* = 2.58, $\beta' = 0.946$, $t = 3.02$, $P < 0.01$) were 2.9 and 2.6 times more likely to have adequate ANC compared to those who were never married. Concerning urban-rural residence, women residing in rural were less likely to achieve adequate ANC compared to those staying in urban areas by 43% (a*RRR* = 0.57, $\beta' = 0.556$, $t = 2.21$, $P < 0.05$).

Unexpectedly, women who had a child loss were less likely to attain adequate ANC relative to those who did not lose a child (a*RRR* = 0.63, $\beta' = 0.458$, $t = 2.87$, $P < 0.01$). Similarly, compared to women from poor household wealth, women from rich household wealth (a*RRR* = 0.57, $\beta' = 0.556$, $t = 2.21$, $P < 0.05$) were associated with a lower likelihood of adequate ANC. Last, with primary or less education as the reference, women with secondary education were found to have reduced odds of having optimal ANC by half (a*RRR* = 0.50, $\beta' = 0.694$, $t = 2.71$, $P < 0.01$).

Table 4
Adjusted multinomial logit model showing correlates of ANC visits in the 2019 Zimbabwe Multiple Indicator Cluster Survey.

Characteristic	Base[†]	Adequate vs. Undesirable ANC visit				Optimal vs. Undesirable ANC visit			
		a*RRR* (95% *CI*)	*β'*	*t*	*P*	a*RRR* (95% *CI*)	*β'*	*t*	*P*
Frequency of reading newspaper/magazine									
Not at all	1		REF				REF		
Less than once a week	1	1.11 (0.78 to 1.59)	0.105	0.58	0.565	1.15 (0.67 to 1.98)	0.139	0.50	0.616
At least once a week	1	1.73 (1.02 to 2.96)	0.551	2.03	0.043*	2.93 (1.49 to 5.75)	1.074	3.12	0.002*
Frequency of listening to radio									
Not at all	1		REF				REF		
Less than once a week	1	1.58 (1.10 to 2.27)	0.457	2.46	0.014*	2.07 (1.22 to 3.53)	0.730	2.7	0.007*
At least once a week	1	1.28 (0.97 to 1.69)	0.247	1.75	0.080	1.37 (0.87 to 2.16)	0.314	1.35	0.177
Frequency of watching television									
Not at all	1		REF				REF		
Less than once a week	1	0.90 (0.51 to 1.59)	−0.107	−0.37	0.711	0.77 (0.32 to 1.87)	−0.260	−0.58	0.565
At least once a week	1	1.72 (1.11 to 2.67)	0.545	2.45	0.015*	1.84 (0.89 to 3.81)	0.608	1.64	0.102
Internet use									
No	1		REF				REF		
Yes	1	1.10 (0.78 to 1.55)	0.092	0.53	0.598	1.48 (0.89 to 2.46)	0.390	1.51	0.133
Computer use									
No	1		REF				REF		
Yes	1	1.17 (0.82 to 1.65)	0.154	0.87	0.385	1.34 (0.81 to 2.20)	0.289	1.14	0.254
Own a mobile phone									
No	1		REF				REF		
Yes	1	1.48 (1.15 to 1.92)	0.394	3.02	0.003*	1.88 (1.17 to 3.02)	0.631	2.62	0.009*
Age									
15–24 years	1		REF				REF		
> 24–34 years	1	0.88 (0.64 to 1.21)	−0.128	−0.78	0.434	0.68 (0.37 to 1.25)	−0.388	−1.25	0.211
> 34–49 years	1	1.03 (0.68 to 1.56)	0.027	0.13	0.898	0.75 (0.34 to 1.67)	−0.282	−0.7	0.486
Health insurance									
No	1		REF				REF		
Yes	1	1.19 (0.59 to 2.40)	0.175	0.49	0.623	4.47 (1.91 to 10.47)	1.498	3.46	<0.001*
Parity									
Primiparous	1		REF				REF		
Double	1	0.81 (0.57 to 1.16)	−0.206	−1.14	0.255	1.23 (0.66 to 2.28)	0.206	0.66	0.512
Multiparous	1	0.78 (0.53 to 1.14)	−0.249	−1.28	0.202	1.42 (0.70 to 2.86)	0.349	0.98	0.329
Child loss									
No	1		REF				REF		
Yes	1	0.63 (0.46 to 0.87)	−0.458	−2.87	0.004*	1.11 (0.64 to 1.92)	0.103	0.37	0.713
Marital status									
Never married	1		REF				REF		
Currently married	1	2.93 (1.81 to 4.75)	1.075	4.38	<0.001*	1.33 (0.67 to 2.63)	0.286	0.83	0.409
Formerly married	1	2.58 (1.39 to 4.76)	0.946	3.02	0.003*	1.11 (0.44 to 2.77)	0.102	0.22	0.826
Household wealth									
Poor	1		REF				REF		
Middle	1	0.94 (0.66 to 1.33)	−0.064	−0.36	0.717	1.09 (0.65 to 1.84)	0.090	0.34	0.735
Rich	1	0.57 (0.35 to 0.94)	−0.556	−2.21	0.027*	0.68 (0.30 to 1.56)	−0.379	−0.90	0.367
Education									
Primary/less	1		REF				REF		
Secondary	1	0.79 (0.58 to 1.07)	−0.240	−1.52	0.129	0.50 (0.30 to 0.83)	−0.694	−2.71	0.007*
Higher	1	1.31 (0.61 to 2.83)	0.271	0.69	0.490	0.87 (0.32 to 2.38)	−0.140	−0.27	0.785
Residence									
Urban	1		REF				REF		
Rural	1	0.54 (0.33 to 0.87)	−0.622	−2.53	0.012*	0.50 (0.24 to 1.02)	−0.700	−1.91	0.057

[†]Undesirable ANC visit; *$P < 0.05$. *β'*: Coefficient; REF: Reference category; ANC: Antenatal care.

4. Discussion

The findings of this study revealed that digital technologies are increasingly becoming important in improving ANC services. However, although the utilization of digital technologies such as mobile phones, radio, television, digital billboards, the internet, and computers may increase the risk of the digital divide, inequity in accessing digital tools may exacerbate existing healthcare disparities, and consequently, exert greater influence on health inequity caused by socioeconomic determinants of health.[9] Other studies revealed that rural-urban and regional discrepancies,[1] especially in resource-constrained rural areas tremendously affect access to ANC services due to several factors such as poor road network,[16] poor mobile phone network, poor economy, lack of reliable power supply,[19] high cost of transport,[20] long-distance traveled to access health facilities,[17] donor dependency,[21] the number of children in the household, and lack of health workers. In addition, the deployment of digital technologies especially in rural health systems is generally affected by the lack of funding, adequate digital infrastructure, and trained staff members.[22] Lack of support from the husband during pregnancy,[23] mother's occupation, place of residence, compulsory HIV testing,[24] and household size also influence ANC utilization.[25] Moreso, transport costs,[11] quality of ANC services, and socio-cultural practices, poor acceptance of cultural practices and beliefs at health centers long distances from and to access health care facilities, poor attitude of health workers,[23] lack of transport,[8] and lack of health workers which consequently lead to delays in receiving care. However, the provision of mobile clinics rendering ANC services in distant rural areas can assist to improve access to care in resource-constrained communities.

The findings of this study revealed that the ages of women did not influence the utilization of ANC. This finding is at variance with that of another study conducted in sub-Saharan Africa which revealed that adequate ANC utilization was highest in the 25–34 years age group.[26] This

is because the age groups in Zimbabwe are evenly distributed in terms of the other sociodemographic characteristics that influence the utilization of ANC. This study also revealed that women who read the newspaper or listened to the radio at least once a week were more likely to have optimal ANC compared to those who did not. This finding concurs with that of a systematic review conducted for studies in Southern Africa which also revealed that women who read newspapers and listened to the radio were more likely to utilize ANC.[27] These findings make sense because newspapers and radios are cheaper than other means of information and they can easily be accessed even on mobile phones. Moreover, the Ministry of Health and Child Care (MoHCC) in Zimbabwe usually sends health educative messages through various platforms such as newspapers, television, mobile phones (SMS), and radios. However, due to inequalities in healthcare access, income status, wealth, and geographical disparities, pregnant women with limited resources may not afford to buy or may not have access to newspapers, television, mobile phones, and radios,[25] which consequently influence their access to ANC services. Alternatively, policymakers may consider utilizing roadshows[28] and community outreach programs aimed at creating ANC awareness, training, and education, disseminating information, and improving ANC services among pregnant women.

Owning a mobile phone was associated with optimal ANC. A similar finding was reported in a study conducted in Zanzibar, which revealed that a mobile phone intervention increased ANC utilization.[10] These findings can be explained by the fact that mobile phones can be used by women to access ANC information and by healthcare workers to send reminders to women about their next visit. This study revealed that currently or formerly married women were more likely to have adequate ANC compared to those who were never married. This finding concurs with the findings of a study done in sub-Saharan Africa, which revealed that married women were more likely to have adequate ANC compared to unmarried women. These results can be explained by the fact that married women are likely to get financial and psychosocial support from their husbands, including access to digital technologies. Women with secondary education were less likely to have optimal ANC compared to those with primary education or less. This finding is at variance with the results of another study, which revealed that more educated women were more likely to have optimal ANC.[27] The results of this study are surprising because educated women have a higher chance of being employed and financially independent, resulting in them having better access to digital technologies, which will improve their understanding of the risks of not receiving adequate ANC during pregnancy. Another surprising finding from this study is that women from rich households were less likely to have adequate ANC. This result is at variance with that of another study which reported that women from rich households were more likely to have adequate ANC.[26] The findings of this study are surprising because we would expect women from rich families to have enough money to be able to have digital technologies and therefore be better informed about ANC.

To improve access to ANC services and visits, there is a need to develop feasible and cost-effective interventions for pregnant women to communicate with health workers. The study revealed that most women own a mobile phone 67.8% (1 310/1 932) and 58.3% (1 126/1 932) listen to the radio but 71.9% (1 390/1 932) did not read a newspaper/magazine at least once a week, 66.0% (1 276/1 932) watch television, 74.0% (1 430/1 932) use the internet, and 81% (1 565/1 932) use a computer or tablet. With such high mobile phone ownership, mobile phone-based interventions are very useful to improve ANC services. There is also a need to improve digital infrastructure, internet coverage, and signal strength to completely realize the benefits of digital technologies in ANC service delivery. The provision of affordable computer networks through community networks and a reliable power supply for recharging mobile phones might increase mobile phone usage, especially in rural communities.

Furthermore, other digital technologies such as social media platforms, mobile health applications,[16] artificial intelligence, mobile technologies,[29] telehealth, telemedicine,[30] big data,[31] and virtual reality can be adopted and utilized to improve ANC service delivery. These technologies perform various functions including teleconsultation, training health workers,[32] educating pregnant and nursing women, improving communication, making appointments, capturing maternal information, sending reminders, and also extracting meaningful insights from huge data. Artificial intelligence (AI), especially deep learning and machine learning can be utilized for predicting, forecasting, and modeling factors influencing ANC service delivery.[33] These technologies may also be used to develop AI-based applications to provide customized information,[34] smart devices for collecting and monitoring pregnant mothers, mapping hotspot areas with high maternal mortality, and training health workers and pregnant mothers. Support and training become crucial to improving the digital skills of pregnant mothers. Pregnant women can be supported to benefit from digital technologies by developing platforms that can provide social contact and connections with other women as this will ensure that women share experiences about ANC. Making digital platforms cheap to access may also improve the utilization of these platforms by women. Moreover, pregnant women who do not know how to use mobile applications should access training so that they can get the maximum benefit from these platforms. The training can be offered by government departments or non-governmental organizations at nominal fees.

However, the adoption of digital technologies requires a sound network and telecommunications infrastructure with good network and signal coverage, consistent power supply, and access to digital devices (mobile phones).[16] Therefore, addressing socio-demographic factors,[35] social inequalities, digital illiteracy, digital divide,[36] intermittent power supply, and crafting policies that support mobile health[13] may reduce apathy in integrating digital technologies to improve ANC service delivery, especially in rural communities.

5. The strengths and limitations of the study

The key strength of this study is the use of a nationwide dataset collected from various provinces in the country, through ZIMSTAT and UNICEF. Therefore, the findings of this study can be generalized. Sampling unit, data normalization, and weighting of data were employed using complex analytics design, to assess the influence of digital technologies on ANC visits in Zimbabwe. To the best of our knowledge, this is the first study to utilize the latest national representation dataset to assess the impact of digital technologies on ANC visits in Zimbabwe. Additionally, the study unraveled the significance of radio, television, internet use, mobile phones, and computers in developing and improving ANC visits as recommended by WHO. However, the study utilized secondary data and was restricted to variables available in the MICS 2019 survey data. Further explorations are required to assess the influence of other digital technologies (social media platforms and mobile health applications), sociodemographic factors, and social inequalities which may affect the utilization of ANC services.

6. The implication of the study on policy and practice

Understanding the role of digital technologies in ANC services presents unprecedented opportunities to improve maternal services. This study revealed that integrating digital technologies can ultimately lead to better uptake of ANC services. For instance, the findings of this study can be used to develop feasible and cost-effective mobile health interventions to provide ANC services such as sending reminders,[37] reporting emergencies and responses, monitoring pregnant mothers, establishing real-time communication between pregnant mothers[38] and healthcare professionals, and most importantly making appointments remotely. However, there is a need for policymakers to design mobile health policies and frameworks[13] supporting the integration of digital technologies and data-driven digital tools[39] into ANC services. Feasible

mobile health applications such as text messaging (SMS)[28] can be developed and deployed to improve ANC services as mobile phones are increasingly becoming ubiquitous and pervasive.

7. Conclusions

Utilization of ANC remains low in sub-Saharan Africa. Access and utilization of ANC can help reduce maternal and newborn health in sub-Saharan Africa. Different methods including integrating feasible digital technologies are required to improve the utilization of ANC services in the region. Digital technologies have been used in other sub-Saharan African countries with success. The results of this study showed that more than two-thirds of the participants owned a mobile phone, and more than half listened to the radio. The results also revealed that access to mass media, owning a mobile phone, internet use, and computer use were significantly associated with optimal ANC in unadjusted multivariate logistic regression while owning a mobile phone, reading a newspaper, and listening to the radio were significantly associated with optimal ANC in adjusted multivariate logistic regression. It is therefore important that digital infrastructure be improved in Zimbabwe so that the benefits of digital technologies in ANC services delivery are realized, especially in rural areas.

Availability of data and materials

This study was based on an analysis of public domain population-based secondary data from the UNICEF MICS initiative (https://mics.unicef.org/) is available upon request.

Consent for publication

The study used anonymized public domain population-based secondary data from the UNICEF MICS website. Therefore, no consent forms were used to access public domain population-based secondary data from the UNICEF MICS website.

Ethics approval and consent to participate

The study used anonymized public domain population-based secondary data from the UNICEF MICS website. No consent forms are required to access the data.

Competing interests

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

CRediT authorship contribution statement

Elliot Mbunge: Conceptualization, Methodology, Writing – original draft, Writing – review & editing. **Garikayi Bernard Chemhaka:** Conceptualization, Methodology, Formal analysis, Writing – review & editing. **Tafadzwa Dzinamarira:** Writing – original draft, Writing – review & editing. **Enos Moyo:** Writing – original draft, Writing – review & editing.

Acknowledgments

We would like to thank the UNICEF MICS initiative for giving us access to data and the reviewers for their fruitful comments.

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