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Multilevel analysis of factors associated with HIV among women of reproductive age (15–49 years old) in Ethiopia: Bayesian approach

Yilkal Negesse[1], Gosa Mankelkl[2], Melsew Setegn[3] and Gossa Fetene[4]

Abstract

Background: Human immunodeficiency virus remains the leading cause of morbidity and mortality throughout the world. Sub-Saharan Africa regions are the most affected regions and accounted for 67% of HIV infections worldwide, and 72% of the world's AIDS-related deaths.

Objective: To estimate the prevalence of HIV and identify factors associated with it among women of reproductive age in Ethiopia.

Methods: This study was conducted based on the 2016 Ethiopian Demographic and Health Surveys data. The data were weighted using sampling weight for probability sampling and non-response to restore the representativeness of the data and get valid statistical estimates. Then, a total of 14,161 weighted sample women were used to investigate the study. Finally, a multilevel analysis was done based on the Bayesian approach to identify factors associated with HIV among women of reproductive age in Ethiopia.

Results: This study showed the prevalence of HIV among reproductive age group women was 0.85%. Being rural resident (adjusted odds ratio = 0.20; 95% CrI = 0.1–0.4), secondary education level (adjusted odds ratio = 0.20; 95% CrI = 0.1–0.4), rich wealth status (adjusted odds ratio = 4; 95% CrI = 3–6), married women but living separately (adjusted odds ratio = 2.3; 95% CrI = 1.2–4.5), long distance from the health facility (adjusted odds ratio = 0.4; 95% CrI = 0.3–0.5), and exposure to media (adjusted odds ratio = 2.9; 95% CrI = 1.8–4.7) were significantly associated with HIV.

Conclusion: Being rural residents, women whose marital status is separated, wealthy, travel a long distance to get health facility, and are exposed to media are risky to be infected by HIV. Whereas being a rural resident and educated are preventive factors for HIV. Therefore, the government of Ethiopia and the ministry of health should consider those factors when they design HIV prevention and control strategies.

Keywords

demographic health survey, Ethiopia, HIV, women

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Introduction

The human immunodeficiency virus (HIV) is a type of virus that affects the immune system of the human cell and results in a decline in $CD4^+$ cell count and immune function, which can lead to life-threatening opportunistic infections, and finally acquired immunodeficiency syndrome (AIDS).[1] After the outbreak was first identified in 1980, worldwide the prevalence of HIV has become hesitant in the progress of human civilization and is a vast concern for people.[2,3] In 2019, 38 million people were living with HIV,

[1]Department of Public Health, College of Health Science, Mizan-Tepi University, Ethiopia
[2]Biomedical Department, College of Health Science, Mizan-Tepi University, Ethiopia
[3]Department of Reproductive Health and Nutrition, School of Public Health, College of Health Science, Mizan-Tepi University, Ethiopia
[4]Department of Midwifery, College of Health Science, Mizan-Tepi University, Ethiopia

Corresponding author:
Yilkal Negesse, Department of Public Health, College of Health Science, Mizan-Tepi University, Po: 260, Mizan-Aman, Ethiopia.
Email: negeseyilkal@gmail.com

of which, 36.2 million adults and 1.8 million were children of age 0–14 years.[4] And also in this region, women of childbearing age comprise 61% of people living with HIV, accounting for over 12 million.[4] Sub-Saharan Africa is home to only 12% of the global population, however, accounts for 71% of the global burden of HIV infection.[5] Of the estimated 6000 new infections that occur globally each day, two out of three are in sub-Saharan Africa with young women continuing to bear a disproportionate burden.[5]

The HIV epidemic has been showing remarkable variations across population subgroups, regions, and countries, at the subnational level between provinces.[6] According to the Ethiopian HIV/AIDS Prevention and Control Office (HAPCO) estimates, 0.9% of the adult population was HIV positive. Nevertheless, this distribution was highly heterogeneous, with the lowest prevalence (0.1%) in Somali and the highest in the Gambela Region (4.8%).[7]

HIV/AIDS is a leading cause of death and disease burden, especially in sub-Saharan Africa.[2,3] The HIV epidemic has had an adverse effect on efforts to reduce maternal mortality rates.[8] The government of Ethiopia has committed to ending AIDS as a public health threat by 2030. Therefore, to prevent and control the pandemic of HIV, it is very important to know factors associated with HIV precisely using an appropriate method of statistical analysis. Traditional multiple regression techniques treat the units of analysis as independent observations.[9] Therefore, standard errors for the coefficients of higher-level predictor variables are highly affected as a result of ignoring grouping. Therefore, standard errors of regression coefficients will be underestimated and leading to an overstatement of statistical significance. Finally, the result is misleading.[9] But in Ethiopia, there are no studies conducted at the national level that shows predictors associated with HIV by considering the clustering effect using the Bayesian analysis approach among women of reproductive age. The Bayesian analysis approach is one of the data analysis approaches independent of the frequentist analysis approach. In the Bayesian analysis approach, the estimates of the parameters are estimated from the posterior distribution which is the combination of the prior information and the likelihood of the data.[10] Therefore, this study aimed to estimate the prevalence of HIV and to identify its associated factors among women of reproductive age in Ethiopia based on the 2016 Ethiopian Demographic and Health Survey (EDHS) data.

Methods

Data source and population

Secondary data analysis was performed based on the 2016 EDHSs data. The EDHSs are nationally representative cross-sectional surveys performed in nine regions and two city administrations in the country every 5 years. In each of the surveys, stratified two-stage sampling of clusters was carried out. Stratification was achieved by separating each region into urban and rural areas. For 2016 EDHS data, a total of 645 enumeration areas (EAs) were randomly selected proportional to the EA size in the first stage. At the second stage, on average 27–32 households per EA were selected.[11–13] The data were accessed from the Measure Demographic and Health Surveys (DHS) website (http://www.dhsprogram.com) after permission was granted through an online request by explaining the objective of this study. All reproductive age group women in the selected EAs and households during the surveys were included in this study. After excluding mothers whose test did not provide a clear negative or positive result, a total of 14,161 weighted sample women were used for this study. The comprehensive procedure for sampling and sample size determination technique, in general, about the survey, is described in the complete EDHS report.[11–13]

Variables

Interviewers collected finger-prick blood specimens from women age 15–49 years who consented to HIV testing.[14] The protocol for blood specimen collection and analysis was based on the anonymously linked protocol developed for the DHS Program.[14] Blood samples were dried overnight and packaged for storage the following morning. Samples were periodically collected from the field and transported to the laboratory at the Ethiopian Public Health Institute (EPHI) in Addis Ababa.[14] Upon arrival at EPHI, each blood sample was tested to know their HIV status.[14] The response variable is dichotomous with possible values Y_i = Yes (coded as "Yes = 1") if the ith woman is positive and Y_i = No (coded as "No = 0"), if the woman is negative for HIV. The independent variables were classified as community and individual-level variables. Place of residence (recoded as rural and urban) and region of the study participants were considered as community-level variables. Whereas marital status (categorized as married, never married, separated, divorced, and widowed), educational level (recoded as no formal education, primary, secondary, and higher), occupation (coded as had and had no work), sex of household head, desire for children (coded as yes and no), heard about HIV (coded as yes and no) media exposure, and wealth status were considered as individual-level variables. Women who were either reading a newspaper, use the Internet, listening to the radio, or watched television at least once a week were considered as exposed to media, otherwise, they are considered as not exposed to media.[14] In 2016 EDHSs data, wealth status was measured using different assets of the households. In the data set, the categories for the wealth index were presented as poorest, poorer, middle, richer, and richest. But, in this study, the

categories are recategorized as "poor," "middle," and" "rich." Poorest and poorer are merged and named as "poor" and richest and richer are merged and named as "rich." But the category middle is taken as it is.

Statistical analysis

Before any statistical analysis, the data were weighted using sampling weight for probability sampling and nonresponse to restore the representativeness of the survey and get reliable statistical estimates.

Multilevel analysis. To see the association between HIV status and independent variables, we applied multilevel analysis using Bayesian statistics. In this study, the hierarchy of data was two levels. Women in the household were considered as level one units and EAs were considered as level two units. Woman in the household was nested within EAs. The dependent variable was represented by

$$Y_{ij} = \begin{cases} Positive\ for\ HIV \\ Negative\ for\ HIV \end{cases}$$

the category is dichotomous. Therefore, Generalized Linear Mixed Model (GLMM) was fitted based on the Bayesian approach. To estimate the parameters of the variable and the extent of random variations between clusters, we used the Brms-R package. It uses No-U-Turn Sampler (NUTS), an extension to HMC uses a recursive algorithm to build a set of likely candidate points that spans a wide swath of the target distribution, stopping automatically when it starts to double back and retrace its steps.[15]

These features allow it to converge to high-dimensional target distributions much more quickly than simpler methods such as the random walk Metropolis or Gibbs sampler.[15] Therefore, this package helped us to fit multilevel models based on the Bayesian approach.[16]

We used flat prior with beta distribution (1, 1) to determine the regression coefficients and gamma distribution (0.001, 0.001) to estimate the variance. And also we used iteration = 10,000, number of iterations that was discarded = 1000, number of cores = 2, chains = 2 adapt delta (controls divergent transition) = 0.95, and initials (the starting values of the iterations) = 0.

Four multilevel binary logistic regression models were fitted using compound symmetry covariance structure. The first model (a model without covariate) was fitted to determine the extent of cluster variation in HIV. The second model was fitted with individual-level factors. The third model was fitted with community variables. The fourth model was fitted with both individual- and community-level factors. Accordingly, all models include a random intercept (random intercept only) at the cluster level to capture heterogeneity among clusters. Then, the models were compared based on their Widely Applicable Information Criteria (WAIC) and the model with a small WAIC value was selected. Finally, all interpretations and inferences were made based on this model. To consider the variation of HIV between the EAs, we used the intraclass correlation coefficient (ICC) value greater than 5%. We used the 95% posterior credible interval test of significance and the interval that does not contain 1 is considered statistically significant. Since the results obtained from the posterior distribution are not reliable until the chain has reached its stationary distribution,[17] we used the most popular and straightforward convergence assessment methods. The methods we used to monitor the convergence of the algorithm were chains of the time series plots mixed well, smooth density plot, Rhat = 1, and Bulk_ESS and Tail_ESS greater than 1000.

Ethical consideration

The EDHS was conducted based on the permission of the government, and informed consent was taken and participants' confidentiality was assured during that time. For this study, we accessed the data set based upon request (www.dhsprogram.com online), and there was no ethical approval required. Moreover, there are no names of individuals or household addresses in the data files.

Results

Characteristics of the study population

In this study, a total of 14,159 women of reproductive age were included from all parts of the country. From this, 76.2% of the respondents were rural residents. The majority of the study participants were from Oromia regional state followed by Amhara regional state with 22%. Sixty-five percent of the women were married and 26% of them were never married. More than three-fourth of the households were led by males (Table 1).

The magnitude of HIV among women in Ethiopia by different characteristics

As shown in Table 2, the prevalence of HIV among women of reproductive age was 0.85%. Among urban residents, 2.4% were positive for HIV. And also 0.4% of rural residents were positive for HIV which is lower than urban residents. Based on region, in Gambela regional state, the highest prevalence was observed (3.9%) followed by Addis Ababa city administration (3.6%).

Multilevel analysis

The variance between clusters (EA) being positive for HIV among reproductive age group women is 2.4. Therefore, we reject the null hypothesis which states that the variation

Table 1. Characteristics frequency and percentage distribution of study participants in Ethiopia in 2016.

Variable	Category	Frequency	Percentage
Residence	Urban	3373	23.8
	Rural	10,788	76.2
Region	Tigray	984	6.9
	Afar	124	0.9
	Amhara	3115	22
	Oromia	5234	37
	Somali	469	3.3
	B/Gumuz	151	1.1
	SNNP	2670	21
	Gambela	40	0.3
	Harari	45	0.3
	Addis Ababa	936	6.6
	Dire-Dawa	97	0.7
Educational level	No formal education	6665	47.1
	Primary	4968	35.1
	Secondary	1694	12
	Higher	834	5.9
Occupation	Had work	6751	47.7
	Had no work	7410	52.3
Wealth status	Poor	4860	34.3
	Medium	2622	18.5
	Rich	6679	47.2
Marriage	Married	9184	64.9
	Never married	3693	26.1
	Separated	216	1.5
	Divorced	679	4.8
	Widowed	391	2.8
Sex of household head	Male	10,731	75.8
	Female	3430	24.2
Distance to a health facility	Not a problem	7112	50.2
	Big problem	7049	49.8
Desire for children	Yes	8417	65.4
	No	4445	34.6
Media exposure	Yes	3901	27.5
	No	10,261	72.5
Heard about HIV	Yes	13,168	93
	No	993	7

SNNP: Southern Nations, Nationalities, and Peoples (United Nations).

across the cluster was zero. So that the variation of to be HIV positive among women of reproductive age in Ethiopia between clusters was none zero. The results also displayed that the ICC was 39%, meaning that roughly 39% of the variability in the prevalence of HIV among women of reproductive age was attributable to the clusters.

Among the four fitted models, the model fitted with individual- and community-level factors has the smallest WAIC (2147) as compared to the model with only individual-level factors (WAIC = 2174), the model with only community-level factors (WAIC = 2298), and random intercept only model or null model (WAIC = 2409). Therefore, this model is the best-fitted model, and every interpretation and report were made based on this model.

Among the factors included in the fitted model (a model fitted by both individual- and community-level factors), residence, educational level, wealth status, occupation, marital status, distance to the health facility, and exposure to media was significantly associated with HIV in Ethiopia (Table 2). The odds of being positive for HIV among rural resident women was 80% (adjusted odds ratio (AOR) = 0.2; 95% CrI = 0.1–0.4) less likely as compared to urban resident women. Based on marital status, women who were separated are 2.3 times (AOR = 2.3; 95% CrI = 1.2–4.5) more likely to be positive for HIV as compared to married

Table 2. The prevalence of HIV based on different characteristics among women of reproductive age in Ethiopia in 2016.

Variables	Characteristics	The magnitude of HIV in percent (%)
Residence	Urban	2.4
	Rural	0.4
Region	Tigray	1.3
	Afar	1.2
	Amhara	1.1
	Oromia	0.4
	Somali	0.1
	B/Gumuz	1.0
	SNNP	0.4
	Gambela	3.9
	Harari	3
	Addis Ababa	3.6
	Dire-Dawa	2.9
Educational level	No formal education	0.4
	Primary	0.8
	Secondary	2.2
	Higher	1.7
Wealth status	Poor	0.2
	Medium	0.5
	Rich	1.5
Occupation	Had work	0.9
	Had no work	0.8
Marriage	Married	0.7
	Never married	0.9
	Separated	2.6
	Divorced	1.2
	Widowed	1.9
Sex of household head	Male	0.7
	Female	1.3
Distance to the health facility	Not a problem	1.2
	Big problem	0.5
Desire for children	Yes	0.7
	No	1.1
Media exposure	Yes	1.7
	No	0.5
Heard about HIV	Yes	1.0
	No	0.3
Over all prevalence		0.85

SNNP: Southern Nations, Nationalities, and Peoples (United Nations).

women. Similarly, women who were rich in wealth were four times (AOR = 4; 95% CrI = 3–6) more likely to be infected by HIV as compared to poor women (Table 3).

Discussion

The prevalence of HIV among reproductive age group women in Ethiopia was 0.85%. This value is lower as compared to the pooled estimates of the Sub-Saharan Africa regions.[18] This variation might be due to the introduction of the Health Extension Program (HEP), implementation of different programs, including education and stigma-reduction programs, behavior change initiatives, improving access to health care, and expansion of HIV testing for all age groups across the territory.[19] The country also has committed to reducing new HIV infections by 50% by 2020 and to ending AIDS as a public health threat by 2030. This is reflected in the Country's Health Sector Transformation Plan II 2015–2020, where one of the major indicators is a reduction of HIV incidence rate.[20]

The multilevel binary logistic regression analysis revealed that place of residence, educational level, occupation, wealth status, marital status, distance to the health facility, and exposure to media have an association with HIV among reproductive age group women in Ethiopia. The risk of being positive for HIV among rural women is less likely as compared to women who were urban residents. This finding is supported by the study conducted in Malawi.[21] This could be, in rural areas, there might be no commercial sex workers who are at risk for HIV. Similarly, the odds of being positive among women whose educational level was secondary were higher as compared to women who had no formal education. The odds of having HIV among women who had no work were more likely than women who had work. This result is supported by a study conducted in Sub-Saharan Africa.[22] This might be due to the richest women tend to be more educated, more mobile, and more likely to live in urban areas, where HIV is more prevalent. The odds of having HIV among separated women were 2.3 times more likely as compared to women who were married. This finding is consistent with a study conducted in South Africa.[23] This could be due to the fact that separated women are exposed to low social cohesion, and the resulting destabilization of sexual relationships may increase the risk of HIV. Women who had travel long distances to reach health facilities were less likely to have HIV as compared to women who live near health facilities. This could be due to the fact that women who lived far from health facilities are mostly rural residents, are less likely to attend nightclubs, and have no commercial sex workers around their living environment, which are the commonest predisposing event to gain HIV.

The odds of having HIV among women who had not been exposed to media were three times more likely than those women who were exposed to media. This study is consistent with a study conducted in Bangladesh,[24] India,[25] and Iran.[26] This might be due to women who had not been exposed to media did not augment their HIV-related knowledge. In addition, they did not enhance their knowledge concerning HIV prevention modalities.

Strengths and limitations of the study

To get fine estimates of the parameters, fitting a multilevel model by considering all the national regional states of Ethiopia was the strength of the study. As a limitation, we

Table 3. Factors associated with HIV among women of reproductive age in Ethiopia in 2016.

Fixed effect	Category	AOR [95% CrI]
ß0-intercept*		
Residence	Urban	Ref
	Rural	0.2* [0.1, 0.4]
Educational level	No formal education	Ref
	Primary	1.4 [0.9, 2.0]
	Secondary	1.7* [1.2, 2.7]
	Higher	1.5 [0.9, 2.5]
Occupation	Have work	Ref
	Have no work	1.4* [1.2, 2.1]
Wealth status	Poor	Ref
	Middle	1 [0.5, 2.0]
	Rich	4* [3, 6]
Marriage	Married	Ref
	Never married	1.5 [0.9, 2.4]
	Separated	2.3* [1.2, 4.5]
	Divorced	1.6 [1.0, 2.5]
	Widowed	1 [0.5, 2.0]
Sex of household head	Male	Ref
	Female	0.9 [0.5, 1.5]
Desire for children	Yes	2.1 [0.8, 5.4]
	No	Ref
Distance to a health facility	Not a problem	Ref
	Big problem	0.4* [0.3, 0.5]
Media exposure	Yes	1
	No	2.9* [1.8, 4.7]
Heard about HIV	Yes	Ref
	No	0.8 [0.4, 1.8]
$\sigma_{\mu_0}{}^2$*		1.4 [0.9, 2.2]
WAIC		2147

AOR: adjusted odds ratio; WAIC: Widely Applicable Information Criteria; Ref: reference category; ß0: *Y*-intercept; $\sigma_{\mu_0}{}^2$* : variance.
*Significant at 5% level of significance.

cannot get some variables (sharing of sharp materials, number of sex partners, and enjoying at a nightclub) to identify risk factors of being positive for HIV.[19]

Conclusion and recommendations

From the factors included in the selected model, place of residence, educational level, marital status, wealth status, occupation, distance to the health facility, and exposure to media have an association with HIV. Therefore, Ethiopian government, the ministry of health, and any other responsible body consider these factors when they design HIV prevention and control strategies.

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Author contributions

Y.N., G.M., M.S., and G.F. were participated in this paper from the inception to design, acquisition of data, data cleaning and coding, data analysis, and interpretation, and drafting and finally revising of the manuscript. Then, the final draft of the manuscript was prepared by Y.N. Finally, all authors read and approved the revised manuscript.

Availability of data and materials

The data were accessed from the Measure DHS website (http://www.dhsprogram.com) after permission was granted through an online request by explaining the objective of this study. The data sets analyzed during this study are available from the corresponding author upon reasonable request.

Declaration of conflicting interests

The author(s) declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

Ethical approval and consent to participate

Ethical clearance for the EDHS data was given by the Ethiopian Health and Nutrition Research Institute (EHNRI) Review Board; the National Research Ethics Review Committee (NRERC) at the Ministry of Science and Technology.[14] After the respondents were informed about the survey and consent was taken for their

participation, voluntary participation was ensured during the interviews.[14] The detail about ethical approval and consent to participate is available in the EDHS's report.[14]

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ORCID iDs

Yilkal Negesse https://orcid.org/0000-0003-4751-3615

Gossa Manikelkil https://orcid.org/0000-0002-7834-8838

Supplemental material

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