BMJ Open

Households' access to improved drinking water sources and toilet facilities in Ethiopia: A multilevel analysis based on 2016 Ethiopian Demographic and Health Survey

Journal:	*BMJ Open*
Manuscript ID	bmjopen-2020-042071
Article Type:	Original research
Date Submitted by the Author:	30-Jul-2020
Complete List of Authors:	Andualem , Zewudu ; University of Gondar College of Medicine and Health Sciences, Department of Environmental and Occupational health and Safety Dagne, Henok; University of Gondar College of Medicine and Health Sciences, Environmental and Occupational Health and Safety; University of Gondar, Environmental and Occupational Health and Safety Azene, Zelalem; University of Gondar College of Medicine and Health Sciences, Department of Women's and family health, School of Midwifery, College of Medicine and Health Sciences, University of Gondar, P. O. Box 196 Gondar, Ethiopia.; University of Gondar, Ethiopia taddese, Asefa; University of Gondar College of Medicine and Health Sciences, Epidemiology and Biostatistics Dagnew, Baye ; University of Gondar College of Medicine and Health Sciences, Human Physiology; Mr. Muluneh, Atalay; University of Gondar College of Medicine and Health Sciences, Epidemiology and Bio statistics ; Yeshaw, Yigizie; University of Gondar College of Medicine and Health Sciences, Medical Physiology
Keywords:	PUBLIC HEALTH, PREVENTIVE MEDICINE, Health policy < HEALTH SERVICES ADMINISTRATION & MANAGEMENT

I, the Submitting Author has the right to grant and does grant on behalf of all authors of the Work (as defined in the below author licence), an exclusive licence and/or a non-exclusive licence for contributions from authors who are: i) UK Crown employees; ii) where BMJ has agreed a CC-BY licence shall apply, and/or iii) in accordance with the terms applicable for US Federal Government officers or employees acting as part of their official duties; on a worldwide, perpetual, irrevocable, royalty-free basis to BMJ Publishing Group Ltd ("BMJ") its licensees and where the relevant Journal is co-owned by BMJ to the co-owners of the Journal, to publish the Work in this journal and any other BMJ products and to exploit all rights, as set out in our licence.

The Submitting Author accepts and understands that any supply made under these terms is made by BMJ to the Submitting Author unless you are acting as an employee on behalf of your employer or a postgraduate student of an affiliated institution which is paying any applicable article publishing charge ("APC") for Open Access articles. Where the Submitting Author wishes to make the Work available on an Open Access basis (and intends to pay the relevant APC), the terms of reuse of such Open Access shall be governed by a Creative Commons licence – details of these licences and which Creative Commons licence will apply to this Work are set out in our licence referred to above.

Other than as permitted in any relevant BMJ Author's Self Archiving Policies, I confirm this Work has not been accepted for publication elsewhere, is not being considered for publication elsewhere and does not duplicate material already published. I confirm all authors consent to publication of this Work and authorise the granting of this licence.

Households' access to improved drinking water sources and toilet facilities in Ethiopia: A multilevel analysis based on 2016 Ethiopian Demographic and Health Survey

Zewudu Andualem[1*], Henok Dagne[1], Zelalem Nigussie Azene[2], Asefa Adimasu Taddese[3], Baye Dagnew[4], Atalay Goshu Muluneh[3], and Yigizie Yeshaw[4]

[1]Department of Environmental and Occupational Health and Safety, Institute of Public Health, College of Medicine and Health Sciences, University of Gondar, P. O. Box 196 Gondar, Ethiopia

[2]Department of Women's and family health, School of Midwifery, College of Medicine and Health Sciences, University of Gondar, P. O. Box 196 Gondar, Ethiopia.

[3]Department of Epidemiology and Biostatistics, Institute of Public Health, College of Medicine and Health Sciences, University of Gondar, P. O. Box 196 Gondar, Ethiopia

[4]Department of Human Physiology, School of Medicine, College of Medicine and Health Sciences, University of Gondar, P. O. Box 196 Gondar, Ethiopia

*Corresponding author

Authors' email address

[ZA] Zewudu Andualem: zewuduandualem12@gmail.com,

[HD] Henok Dagne: enoch2313@gmail.com,

[ZNA] Zelalem Nigussie Azene: znigussie35@gmail.com,

[AAT] Asefa Adimasu Taddese: adimasuasefa@gmail.com,

[BD] Baye Dagnew: bayedagnew7@gmail.com,

[AG] Atalay Goshu: atalayg1921@gmail.com, and

[YY] Yigizie Yeshaw: yigizieyeshaw29@gmail.com

ABSTRACT

Objective: The aim of this study was to assess households' access to improved drinking water sources and sanitation facilities and their associated factors in Ethiopia

Design: Cross-sectional study

Setting: Ethiopia

Participants: Household heads

Primary outcomes: Access to improved drinking water sources and sanitation facilities

Methods: We conducted an in-depth secondary data analysis of the 2016 Ethiopian Demographic and Health Survey (EDHS). Data from a total of 16650 households and 645 clusters were included in the analysis. The households in the EDHS were selected using a stratified two-stage cluster sampling technique. Multilevel binary logistic regression analyses were performed to identify factors associated with access to improved drinking water source and toilet facilities. Adjusted odds ratio with a 95% CI were reported. P-value < 0.05 was used to declare significant association of the covariates and outcomes.

Results: The proportions of households' access to improved sources of drinking water and toilet facilities were 69.94%, [95% CI: (69.23, 70.63)], and 25.36%, [95% CI: (24.69, 26.03)], respectively. Female headed households [AOR = 1.18, 95% CI: (1.01, 1.37)] and better wealth index, ≥ 30 minutes time to obtain drinking water [AOR = 0.65, 95% CI: (0.58, 0.73)], rural residence [AOR = 0.06, 95% CI: (0.03, 0.11)] and region were factors associated with access to improved drinking water source. Whereas, higher educational status [AOR = 2.21, 95% CI: (1.12, 4.36)], being widowed [AOR = 0.75, 95% CI: (0.57, 0.98)], improved source of drinking water

[AOR =1.37, 95% CI: (1.12, 1.66)], household size [4 to 6] [AOR = 0.86, 95% CI: (0.75, 0.98)], rural residence [AOR = 0.28, 95% CI: (0.20, 0.38)], households with better wealth index, and region were significantly associated with access to improved toilet facilities

Conclusion: The proportions of households' access to improved drinking water sources and toilet facilities in Ethiopia was relatively low.

Keywords: Improved toilet facilities, Improved water sources, Multilevel analysis, Ethiopia

Strength and limitations of the study

- The use of nationally representative data that can enhance the generalizability of the finding is one of the strength of the study.
- Due to the inherent nature of a cross-sectional study, it does not show the temporal relationship between the outcome status and predictors.
- Moreover, important variables such as culture, traditions, and social norms were not available in EDHS data which could influence the use of toilet facility type.

INTRODUCTION

Access to safe water and basic sanitation is one of the fundamental human rights, and an essential step towards improving living standards to maintain and improve health, human growth, and development.[1-3] It is one of the critical sustainable development challenges. Sustainable Development Goal (SDG) 6 aims to ensure the availability and sustainable management of water and sanitation for all by 2030. [4]

Unimproved sources of drinking water and sanitation facilities are responsible for increased risks of various infectious diseases such as; cholera, typhoid, schistosomiasis, infections of the respiratory systems, skin, and eye. [1, 5, 6] The currently available evidences also indicate that to prevent the novel coronavirus disease (COVID-19) outbreak, the provision of safe water, sanitation, and hygienic conditions is essential. [7]

Globally, 2 billion people lack basic sanitation services and 785 million people have no access to clean water. [8] More than 1.9 million deaths and 123 million disability-adjusted life-years (DALYs) could have been prevented by provision of adequate access to water, hygiene and sanitation (WASH) worldwide. The WASH-attributable disease burden accounts to 4.6% of global DALYs and 3.3% of global mortality. [9] The burden of under 5 mortality was 13%. [10] In Ethiopia, 60 to 80 % of communicable diseases are attributed to limited access to safe water, inadequate sanitation, and hygiene services. [11]

Regarding factors associated with improved drinking water sources and toilet facilities: Sex of household heads, region, residence, family size, time to get to drinking water source, age of household head, educational level, and marital status of the household heads were factors associated with access to an improved drinking water source and toilet facilities based on previous studies. [2, 12-16]

In Sub-Saharan Africa, particularly in Ethiopia access to improved sources of drinking water and toilet facilities is still lacking and people are practicing open defecation. [17, 18] Therefore, the current study aimed to assess access to improved drinking water sources and toilet facilities and their associated factors in Ethiopia using EDHS 2016 data.

METHODS

Patient and public involvement

This study was based on a publicly available data set (EDHS 2016). Thus, there were no patients or members of the public involved.

Study design and area

The 2016 main EDHS was a cross-sectional survey conducted from 18 January 2016 to 27 June 2016 in Ethiopia by the Ethiopian Central Statistical Agency (ECSA). For our case, we use an in-depth secondary data analysis of the survey. The 2016 EDHS survey was the fourth survey conducted in each of the 11 regions of Ethiopia (9 regional states and 2 administrative cities). Administratively, each region in Ethiopia is divided into Zones, each Zone, in turn, is divided into Woredas, and each Woreda into Kebeles (the lowest administrative units in the country). [19]

Data sources

Data were obtained from 2016 Ethiopian Demographic and Health Survey (EDHS-2016) after being registered as an authorized user. The survey collects data on key indicators of health and health-related events including access to drinking water and toilet facilities. A total of 16,650 households from 645 Enumeration Areas (EAs) were included in the survey. [19]

Sample size and sampling procedure

A two-stage stratified cluster sampling technique was employed to select study participants. Sampling frame of the 2007 Population and Housing Censuses in which EAs were the sampling units for the first stage and households for the second stage was used. The detailed sampling

procedure is presented elsewhere. [19] The current study included individual-level data for 16650 household heads as well as community characteristics of 645 clusters.

Variables of the study

The outcome variables are; access to improved drinking water sources and improved toilet facilities. The explanatory variables; include sex, age, educational level, marital status of the household heads, household wealth index, time to get to drinking water sources, family size, religion, media use, place of residence, and region.

Operational definitions

Improved sources of drinking water: a household is said to have access to an improved drinking water source if it has water piped into its dwelling, water piped to a yard/plot, a public tap/standpipe, a tube well/borehole, a protected dug well, a protected spring, rainwater, bottled water, or sachet water. [20]

Improved types of toilet facilities: a household is said to have access to improved toilet facilities if it has unshared flush/pour flush to piped sewer systems, septic tanks or pit latrines, ventilated improved pit latrines, composting toilets, or pit latrines with slabs. [20]

Data processing and analysis

Statistical analysis was performed using Stata 16.00 software. The weighted frequencies and the percentages (based on the population size of each region) were computed. The detailed weighting procedure is described elsewhere. [19]

Multilevel binary logistic regression model was used to assess the impact of individual and community-level factors on households' access to an improved source of drinking water and improved toilet facilities. The model, which is most appropriate to consider the cluster random

effect in a multivariate setting and the reason to apply multilevel modeling was the nature of the data collected which have a hierarchical or clustered structure. The first level represents the individual and household and the second level factor is the clusters. Four models were tested in each of the cases (access to an improved source of drinking water and toilet facilities). **Model 0** (the null model) was fitted without explanatory variables to test random variability in the intercept and to estimate the intraclass correlation coefficient (ICC). **Model I** was used to investigate the impact of individual-level factors on the likelihood of having access to improved sources of drinking water and toilet facilities. **Model II** was used to assess the impact of community-level factors on the likelihood of having access to improved sources of drinking water and toilet facilities. **Model III** was employed to assess the impact of individual and community-level factors altogether on access to improved sources of drinking water and toilet facilities.

The random effects (variation of effects) were measured by ICC, percentage change in variance (PCV), Median Odds Ratio (MOR), and deviance (-2log likelihood), which measure the variability between clusters in the multilevel models. The ICC explains the cluster variability, while MOR used to quantify unexplained cluster variability (heterogeneity). The MOR was used to translate cluster variance into OR scale. [21-23] In the multilevel model, deviance can measure the total variation due to factors at the community and individual level. [22, 24]

Adjusted odds ratio with a 95% confidence interval were reported. P-value < 0.05 was used to declare a significant association among covariates and outcome variables. A multicollinearity test was performed to rule out if there was a significant correlation between explanatory variables. If the values of variance inflation factor (VIF) was lower than 10, then the collinearity problem was considered as less likely. [25]

RESULTS

Sociodemographic characteristics of study participants

A total of 16650 study participants were included in the study. The median (±SD) age of the household heads was 40 years (± 16.22 years, range 15 - 95). Approximately, seven out of ten (69.94%) of the households had access to improved sources of drinking water and only one-fourth (25.36%) of households had access to an improved source of toilet facilities. Majority (98.37%) of respondents had no education. About 68.55% of households were male-headed. [**Table 1**].

Table 1: Sociodemographic characteristics of study participants in Ethiopia, EDHS 2016 (n= 16650).

Variables		Frequency	Percent (%)
Source of drinking water	Improved	11,645	69.94
	Unimproved	5,005	30.06
Toilet facilities	Improved	4,222	25.36
	Unimproved	12,428	74.64
Sex of household head	Male	11,413	68.55
	Female	5,237	31.45
Age of household head (years)	13 to 30	4,257	25.57
	31 to 40	4,132	24.82
	41 to 56	4,230	25.41
	≥ 57	4,031	24.21
Education level of the household head	No education	16,378	98.37
	Primary education	93	0.56
	Secondary education	114	0.68
	Higher education	65	0.39
Current marital status household head	Never married	1,046	6.29
	Married	12,064	72.50

	Widowed	2,108	12.67
	Divorced	1,423	8.55
Wealth index	Poorest	4,676	28.08
	Poorer	2,348	14.10
	Middle	2,057	12.35
	Richer	2,020	12.13
	Richest	5,549	33.33
Time to get drinking water	≤ 30 minutes	9,821	58.98
	> 30 minutes	6,829	41.02
Number of household members	1 – 3 members	6,258	37.59
	4 – 6 members	7,031	42.23
	7 members and above	3,361	20.19
Residence	Urban	5,232	31.42
	Rural	11,418	68.58
Region	Tigray	1,734	10.41
	Afar	1,220	7.33
	Amhara	1,902	11.42
	Oromia	1,988	11.94
	Somali	1,564	9.39
	Benishangul-Gumuz	1,280	7.69
	SNNPR	1,897	11.39
	Gambella	1,280	7.69
	Harari	1,135	6.82
	Dire Dawa	1,161	6.97
	Addis Ababa	1,489	8.94

Regional distribution in terms of improved drinking water and toilet facility sources in Ethiopia

Among Ethiopian regions, nearly all households in Addis Abeba (99.40%) had access to improved sources of drinking water. On the contrary, Somali (56.52%) and Afar regions (51.39%) had the

least access to an improved sources of drinking water. Households in Benishangul-Gumuz and Amhara regions were lowest in access to toilet facilities with 4.30% and 6.31%, respectively while households in Dire Dawa and Addis Ababa had the highest access to improved toilet facilities with 65.20% and 79.31%, respectively **[S1 Table 1].**

Factors associated with access to improved drinking water sources

The proportion of households which had access to an improved sources of drinking water was 69.94% at [95% CI: (69.23, 70.63)]. Both individual-level factors and community-level factors had an impact on accessing improved drinking water sources in this study. Among individual-level factors; sex of household head and from community-level factors; wealth index, time to get to drinking water sources, residence and region were significantly associated with access to improved drinking water sources

Female-headed households were 1.18 [AOR = 1.18, CI: (1.01, 1.37)] times more likely to have access to improved drinking water sources than male-headed households.

Compared to poorest households, poorer [AOR = 1.48, CI: (1.26, 1.74)], middle-income [AOR = 2.42, CI: (2.03, 2.90)], richer [AOR = 3.26, CI: (2.68, 3.97)] and richest [AOR = 6.97, CI: (5.17, 9.41)] households were 1.48, 2.42, 3.26, and 6.97 times more likely to access improved drinking water sources at, respectively.

In contrasted with family units who got drinking water < 30 minutes, households who got drinking water ≥ 30 minutes were 35% less likely to access drinking water [AOR = 0.65, CI: (0.58, 0.73)].

The adjusted odds of access to improved drinking water sources in rural area was 94.00% less likely compared to urban area [AOR = 0.06, CI: (0.03, 0.11)].

The likelihood of access to improved sources of drinking water were 95.00% [AOR = 0.05, (0.01, 0.21)] in Afar, 94.00% [AOR = 0.06, (0.01, 0.27)] in Amhara, 92.00% [AOR = 0.08, (0.02, 0.35)] in Oromia, 98.00% [AOR = 0.02, (0.01, 0.10)] in Somalia , 93.00% [AOR = 0.07, (0.02, 0.30)] in SNNPR, and 82.00% [AOR = 0.18 (0.04, 0.89)] in Harari as compared to improved water access in Addis Ababa city **[Table 2].**

Table 2: Multivariate multilevel logistic regression model of the effects of individual- and community-level factors on improved drinking water sources in Ethiopia, EDHS 2016

Variables		Null Model	Model I	Model II	Model III
			AOR(95% CI)	AOR(95% CI)	AOR(95% CI)
Sex of household head	Male		1		1
	Female		1.13 (0.97, 1.32)		**1.18 (1.01, 1.37)[a]**
Age of household head	13 to 30		1		1
	31 to 40		0.99 (0.85, 1.14)		1.04 (0.89, 1.22)
	41 to 56		1.07 (0.92, 1.24)		1.13 (0.96, 1.33)
	≥ 57		0.93 (0.80, 1.09)		1.00 (0.85, 1.17)
Education level of the household head	No education		1		1
	Primary		0.93 (0.50, 1.73)		0.98 (0.52, 1.83)
	Secondary		1.69 (0.82, 3.49)		1.74 (0.83, 3.65)
	Higher		1.51 (0.40, 5.70)		1.37 (0.34, 5.55)
Current marital status household head	Never married		1		1
	Married		0.74 (0.54, 1.02)		1.02 (0.72, 1.43)
	Divorced		0.71 (0.49, 1.04)		1.01 (0.68, 1.50)
	Widowed		0.72 (0.49, 1.05)		0.98 (0.66, 1.45)
Wealth index	Poorest			1	1
	Poorer			1.47 (1.25, 1.73)[b]	**1.48 (1.26, 1.74)[b]**
	Middle			2.41 (2.01, 2.88)[b]	**2.42 (2.03, 2.90)[b]**
	Richer			3.23 (2.66, 3.92)[b]	**3.26 (2.68, 3.97)[b]**
	Richest			6.84 (5.07, 9.22)[b]	**6.97 (5.17, 9.41)[b]**
Time to get drinking water	< 30 minutes			1	1
	≥ 30 minutes			0.66 (0.58, 0.74)[b]	**0.65 (0.58, 0.73)[b]**

Number of household members		1 – 3 members			1	1
		4 – 6 members			0.86 (0.77, 0.97)[a]	0.88 (0.77, 1.00)
		7+			0.88 (0.76, 1.01)	0.88 (0.75, 1.04)
Residence		Urban			1	1
		Rural			0.06 (0.03, 0.10) [b]	**0.06 (0.03, 0.11)[b]**
Region		Tigray			0.26 (0.06, 1.18)	0.26 (0.06, 1.17)
		Afar			0.05 (0.01, 0.21)[b]	**0.05 (0.01, 0.21)[b]**
		Amhara			0.06 (0.01, 0.27)[b]	**0.06 (0.01, 0.27)[b]**
		Oromia			0.08 (0.02, 0.35)[b]	**0.08 (0.02, 0.35)[b]**
		Somali			0.02 (0.01, 0.10)[b]	**0.02 (0.01, 0.10)[b]**
		Benishangul Gumuz			0.39 (0.08, 1.80)	0.39 (0.08, 1.81)
		SNNPR			0.07 (0.02, 0.30)[b]	**0.07 (0.02, 0.30)[b]**
		Gambella			0.30 (0.06, 1.35)	0.29 (0.06, 1.33)
		Harari			0.18 (0.04, 0.88)[a]	**0.18 (0.04, 0.89)[a]**
		Dire Dawa			0.33 (0.07, 1.64)	0.33 (0.07, 1.63)
		Addis Ababa			1	1
Random effect	Community level variance(SE)		12.24 (1.13)[b]	12.05 (1.11)[b]	4.75 (0.42)[b]	4.73 (0.41)[b]
	ICC (%)		78.81%	78.55%	59.08%	58.97%
	MOR		9.05	8.96	5.64	5.62
	PCV		Reference	1.55%	61.19	61.36%
Model fit statistics	Log-likelihood		-5997.01	-5987.89	-5619.38	-5611.48
	Deviance		11994.02	11975.78	11238.76	11222.96

Note:

[a, b] significant at [a] $P < 0.05$; [b] $P < 0.001$;

AOR: Adjusted Odds Ratio,

CI: Confidence Interval,

Model 0- Empty (null) model

Model I- Only individual-level explanatory variables included in the model;

Model II- Only community-level explanatory variables included in the model;

Model III- Combined model; both individual-level and community-level explanatory variables

PCV: Proportional Change in Variance,

MOR: Median Odds Ratio

Factors associated with access to improved toilet facilities

The proportion of households with access to an improved source of toilet facility was 25.36% at [95% CI: (24.69%, 26.03%)]. Individual-level factors such as educational level of the household heads, marital status, and community level factors such as wealth index, source of drinking water, number of household members, residence, and region were factors significantly associated with households' access to improved toilet facilities.

Compared with households whose household heads had no education, households headed with those who attained higher education were 2.21 times more likely to have access to improved toilet facilities at [AOR = 2.21 CI: (1.12, 4.36)]. The likelihood of access to toilet facilities was 25% [AOR = 0.75, CI: (0.57, 0.98)] lower in households with widowed household heads, as compared to those who never married.

Households with poorer [AOR = 3.97 CI: (2.99, 5.29)], middle [AOR = 5.82 CI: (4.35, 7.80)], richer [AOR = 8.58 CI: (6.40, 11.50)], and richest wealth index [AOR = 23.94 CI: (17.45, 32.83)], were 3.97, 5.82, 8.58, and 23.94 times more likely to access improved toilet facilities as compared to households with the poorest wealth index, respectively.

Households who had improved sources of drinking water were 1.37 [AOR = 1.37 CI: (1.12, 1.66)] times more likely to have access to improved toilet facilities, compared with their counterparts. Compared to household which had one to three members, 24% of those with four to six members were [AOR = 0.86 (0.75, 0.98)] less likely to access improved toilet facilities.

About 72% of rural households were less likely to have access to improved toilet facilities as compared with those from urban residence [AOR = 0.28 CI: (0.20, 0.38)]. About 72.00% in Tigray [AOR = 0.28, CI: (0.17, 0.46)] , 63.00% in Afar [AOR = 0.37, CI: (0.21, 0.67)], 96.00% in Amhara

[AOR = 0.04, (0.02, 0.06)], 90.00% in Oromia [AOR = 0.10, CI: (0.06, 0.17)], 95.00% in Benishangul Gumuz [AOR = 0.05 CI: (0.03, 0.10)], 80.00% in SNNPR [AOR = 0.20 CI: (0.12, 0.33)], 85% in Gambella [AOR = 0.15 CI:(0.09, 0.26)], and 60.00% in Harari [AOR = 0.40 CI: (0.24, 0.66)] households were more likely to have access to improved toilet facilities as compared to households in Addis Ababa city **[Table 3].**

Table 3: Multivariate multilevel logistic regression model of the effects of individual- and community-level factors on improved sources of toilet facilities in Ethiopia, EDHS 2016

Variables		Null Model	Model I	Model II	Model III
			AOR(95% CI)	AOR(95% CI)	AOR(95% CI)
Sex of household head	Male		1		1
	Female		1.01 (0.88, 1.16)		1.03 (0.89, 1.19)
Age of household head	13 to 30		1		1
	31 to 40		0.99 (0.85, 1.15)		1.04 (0.89, 1.21)
	41 to 56		0.98 (0.84, 1.15)		1.02 (0.86, 1.20)
	≥ 57		0.98 (0.83, 1.16)		1.08 (0.91, 1.28)
Education level of the household head	No education		1		1
	Primary		1.34 (0.67, 2.67)		1.19 (0.59, 2.40)
	Secondary		0.74 (0.40, 1.36)		0.75 (0.41, 1.38)
	Higher		2.26 (1.13, 4.54)		**2.21 (1.12, 4.36)[b]**
Current marital status household head	Never married		1		1
	Married		0.87 (0.71, 1.08)		0.99 (0.80, 1.22)
	Divorced		0.69 (0.52, 0.91)[b]		0.82 (0.62, 1.08)
	Widowed		0.66 (0.50, 0.86)[c]		**0.75 (0.57, 0.98)[b]**
Wealth index	Poorest			1	1
	Poorer			3.99 (3.00, 5.31)[c]	**3.97 (2.99, 5.29)[c]**
	Middle			5.87 (4.39, 7.86)[c]	**5.82 (4.35, 7.80)[c]**
	Richer			8.65 (6.46, 11.58)[c]	**8.58 (6.40, 11.50)[c]**
	Richest			24.76 (18.08, 33.91)[c]	**23.94 (17.45, 32.83)[c]**
Source of drinking water	Unimproved			1	1
	Improved			1.36 (1.12, 1.65)[c]	**1.37 (1.12, 1.66)[c]**

Number of household members	1 – 3 members			1	1
	4 – 6 members			0.88 (0.78, 0.99)[a]	**0.86 (0.75, 0.98)[c]**
	7+			1.07 (0.91, 1.26)	1.02 (0.86, 1.22)
Residence	Urban			1	1
	Rural			0.28 (0.21, 0.39)[c]	**0.28 (0.20, 0.38)[c]**
Region	Tigray			0.27 (0.16, 0.45)[c]	**0.28 (0.17, 0.46)[c]**
	Afar			0.38 (0.21, 0.68)[c]	**0.37 (0.21, 0.67)[c]**
	Amhara			0.04 (0.02, 0.06)[c]	**0.04 (0.02, 0.06)[c]**
	Oromia			0.10 (0.06, 0.17)[c]	**0.10 (0.06, 0.17)[c]**
	Somali			1.33 (0.79, 2.22)	1.32 (0.79, 2.21)
	Benishangul G.			0.05 (0.03, 0.10)[c]	**0.05 (0.03, 0.10)[c]**
	SNNPR			0.20 (0.12, 0.34)[c]	**0.20 (0.12, 0.33)[c]**
	Gambella			0.15 (0.09, 0.26)[c]	**0.15 (0.09, 0.26)[c]**
	Harari			0.40 (0.24, 0.66)[c]	**0.40 (0.24, 0.66)[c]**
	Dire Dawa			1.13 (0.69, 1.87)	1.14 (0.69, 1.89)
	Addis Ababa			1	1
Random effect	Community level variance(SE)	8.66 (0.73)[c]	8.71 (0.74)[c]	1.21 (0.12)[c]	1.22 (0.12)[c]
	ICC (%)	72.46%	72.58%	26.95%	27.08%
	MOR	16.37	16.50	2.84	2.86
	PCV	reference	-1.07%	86.03	85.91%
Model fit statistics	Log-likelihood	-5621.74	-5603.26	-5029.24	-5018.39
	Deviance	11243.48	11206.52	11036.78	10058.48

Note:

[a, b, c] significant at [a] $P < 0.05$; [b] $p < 0.01$, [c] $P < 0.001$;

AOR: Adjusted Odds Ratio,

CI: Confidence Interval,

Model 0- Empty (null) model

Model I- Only individual-level explanatory variables included in the model;

Model II- Only community-level explanatory variables included in the model;

Model III- Combined model; both individual-level and community-level explanatory variables

PCV: Proportional Change in Variance,

MOR: Median Odds Ratio

Random-effects analysis

The prevalence rate of access to improved drinking water sources varied across communities (community-level variance = 12.24, p = <0.001) **[Table 2]**. The null model revealed that 78.81% of the total variance in the odds of access to improved drinking water sources was accounted by between-cluster variation of characteristics (ICC = 0.7881). The inter-cluster variability declined over successive models, from 78.81% in the null model to 78.55% in the only individual-level, 59.08% in the only community-level, and 58.97% in the final (combined) models. The proportional change in variance indicated that the addition of predictors to the empty model explained an increased proportion of variation in access to improved drinking water sources. The combined model showed that a higher PCV, i.e., 61.36% of the variance in access to improved drinking water sources could be explained by the combined factors at the individual- and community-levels.

In [**Table 3]** the final model (**Model III**), ICC value of 0.2708 indicates that 27.08% of the total variation in access to improved toilet facilities is accounted for the community-level factors. The remaining 72.92% variation is therefore triggered by the individual- level and other unknown factors. The proportional change in variance indicated that the addition of predictors to the empty model explained an increased proportion of variation in access to improved toilet facilities. The combined model showed a higher PCV, i.e., 85.91% of the variance in access to improved toilet facilities could be explained by the combined factors at the individual- and community-levels.

Model fit statistics

As shown in [**Tables 2 & 3**] (model fit statistics), the values of log-likelihood and Deviance showed a subsequent reduction which indicates that each model represents a significant

improvement over the previous model and it points to the goodness of fit for the final model built in the analysis.

DISCUSSION

In this study, we aimed to assess access to improved drinking water sources and sanitation facilities and their associated factors in Ethiopia. Accordingly, the proportion of households' access to improved drinking water sources was 69.94%, [95% CI: (69.23, 70.63)]. This finding is lower than reports from studies conducted in Ghana,[2] Viet Nam,[16], and Eswatini. [14] Whereas, it is higher than a reported proportion from a study conducted in Nepal. [15] The proportion of households' access to toilet facilities was 25.36%, [95% CI: (24.69, 26.03)]. This result is higher than the one reported from Ghana,[2] However, lower than studies from Nigeria,[26] and Viet Nam. [16] The variation could be the disparities in GDP status and literacy rate among countries, study period, and setting.

Individual-level factors were associated with access to improved drinking water sources and toilet facilities in the present study. Female-headed households were 1.18 times more likely than male-headed households to access improved drinking water sources. Similar findings were reported from Ghana, Vietnam, and Nigeria. [2, 16, 27] Gender differences may play an important role in the work division in developing countries. Most of the time women have higher household responsibilities such as fetching water, cleaning compound, childcare, and food preparation, etc. Therefore, this might be directly linked with water and sanitation in the sense that women may be preoccupied with other daily routines than WASH.

Those households with heads having better educational status were 2.21 times more likely to access improved toilet facilities. This finding supported by evidence from previous studies.[14, 26, 28] Households who are led by heads who have no education had a lower probability of access to improved toilet facilities. In sub-Saharan Africa, education is a resource factor of quality health outcomes, and educated people usually are more aware of the condition that guarantees their well beings. This implies that educated household heads in this study may have utilized their resources to provide their households with improved toilet facilities.

In addition to individual level factors, community-level factors were also associated with access to improved drinking water sources and toilet facilities. When compared to households within a poorest category, households within poorer, middle, richer and richest wealth index category were 1.48, 2.42, 3.26, and 6.97 times more likely to have access to improved sources of drinking water and 3.97, 5.82, 8.58, and 23.94 times higher odds to access improved toilet facilities, respectively. This result is consistent with results from previous studies.[13, 14, 29] People who have better income would intend to fulfill the necessities of life. Economically, the rich can afford the initial high cost of both water and sanitation facilities and the poor may be disproportionately underserved in the distribution of public utility, and hence consume poor quality water and use unimproved sanitation facilities.

Compared with households that got drinking water < 30 minutes, households which obtained drinking water ≥ 30 minutes were 35% less likely to access improved drinking water sources. Hence, the length of time to get drinking (proximity of a house to a drinking water source) water might make difference in access to improved sources of drinking water and coverage (%) with improved water supply (HH connection, public standpipes, protected underground water sources,

rainwater collection). This is not surprising as physical distance is one of the reasons of WASH service in accessibilities.

The adjusted odds of access to improved drinking water sources and toilet facilities were 94.00% and 72.00% less likely among rural households as compared to urban households, respectively. The rural-urban disparity in access to improved sources of drinking water and toilet facilities have been reported by several other previous studies, too. [12, 30, 31]. The disparity might be, in sub-Saharan Africa, most of the people live in rural areas and their economic status is poor. Therefore, they do not have adequate financial resources to acquire improved drinking water sources and toilet facilities.

Furthermore, households who had improved sources of drinking water were 1.37 times more likely to access an improved toilet facilities. This study finding is consistent with an earlier study. [26] The possible explanation could be a lack of access to adequate sanitation is also linked to the limited access to water supply and households who had improved water sources may be practicing more in hygiene and sanitation.

Lastly, those households with four to six were 24% less likely access to improved toilet facilities compared to households with a family size of one to three. This is contrary to that of an earlier study. [2] The possible explanation could be the highest number of household members, the fewer resources they could have to build improved toilet facilities.

CONCLUSION

The proportion of households' access to an improved source of drinking water and sanitation facility was low in the country. Sex of household head, wealth index, time to get drinking water, residence, and region were associated with access to improved drinking water sources. Educational level of the household head, wealth index, being widowed, source of drinking water, number of household members, residence, and region were factors associated with access to improved toilet facilities. Thus, governmental and non-governmental organizations working on water, hygiene, and sanitation should consider a multi-faceted policy approach that accounts for the regions and residence variations and other identified factors to ease the problem.

Acknowledgments

We would like to thank the Demographic and Health Survey (DHS) Programme for allowing the use of Ethiopian Demographic and Health Survey (EDHS) data for this study.

Competing interests: None declared.

Patient consent for publication: Not required.

Ethics approval: The EDHS 2016 was approved by the National Research Ethics Review Committee of Ethiopia and ICF Macro International. The approval letter was obtained from the measure DHS for the use of this data, and the dataset was downloaded from www.meauredhs.com. This analysis was approved by the Department of Environmental and occupational health and safety, University of Gondar.

Funding

The author(s) received no specific funding for this work.

Availability of data and materials

The dataset analyzed during the current study available from the corresponding author on reasonable request.

Authors' contributions

ZA wrote the analyzed data, drafted the paper, and prepared the manuscript. HD, ZNA, AAT, BD, AG, and YY drafted the paper, writing – review & editing, and commented on the manuscript. All the authors read and approved the final manuscript.

REFERENCES

1. Prüss-Ustün A, Wolf J, Bartram J, Clasen T, Cumming O, Freeman MC, et al. Burden of disease from inadequate water, sanitation and hygiene for selected adverse health outcomes: An updated analysis with a focus on low-and middle-income countries. International journal of hygiene and environmental health. 2019;222(5):765-77.

2. Agbadi P, Darkwah E, Kenney PL. A Multilevel Analysis of Regressors of Access to Improved Drinking Water and Sanitation Facilities in Ghana. Journal of environmental and public health. 2019;2019.

3. Assembly UG. Resolution on Human Right to Water and Sanitation. New York: United Nations. 2010.

4. Brookes JD, Carey CC. Ensure availability and sustainable management of water and sanitation for all. UN Chronicle. 2015;51(4):15-6.

5. Mills JE, Cumming O. The impact of water, sanitation and hygiene on key health and social outcomes. URL: https://www lshtm ac uk/sites/default/files/2017-07/WASHEvidencePaper_HighRes_01. 2016;23.

6. Saxena SK, Kumar S, Haikerwal A, Bhatt ML. Introductory chapter: Neglected tropical waterborne infectious diseases-strategies for mitigation. Water Challenges of an Urbanizing World. 2018:1.

7. Organization WH. Water, sanitation, hygiene, and waste management for the COVID-19 virus: interim guidance, 23 April 2020. World Health Organization, 2020.

8. Organization WH. Progress on drinking water, sanitation and hygiene: 2017 update and SDG baselines. 2017.

9. Organization WH. Water, sanitation, hygiene and health: a primer for health professionals. World Health Organization, 2019.

10. Organization WH. Safer water, better health. 2019.

11. UNICEF. Water, sanitation and hygiene (WASH) 2020 [cited 2020 April, 14]. Available from: https://www.unicef.org/ethiopia/water-sanitation-and-hygiene-wash.

12. Mulenga JN, Bwalya BB, Kaliba-Chishimba K. Determinants and inequalities in access to improved water sources and sanitation among the Zambian households. International Journal of Development and Sustainability. 2017;6(8):746-62.

13. Morakinyo OM, Adebowale SA, Oloruntoba EO. Wealth status and sex differential of household head: implication for source of drinking water in Nigeria. Archives of Public Health. 2015;73(1):58.

14. Simelane MS, Shongwe MC, Vermaak K, Zwane E. Determinants of Households' Access to Improved Drinking Water Sources: A Secondary Analysis of Eswatini 2010 and 2014 Multiple Indicator Cluster Surveys. Advances in Public Health. 2020;2020.

15. Wang C, Pan J, Yaya S, Yadav RB, Yao D. Geographic Inequalities in Accessing Improved Water and Sanitation Facilities in Nepal. International journal of environmental research and public health. 2019;16(7):1269.

16. Tuyet-Hanh TT, Long TK, Van Minh H, Huong LTT. Longitudinal household trends in access to improved water sources and sanitation in Chi Linh town, Hai Duong province, Viet Nam and associated factors. AIMS public health. 2016;3(4):880.

17. Organization WH, UNICEF. Progress on drinking water and sanitation: special focus on sanitation. Progress on drinking water and sanitation: special focus on sanitation2008.

18. Beyene A, Hailu T, Faris K, Kloos H. Current state and trends of access to sanitation in Ethiopia and the need to revise indicators to monitor progress in the Post-2015 era. BMC public health. 2015;15:451-.

19. Central Statistical Agency (CSA). Central Statistical Agency (CSA) [Ethiopia] and ICF Ethiopia demographic and health Survey 2016. Addis Ababa, Ethiopia, and Rockville, Maryland, USA: CSA and ICF,2017.

20. Supply WUJW, Programme SM, Organization WH, Supply WUJMPfW, Sanitation, UNICEF. Water for life: making it happen: World health organization; 2005.

21. Merlo J, Chaix B, Ohlsson H, Beckman A, Johnell K, Hjerpe P, et al. A brief conceptual tutorial of multilevel analysis in social epidemiology: using measures of clustering in multilevel logistic regression to investigate contextual phenomena. Journal of Epidemiology & Community Health. 2006;60(4):290-7.

22. Merlo J, Yang M, Chaix B, Lynch J, Råstam L. A brief conceptual tutorial on multilevel analysis in social epidemiology: investigating contextual phenomena in different groups of people. Journal of Epidemiology & Community Health. 2005;59(9):729-36.

23. Larsen K, Merlo J. Appropriate assessment of neighborhood effects on individual health: integrating random and fixed effects in multilevel logistic regression. American journal of epidemiology. 2005;161(1):81-8.

24. Spiegelhalter DJ, Best NG, Carlin BP, Van Der Linde A. Bayesian measures of model complexity and fit. Journal of the royal statistical society: Series b (statistical methodology). 2002;64(4):583-639.

25. Hair Jr JF. Multivariate Data Analysis Joseph F. Hair Jr. William C. Black Barry J. Babin Rolph E. Anderson Seventh Edition.

26. Abubakar IR. Access to sanitation facilities among Nigerian households: determinants and sustainability implications. Sustainability. 2017;9(4):547.

27. Morakinyo OM, Adebowale SA, Oloruntoba EO. Wealth status and sex differential of household head: implication for source of drinking water in Nigeria. Archives of public health = Archives belges de sante publique. 2015;73:58.

28. Akpakli DE, Manyeh AK, Akpakli JK, Kukula V, Gyapong M. Determinants of access to improved sanitation facilities in rural districts of southern Ghana: evidence from Dodowa Health and Demographic Surveillance Site. BMC Res Notes. 2018;11(1):473-.

29. Njuguna J. Progress in sanitation among poor households in Kenya: evidence from demographic and health surveys. BMC public health. 2019;19(1):135.

30. Irianti S, Prasetyoputra P, Sasimartoyo TP. Determinants of household drinking-water source in Indonesia: An analysis of the 2007 Indonesian family life survey. Cogent Medicine. 2016;3(1).

31. Prasetyoputra P, Irianti S. Access to improved sanitation facilities in indonesia: An econometric analysis of geographical and socioeconomic disparities. Journal of Applied Sciences in Environmental Sanitation. 2013;8(3).

Supplementary Table 1: Regional distribution of access to improved drinking water sources and toilet facilities in Ethiopia, EDHS, 2016.

Region	Source of drinking water		Toilet facilities	
	Unimproved	Improved	Unimproved	Improved
Tigray	410 (23.64%)	1,324 (76.36%)	1,380 (79.58%)	354 (20.42%)
Afar	627 (51.39%)	593 (48.61%)	1,032 (84.59%)	188 (15.41%)
Amhara	741 (38.96%)	1,161 (61.04%)	1,782 (93.69%)	120 (6.31%)
Oromia	746 (37.53%)	1,242 (62.47%)	1,785 (89.79%)	203 (10.21%)
Somali	884 (56.52%)	680 (43.48%)	1,145 (73.21%)	419 (26.79%)
Benishangul Gumuz	271 (21.17%)	1,009 (78.83%)	1,225 (95.70%)	55 (4.30%)
SNNPR	775 (40.85%)	1,122 (59.15%)	1,650 (86.98%)	247 (13.02%)
Gambella	246 (19.22%)	1,034 (80.78%)	1,098 (85.78%)	182 (14.22%)
Harari	179 (15.77%)	956 (84.23%)	619 (54.54%)	516 (45.46%)
Dire Dawa	117 (10.08%)	1,044 (89.92%)	404 (34.80%)	757 (65.20%)
Addis Ababa	9 (0.60%)	1,480 (99.40%)	308 (20.69%)	1,181 (79.31%)
Total	5005(30.06%)	11,645 (69.94%)	12,428 (74.64%)	4,222 (25.36%)

STROBE (Strengthening The Reporting of OBservational Studies in Epidemiology) Checklist

A checklist of items that should be included in reports of observational studies. You must report the page number in your manuscript where you consider each of the items listed in this checklist. If you have not included this information, either revise your manuscript accordingly before submitting or note N/A.

Note: An Explanation and Elaboration article discusses each checklist item and gives methodological background and published examples of transparent reporting. The STROBE checklist is best used in conjunction with this article (freely available on the Web sites of PLoS Medicine at http://www.plosmedicine.org/, Annals of Internal Medicine at http://www.annals.org/, and Epidemiology at http://www.epidem.com/). Information on the STROBE Initiative is available at www.strobe-statement.org.

Section and Item	Item No.	Recommendation	Reported on Page No.
Title and Abstract	1	(*a*) Indicate the study's design with a commonly used term in the title or the abstract	
		(*b*) Provide in the abstract an informative and balanced summary of what was done and what was found	
Introduction			
Background/Rationale	2	Explain the scientific background and rationale for the investigation being reported	
Objectives	3	State specific objectives, including any prespecified hypotheses	
Methods			
Study Design	4	Present key elements of study design early in the paper	
Setting	5	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection	
Participants	6	(*a*) *Cohort study*—Give the eligibility criteria, and the sources and methods of selection of participants. Describe methods of follow-up *Case-control study*—Give the eligibility criteria, and the sources and methods of case ascertainment and control selection. Give the rationale for the choice of cases and controls *Cross-sectional study*—Give the eligibility criteria, and the sources and methods of selection of participants	
		(*b*) *Cohort study*—For matched studies, give matching criteria and number of exposed and unexposed *Case-control study*—For matched studies, give matching criteria and the number of controls per case	
Variables	7	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable	

Section and Item	Item No.	Recommendation	Reported on Page No.
Data Sources/ Measurement	8*	For each variable of interest, give sources of data and details of methods of assessment (measurement). Describe comparability of assessment methods if there is more than one group	
Bias	9	Describe any efforts to address potential sources of bias	
Study Size	10	Explain how the study size was arrived at	
Quantitative Variables	11	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why	
Statistical Methods	12	(*a*) Describe all statistical methods, including those used to control for confounding	
		(*b*) Describe any methods used to examine subgroups and interactions	
		(*c*) Explain how missing data were addressed	
		(*d*) *Cohort study*—If applicable, explain how loss to follow-up was addressed *Case-control study*—If applicable, explain how matching of cases and controls was addressed *Cross-sectional study*—If applicable, describe analytical methods taking account of sampling strategy	
		(*e*) Describe any sensitivity analyses	
Results			
Participants	13*	(a) Report numbers of individuals at each stage of study—eg numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analysed	
		(b) Give reasons for non-participation at each stage	
		(c) Consider use of a flow diagram	
Descriptive Data	14*	(a) Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders	
		(b) Indicate number of participants with missing data for each variable of interest	
		(c) *Cohort study*—Summarise follow-up time (eg, average and total amount)	
Outcome Data	15*	*Cohort study*—Report numbers of outcome events or summary measures over time	
		Case-control study—Report numbers in each exposure category, or summary measures of exposure	
		Cross-sectional study—Report numbers of outcome events or summary measures	

Section and Item	Item No.	Recommendation	Reported on Page No.
Main Results	16	(*a*) Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (eg, 95% confidence interval). Make clear which confounders were adjusted for and why they were included	
		(*b*) Report category boundaries when continuous variables were categorized	
		(*c*) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period	
Other Analyses	17	Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses	
Discussion			
Key Results	18	Summarise key results with reference to study objectives	
Limitations	19	Discuss limitations of the study, taking into account sources of potential bias or imprecision. Discuss both direction and magnitude of any potential bias	
Interpretation	20	Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence	
Generalisability	21	Discuss the generalisability (external validity) of the study results	
Other Information			
Funding	22	Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based	

*Give information separately for cases and controls in case-control studies and, if applicable, for exposed and unexposed groups in cohort and cross-sectional studies.

Once you have completed this checklist, please save a copy and upload it as part of your submission. DO NOT include this checklist as part of the main manuscript document. It must be uploaded as a separate file.

BMJ Open

Households' access to improved drinking water sources and toilet facilities in Ethiopia: A multilevel analysis based on 2016 Ethiopian Demographic and Health Survey

Journal:	*BMJ Open*
Manuscript ID	bmjopen-2020-042071.R1
Article Type:	Original research
Date Submitted by the Author:	11-Jan-2021
Complete List of Authors:	Andualem , Zewudu ; University of Gondar College of Medicine and Health Sciences, Department of Environmental and Occupational health and Safety Dagne, Henok; University of Gondar College of Medicine and Health Sciences, Environmental and Occupational Health and Safety; University of Gondar, Environmental and Occupational Health and Safety Azene, Zelalem; University of Gondar College of Medicine and Health Sciences, Department of Women's and family health, School of Midwifery, College of Medicine and Health Sciences, University of Gondar, P. O. Box 196 Gondar, Ethiopia.; University of Gondar, Ethiopia taddese, Asefa; University of Gondar College of Medicine and Health Sciences, Epidemiology and Biostatistics Dagnew, Baye ; University of Gondar College of Medicine and Health Sciences, Human Physiology; Mr. Fisseha, Roman ; Department of Medical Microbiology, School of Biomedical and Laboratory Sciences, College of Medicine and Health Sciences, University of Gondar, P. O. Box 196 Gondar, Ethiopia. Muluneh, Atalay; University of Gondar College of Medicine and Health Sciences, Epidemiology and Bio statistics ; Yeshaw, Yigizie; University of Gondar College of Medicine and Health Sciences, Medical Physiology
Primary Subject Heading:	Public health
Secondary Subject Heading:	Occupational and environmental medicine
Keywords:	PUBLIC HEALTH, PREVENTIVE MEDICINE, Health policy < HEALTH SERVICES ADMINISTRATION & MANAGEMENT

I, the Submitting Author has the right to grant and does grant on behalf of all authors of the Work (as defined in the below author licence), an exclusive licence and/or a non-exclusive licence for contributions from authors who are: i) UK Crown employees; ii) where BMJ has agreed a CC-BY licence shall apply, and/or iii) in accordance with the terms applicable for US Federal Government officers or employees acting as part of their official duties; on a worldwide, perpetual, irrevocable, royalty-free basis to BMJ Publishing Group Ltd ("BMJ") its licensees and where the relevant Journal is co-owned by BMJ to the co-owners of the Journal, to publish the Work in this journal and any other BMJ products and to exploit all rights, as set out in our licence.

The Submitting Author accepts and understands that any supply made under these terms is made by BMJ to the Submitting Author unless you are acting as an employee on behalf of your employer or a postgraduate student of an affiliated institution which is paying any applicable article publishing charge ("APC") for Open Access articles. Where the Submitting Author wishes to make the Work available on an Open Access basis (and intends to pay the relevant APC), the terms of reuse of such Open Access shall be governed by a Creative Commons licence – details of these licences and which Creative Commons licence will apply to this Work are set out in our licence referred to above.

Other than as permitted in any relevant BMJ Author's Self Archiving Policies, I confirm this Work has not been accepted for publication elsewhere, is not being considered for publication elsewhere and does not duplicate material already published. I confirm all authors consent to publication of this Work and authorise the granting of this licence.

Households' access to improved drinking water sources and toilet facilities in Ethiopia: A multilevel analysis based on 2016 Ethiopian Demographic and Health Survey

Zewudu Andualem[1*], Henok Dagne[1], Zelalem Nigussie Azene[2], Asefa Adimasu Taddese[3], Baye Dagnew[4], Roman Fisseha[5], Atalay Goshu Muluneh[3], and Yigizie Yeshaw[4]

[1]Department of Environmental and Occupational Health and Safety, Institute of Public Health, College of Medicine and Health Sciences, University of Gondar, P. O. Box 196 Gondar, Ethiopia

[2]Department of Women's and family health, School of Midwifery, College of Medicine and Health Sciences, University of Gondar, P. O. Box 196 Gondar, Ethiopia.

[3]Department of Epidemiology and Biostatistics, Institute of Public Health, College of Medicine and Health Sciences, University of Gondar, P. O. Box 196 Gondar, Ethiopia

[4]Department of Human Physiology, School of Medicine, College of Medicine and Health Sciences, University of Gondar, P. O. Box 196 Gondar, Ethiopia

[5]Department of Medical Microbiology, School of Biomedical and Laboratory Sciences, College of Medicine and Health Sciences, University of Gondar, P. O. Box 196 Gondar, Ethiopia.

*Corresponding author

Authors' email address

[ZA] Zewudu Andualem: zewuduandualem12@gmail.com, [HD] Henok Dagne: enoch2313@gmail.com, [ZNA] Zelalem Nigussie Azene: znigussie35@gmail.com, [AAT] Asefa Adimasu Taddese: adimasuasefa@gmail.com, [BD] Baye Dagnew: bayedagnew7@gmail.com, [RF] Roman Fisseha: romanfisseha85@gmail.com, [AGM] Atalay Goshu Muluneh: atalayg1921@gmail.com, and [YY] Yigizie Yeshaw: yigizieyeshaw29@gmail.com

ABSTRACT

Objective: This study aimed to assess households' access to improved drinking water sources and sanitation facilities and their associated factors in Ethiopia

Design: Cross-sectional study

Setting: Ethiopia

Participants: Household heads

Primary outcomes: Access to improved drinking water sources and sanitation facilities

Methods: We conducted an in-depth secondary data analysis of 2016 Ethiopian Demographic and Health Survey (EDHS). Data from a total of 16650 households and 645 clusters were included in the analysis. The households in the EDHS were selected using a stratified two-stage cluster sampling technique. Multilevel binary logistic regression analyses were performed to identify factors associated with access to an improved drinking water source and toilet facilities. Adjusted odds ratio with a 95% CI were reported. P-value < 0.05 was used to declare a significant association between the covariates and outcomes.

Results: The proportions of households' access to improved sources of drinking water and toilet facilities were 69.94%, [95% CI: (69.23, 70.63)], and 25.36%, [95% CI: (24.69, 26.03)], respectively. Female headed households [AOR = 1.18, 95% CI: (1.01, 1.37)] and better wealth index, ≥ 30 minutes time to obtain drinking water [AOR = 0.65, 95% CI: (0.58, 0.73)], rural residence [AOR = 0.06, 95% CI: (0.03, 0.11)] and region were factors associated with access to improved drinking water source. Whereas, higher educational status [AOR = 2.21, 95% CI: (1.12, 4.36)], being widowed [AOR = 0.75, 95% CI: (0.57, 0.98)], improved source of drinking water

[AOR =1.37, 95% CI: (1.12, 1.66)], household size [4 to 6] [AOR = 0.86, 95% CI: (0.75, 0.98)], rural residence [AOR = 0.28, 95% CI: (0.20, 0.38)], households with better wealth index, and region were significantly associated with access to improved toilet facilities

Conclusion: The proportions of households' access to improved drinking water sources and toilet facilities in Ethiopia was relatively low.

Keywords: Improved toilet facilities, improved water sources, multilevel analysis, Ethiopia

Strength and limitations of the study

- The use of nationally representative data that can enhance the generalizability of the finding is one of the strength of the study.
- Due to the inherent nature of a cross-sectional study, it does not show the temporal relationship between the outcome status and predictors.
- Moreover, important variables such as culture, traditions, and social norms were not available in EDHS data which could influence the use of toilet facility type.

INTRODUCTION

Access to safe water and basic sanitation is one of the fundamental human rights, and an essential step towards improving living standards to maintain and improve health, human growth, and development. [1-3] It is one of the critical sustainable development challenges. Sustainable Development Goal (SDG) 6 aims to ensure the availability and sustainable management of water and sanitation for all by 2030. [4]

Unimproved sources of drinking water and sanitation facilities are responsible for increased risks of various infectious diseases such as; cholera, typhoid, schistosomiasis, infections of the respiratory systems, skin, and eye. [1, 5, 6] The currently available evidences also indicate that to prevent the novel coronavirus disease (COVID-19) outbreak, the provision of safe water, sanitation, and hygienic conditions is essential. [7]

Globally, 2 billion people lack basic sanitation services and 785 million people have no access to clean water. [8] More than 1.9 million deaths and 123 million disability-adjusted life-years (DALYs) could have been prevented by the provision of adequate access to water, hygiene, and sanitation (WASH) worldwide. The WASH-attributable disease burden accounts to 4.6% of global DALYs and 3.3% of global mortality. [9] The burden of under 5 mortality was 13%. [10] In Ethiopia, 60 to 80 % of communicable diseases are attributed to limited access to safe water, inadequate sanitation, and hygiene services. [11]

Regarding factors associated with improved drinking water sources and toilet facilities: Sex of household heads, region, residence, family size, time to get to drinking water source, age of household head, educational level, and marital status of the household heads were factors associated with access to an improved drinking water source and toilet facilities based on previous studies. [2, 12-16]

In Sub-Saharan Africa, particularly in Ethiopia access to improved sources of drinking water and toilet facilities is still lacking and people are practicing open defecation. [17, 18] There was no statistical approach in the study using nationally representative data (2016 EDHS data), which accounts for the hierarchical nature of the data. However, in 2014 national studies conducted in Sub-Saharan African countries indicates that the spatial coverage in use of improved drinking water supply and sanitation. [19] Therefore, the current study aimed to assess access to improved drinking water sources and toilet facilities and their associated factors in Ethiopia using EDHS 2016 data.

METHODS

Patient and public involvement

This study was based on a publicly available data set (EDHS 2016). Thus, there were no patients or members of the public involved.

Study design and area

The 2016 main EDHS was a cross-sectional survey conducted from 18 January 2016 to 27 June 2016 in Ethiopia by the Ethiopian Central Statistical Agency (ECSA). For our case, we use an in-depth secondary data analysis of the survey. The 2016 EDHS survey was the fourth survey conducted in each of the 11 regions of Ethiopia (9 regional states and 2 administrative cities). Administratively, each region in Ethiopia is divided into Zones, each Zone, in turn, is divided into Woredas, and each Woreda into Kebeles (the lowest administrative units in the country). [20]

Data sources

Data were obtained from 2016 Ethiopian Demographic and Health Survey (EDHS-2016) after being registered as an authorized user. The survey collects data on key indicators of health and health-related events including access to drinking water and toilet facilities. A total of 16,650 households from 645 Enumeration Areas (EAs) were included in the survey. [20]

Sample size and sampling procedure

A two-stage stratified cluster sampling technique was employed to select study participants. Sampling frame of the 2007 Population and Housing Censuses in which EAs were the sampling units for the first stage and households for the second stage was used. A total of 18,008 households were selected for the sample, of which 17,067 were occupied. Of the occupied households, 16,650

were successfully interviewed, yielding a response rate of 98%. [20] The current study included individual-level data for 16650 household heads as well as community characteristics of 645 clusters.

Variables of the study

The outcome variables are; access to improved drinking water sources and improved toilet facilities. The explanatory variables; include sex, age, educational level, marital status of the household heads, household wealth index, time to get to drinking water sources, family size, religion, media use, place of residence, and region.

Operational definitions

Improved sources of drinking water: a household is said to have access to an improved drinking water source if it has water piped into its dwelling, water piped to a yard/plot, a public tap/standpipe, a tube well/borehole, a protected dug well, a protected spring, rainwater, bottled water, or sachet water. [21]

Improved types of toilet facilities: a household is said to have access to improved toilet facilities if it has unshared flush/pour flush to piped sewer systems, septic tanks or pit latrines, ventilated improved pit latrines, composting toilets, or pit latrines with slabs. [21]

Data processing and analysis

Statistical analysis was performed using Stata 16.00 software. The weighted frequencies and the percentages (based on the population size of each region) were computed. The detailed weighting procedure is described elsewhere. [20]

Multilevel binary logistic regression model was used to assess the impact of individual and community-level factors on households' access to an improved source of drinking water and

improved toilet facilities. The model, which is most appropriate to consider the cluster random effect in a multivariate setting and the reason to apply multilevel modeling was the nature of the data collected which have a hierarchical or clustered structure. The first level represents the individual and household and the second level factor is the clusters. Four models were tested in each of the cases (access to an improved source of drinking water and toilet facilities). **Model 0** (the null model) was fitted without explanatory variables to test random variability in the intercept and to estimate the intraclass correlation coefficient (ICC). **Model I** was used to investigate the impact of individual-level factors on the likelihood of having access to improved sources of drinking water and toilet facilities. **Model II** was used to assess the impact of community-level factors on the likelihood of having access to improved sources of drinking water and toilet facilities. **Model III** was employed to assess the impact of individual and community-level factors altogether on access to improved sources of drinking water and toilet facilities.

The random effects (variation of effects) were measured by ICC, percentage change in variance (PCV), Median Odds Ratio (MOR), and deviance (-2log likelihood), which measure the variability between clusters in the multilevel models. The ICC explains the cluster variability, while MOR is used to quantify unexplained cluster variability (heterogeneity). The MOR was used to translate cluster variance into OR scale. [22-24] In the multilevel model, deviance can measure the total variation due to factors at the community and individual levels. [23, 25]

Adjusted odds ratio with a 95% confidence interval were reported. P-value < 0.05 was used to declare a significant association among covariates and outcome variables. A multicollinearity test was performed to rule out if there was a significant correlation between explanatory variables. If the values of variance inflation factor (VIF) was lower than 10, then the collinearity problem was considered as less likely. [26]

RESULTS

Socio-demographic characteristics of study participants

A total of 16650 study participants were included in the study. The median (±SD) age of the household heads was 40 years (± 16.22 years, range 15 - 95). Approximately, seven out of ten (69.94%) of the households had access to improved sources of drinking water and only one-fourth (25.36%) of households had access to an improved source of toilet facilities. Majority (98.37%) of respondents had no education. About 68.55% of households were male-headed. [**Table 1**].

Table 1: Socio-demographic characteristics of study participants in Ethiopia, EDHS 2016 (n= 16650)

Variables		Frequency	Percent (%)
Source of drinking water	Improved	11,645	69.94
	Unimproved	5,005	30.06
Toilet facilities	Improved	4,222	25.36
	Unimproved	12,428	74.64
Sex of household head	Male	11,413	68.55
	Female	5,237	31.45
Age of household head (years)	13 to 30	4,257	25.57
	31 to 40	4,132	24.82
	41 to 56	4,230	25.41
	≥ 57	4,031	24.21
Education level of the household head	No education	16,378	98.37
	Primary education	93	0.56
	Secondary education	114	0.68
	Higher education	65	0.39
Current marital status household head	Never married	1,046	6.29
	Married	12,064	72.50

	Widowed	2,108	12.67
	Divorced	1,423	8.55
Wealth index	Poorest	4,676	28.08
	Poorer	2,348	14.10
	Middle	2,057	12.35
	Richer	2,020	12.13
	Richest	5,549	33.33
Time to get drinking water	≤ 30 minutes	9,821	58.98
	> 30 minutes	6,829	41.02
Number of household members	1 – 3 members	6,258	37.59
	4 – 6 members	7,031	42.23
	7 members and above	3,361	20.19
Residence	Urban	5,232	31.42
	Rural	11,418	68.58
Region	Tigray	1,734	10.41
	Afar	1,220	7.33
	Amhara	1,902	11.42
	Oromia	1,988	11.94
	Somali	1,564	9.39
	Benishangul-Gumuz	1,280	7.69
	SNNPR	1,897	11.39
	Gambella	1,280	7.69
	Harari	1,135	6.82
	Dire Dawa	1,161	6.97
	Addis Ababa	1,489	8.94

Regional distribution in terms of improved drinking water and toilet facility sources in Ethiopia

Among Ethiopian regions, nearly all households in Addis Abeba (99.40%) had access to improved sources of drinking water. On the contrary, Somali (56.52%) and Afar regions (51.39%) had the

least access to improved sources of drinking water. Households in Benishangul-Gumuz and Amhara regions were lowest in access to toilet facilities with 4.30% and 6.31%, respectively while households in Dire Dawa and Addis Ababa had the highest access to improved toilet facilities with 65.20% and 79.31%, respectively **[S1 Table 1].**

Factors associated with access to improved drinking water sources

The proportion of households which had access to improved sources of drinking water was 69.94% at [95% CI: (69.23, 70.63)]. Both individual-level factors and community-level factors had an impact on accessing improved drinking water sources in this study. Among individual-level factors; sex of household head and from community-level factors; wealth index, time to get to drinking water sources, residence, and region were significantly associated with access to improved drinking water sources

Female-headed households were 1.18 [AOR = 1.18, CI: (1.01, 1.37)] times more likely to have access to improved drinking water sources than male-headed households.

Compared to poorest households, poorer [AOR = 1.48, CI: (1.26, 1.74)], middle-income [AOR = 2.42, CI: (2.03, 2.90)], richer [AOR = 3.26, CI: (2.68, 3.97)] and richest [AOR = 6.97, CI: (5.17, 9.41)] households were 1.48, 2.42, 3.26, and 6.97 times more likely to access improved drinking water sources, respectively.

In contrasted with family units who got drinking water < 30 minutes, households who got drinking water ≥ 30 minutes were 35% less likely to access drinking water [AOR = 0.65, CI: (0.58, 0.73)].

The adjusted odds of access to improved drinking water sources in rural area was 94.00% less likely compared to urban area [AOR = 0.06, CI: (0.03, 0.11)].

The likelihood of access to improved sources of drinking water were 95.00% [AOR = 0.05, (0.01, 0.21)] in Afar, 94.00% [AOR = 0.06, (0.01, 0.27)] in Amhara, 92.00% [AOR = 0.08, (0.02, 0.35)] in Oromia, 98.00% [AOR = 0.02, (0.01, 0.10)] in Somalia , 93.00% [AOR = 0.07, (0.02, 0.30)] in SNNPR, and 82.00% [AOR = 0.18 (0.04, 0.89)] in Harari as compared to improved water access in Addis Ababa city **[Table 2].**

Table 2: Multivariable multilevel logistic regression model of the effects of individual- and community-level factors on improved drinking water sources in Ethiopia, EDHS 2016

Variables		Null Model	Model I	Model II	Model III
			AOR(95% CI)	AOR(95% CI)	AOR(95% CI)
Sex of household head	Male		1		1
	Female		1.13 (0.97, 1.32)		**1.18 (1.01, 1.37)[a]**
Age of household head	13 to 30		1		1
	31 to 40		0.99 (0.85, 1.14)		1.04 (0.89, 1.22)
	41 to 56		1.07 (0.92, 1.24)		1.13 (0.96, 1.33)
	≥ 57		0.93 (0.80, 1.09)		1.00 (0.85, 1.17)
Education level of the household head	No education		1		1
	Primary		0.93 (0.50, 1.73)		0.98 (0.52, 1.83)
	Secondary		1.69 (0.82, 3.49)		1.74 (0.83, 3.65)
	Higher		1.51 (0.40, 5.70)		1.37 (0.34, 5.55)
Current marital status household head	Never married		1		1
	Married		0.74 (0.54, 1.02)		1.02 (0.72, 1.43)
	Divorced		0.71 (0.49, 1.04)		1.01 (0.68, 1.50)
	Widowed		0.72 (0.49, 1.05)		0.98 (0.66, 1.45)
Wealth index	Poorest			1	1
	Poorer			1.47 (1.25, 1.73)[b]	**1.48 (1.26, 1.74)[b]**
	Middle			2.41 (2.01, 2.88)[b]	**2.42 (2.03, 2.90)[b]**
	Richer			3.23 (2.66, 3.92)[b]	**3.26 (2.68, 3.97)[b]**
	Richest			6.84 (5.07, 9.22)[b]	**6.97 (5.17, 9.41)[b]**
Time to get drinking water	< 30 minutes			1	1
	≥ 30 minutes			0.66 (0.58, 0.74)[b]	**0.65 (0.58, 0.73)[b]**

Number of household members		1 – 3 members			1	1
		4 – 6 members			0.86 (0.77, 0.97)[a]	0.88 (0.77, 1.00)
		7+			0.88 (0.76, 1.01)	0.88 (0.75, 1.04)
Residence		Urban			1	1
		Rural			0.06 (0.03, 0.10) [b]	**0.06 (0.03, 0.11)[b]**
Region		Tigray			0.26 (0.06, 1.18)	0.26 (0.06, 1.17)
		Afar			0.05 (0.01, 0.21)[b]	**0.05 (0.01, 0.21)[b]**
		Amhara			0.06 (0.01, 0.27)[b]	**0.06 (0.01, 0.27)[b]**
		Oromia			0.08 (0.02, 0.35)[b]	**0.08 (0.02, 0.35)[b]**
		Somali			0.02 (0.01, 0.10)[b]	**0.02 (0.01, 0.10)[b]**
		Benishangul Gumuz			0.39 (0.08, 1.80)	0.39 (0.08, 1.81)
		SNNPR			0.07 (0.02, 0.30)[b]	**0.07 (0.02, 0.30)[b]**
		Gambella			0.30 (0.06, 1.35)	0.29 (0.06, 1.33)
		Harari			0.18 (0.04, 0.88)[a]	**0.18 (0.04, 0.89)[a]**
		Dire Dawa			0.33 (0.07, 1.64)	0.33 (0.07, 1.63)
		Addis Ababa			1	1
Random effect	Community level variance(SE)		12.24 (1.13)[b]	12.05 (1.11)[b]	4.75 (0.42)[b]	4.73 (0.41)[b]
	ICC (%)		78.81%	78.55%	59.08%	58.97%
	MOR		9.05	8.96	5.64	5.62
	PCV		Reference	1.55%	61.19	61.36%
Model fit statistics	Log-likelihood		-5997.01	-5987.89	-5619.38	-5611.48
	Deviance		11994.02	11975.78	11238.76	11222.96

Note:

[a, b] significant at [a] $P < 0.05$; [b] $P < 0.001$;

AOR: Adjusted Odds Ratio,

CI: Confidence Interval,

Model 0- Empty (null) model

Model I- Only individual-level explanatory variables included in the model;

Model II- Only community-level explanatory variables included in the model;

Model III- Combined model; both individual-level and community-level explanatory variables

PCV: Proportional Change in Variance,

MOR: Median Odds Ratio

199

Factors associated with access to improved toilet facilities

The proportion of households with access to an improved source of toilet facility was 25.36% at [95% CI: (24.69%, 26.03%)]. Individual-level factors such as educational level of the household heads, marital status, and community level factors such as wealth index, source of drinking water, number of household members, residence, and region were factors significantly associated with households' access to improved toilet facilities.

Compared with households whose household heads had no education, households headed with those who attained higher education were 2.21 times more likely to have access to improved toilet facilities at [AOR = 2.21 CI: (1.12, 4.36)]. The likelihood of access to toilet facilities was 25% [AOR = 0.75, CI: (0.57, 0.98)] lower in households with widowed household heads, as compared to those who never married.

Households with poorer [AOR = 3.97 CI: (2.99, 5.29)], middle [AOR = 5.82 CI: (4.35, 7.80)], richer [AOR = 8.58 CI: (6.40, 11.50)], and richest wealth index [AOR = 23.94 CI: (17.45, 32.83)], were 3.97, 5.82, 8.58, and 23.94 times more likely to access improved toilet facilities as compared to households with the poorest wealth index, respectively.

Households who had improved sources of drinking water were 1.37 [AOR = 1.37 CI: (1.12, 1.66)] times more likely to have access to improved toilet facilities, compared with their counterparts. Compared to household which had one to three members, 24% of those with four to six members were [AOR = 0.86 (0.75, 0.98)] less likely to access improved toilet facilities.

About 72% of rural households were less likely to have access to improved toilet facilities as compared with those from urban residence [AOR = 0.28 CI: (0.20, 0.38)]. About 72.00% in Tigray [AOR = 0.28, CI: (0.17, 0.46)] , 63.00% in Afar [AOR = 0.37, CI: (0.21, 0.67)], 96.00% in Amhara

[AOR = 0.04, (0.02, 0.06)], 90.00% in Oromia [AOR = 0.10, CI: (0.06, 0.17)], 95.00% in Benishangul Gumuz [AOR = 0.05 CI: (0.03, 0.10)], 80.00% in SNNPR [AOR = 0.20 CI: (0.12, 0.33)], 85% in Gambella [AOR = 0.15 CI:(0.09, 0.26)], and 60.00% in Harari [AOR = 0.40 CI: (0.24, 0.66)] households were more likely to have access to improved toilet facilities as compared to households in Addis Ababa city **[Table 3].**

Table 3: Multivariable multilevel logistic regression model of the effects of individual- and community-level factors on improved sources of toilet facilities in Ethiopia, EDHS 2016

Variables		Null Model	Model I	Model II	Model III
			AOR(95% CI)	AOR(95% CI)	AOR(95% CI)
Sex of household head	Male		1		1
	Female		1.01 (0.88, 1.16)		1.03 (0.89, 1.19)
Age of household head	13 to 30		1		1
	31 to 40		0.99 (0.85, 1.15)		1.04 (0.89, 1.21)
	41 to 56		0.98 (0.84, 1.15)		1.02 (0.86, 1.20)
	≥ 57		0.98 (0.83, 1.16)		1.08 (0.91, 1.28)
Education level of the household head	No education		1		1
	Primary		1.34 (0.67, 2.67)		1.19 (0.59, 2.40)
	Secondary		0.74 (0.40, 1.36)		0.75 (0.41, 1.38)
	Higher		2.26 (1.13, 4.54)		**2.21 (1.12, 4.36)[b]**
Current marital status household head	Never married		1		1
	Married		0.87 (0.71, 1.08)		0.99 (0.80, 1.22)
	Divorced		0.69 (0.52, 0.91)[b]		0.82 (0.62, 1.08)
	Widowed		0.66 (0.50, 0.86)[c]		**0.75 (0.57, 0.98)[b]**
Wealth index	Poorest			1	1
	Poorer			3.99 (3.00, 5.31)[c]	**3.97 (2.99, 5.29)[c]**
	Middle			5.87 (4.39, 7.86)[c]	**5.82 (4.35, 7.80)[c]**
	Richer			8.65 (6.46, 11.58)[c]	**8.58 (6.40, 11.50)[c]**
	Richest			24.76 (18.08, 33.91)[c]	**23.94 (17.45, 32.83)[c]**
Source of drinking	Unimproved			1	1

water		Improved			1.36 (1.12, 1.65) [c]	**1.37 (1.12, 1.66) [c]**
Number of household members		1 – 3 members			1	1
		4 – 6 members			0.88 (0.78, 0.99)[a]	**0.86 (0.75, 0.98) [c]**
		7+			1.07 (0.91, 1.26)	1.02 (0.86, 1.22)
Residence		Urban			1	1
		Rural			0.28 (0.21, 0.39) [c]	**0.28 (0.20, 0.38)[c]**
Region		Tigray			0.27 (0.16, 0.45) [c]	**0.28 (0.17, 0.46) [c]**
		Afar			0.38 (0.21, 0.68) [c]	**0.37 (0.21, 0.67) [c]**
		Amhara			0.04 (0.02, 0.06) [c]	**0.04 (0.02, 0.06) [c]**
		Oromia			0.10 (0.06, 0.17) [c]	**0.10 (0.06, 0.17) [c]**
		Somali			1.33 (0.79, 2.22)	1.32 (0.79, 2.21)
		Benishangul G.			0.05 (0.03, 0.10) [c]	**0.05 (0.03, 0.10) [c]**
		SNNPR			0.20 (0.12, 0.34) [c]	**0.20 (0.12, 0.33) [c]**
		Gambella			0.15 (0.09, 0.26) [c]	**0.15 (0.09, 0.26) [c]**
		Harari			0.40 (0.24, 0.66) [c]	**0.40 (0.24, 0.66) [c]**
		Dire Dawa			1.13 (0.69, 1.87)	1.14 (0.69, 1.89)
		Addis Ababa			1	1
Random effect	Community level variance(SE)		8.66 (0.73)[c]	8.71 (0.74)[c]	1.21 (0.12)[c]	1.22 (0.12)[c]
	ICC (%)		72.46%	72.58%	26.95%	27.08%
	MOR		16.37	16.50	2.84	2.86
	PCV		reference	-1.07%	86.03	85.91%
Model fit statistics	Log-likelihood		-5621.74	-5603.26	-5029.24	-5018.39
	Deviance		11243.48	11206.52	11036.78	10058.48

Note:

[a, b, c] significant at [a] P < 0.05; [b] p < 0.01, [c] P < 0.001;

AOR: Adjusted Odds Ratio,

CI: Confidence Interval,

Model 0- Empty (null) model

Model I- Only individual-level explanatory variables included in the model;

Model II- Only community-level explanatory variables included in the model;

Model III- Combined model; both individual-level and community-level explanatory variables

PCV: Proportional Change in Variance,

MOR: Median Odds Ratio

229

Random-effects analysis

The prevalence rate of access to improved drinking water sources varied across communities (community-level variance = 12.24, p = <0.001) **[Table 2]**. The null model revealed that 78.81% of the total variance in the odds of access to improved drinking water sources was accounted by between-cluster variation of characteristics (ICC = 0.7881). The inter-cluster variability declined over successive models, from 78.81% in the null model to 78.55% in the only individual-level, 59.08% in the only community-level, and 58.97% in the final (combined) models. The proportional change in variance indicated that the addition of predictors to the empty model explained an increased proportion of variation in access to improved drinking water sources. The combined model showed that a higher PCV, i.e., 61.36% of the variance in access to improved drinking water sources could be explained by the combined factors at the individual- and community-levels.

In [**Table 3]** the final model (**Model III**), ICC value of 0.2708 indicates that 27.08% of the total variation in access to improved toilet facilities is accounted for the community-level factors. The remaining 72.92% variation is therefore triggered by the individual- level and other unknown factors. The proportional change in variance indicated that the addition of predictors to the empty model explained an increased proportion of variation in access to improved toilet facilities. The combined model showed a higher PCV, i.e., 85.91% of the variance in access to improved toilet facilities could be explained by the combined factors at the individual- and community-levels.

Model fit statistics

As shown in [**Tables 2 & 3**] (model fit statistics), the values of log-likelihood and Deviance showed a subsequent reduction which indicates that each model represents a significant

improvement over the previous model and it points to the goodness of fit for the final model built in the analysis.

DISCUSSION

In this study, we aimed to assess access to improved drinking water sources and sanitation facilities and their associated factors in Ethiopia. Accordingly, the proportion of households' access to improved drinking water sources was 69.94%, [95% CI: (69.23, 70.63)]. This finding is lower than reports from studies conducted in Ghana,[2] Viet Nam,[16], and Eswatini. [14] Whereas, it is higher than a reported proportion from a study conducted in Nepal. [15] The proportion of households' access to toilet facilities was 25.36%, [95% CI: (24.69, 26.03)]. This result is higher than the one reported from Ghana,[2] However, lower than studies from Nigeria,[27] and Viet Nam. [16] The variation could be the disparities in GDP status and literacy rate among countries, study period, and setting.

Individual-level factors were associated with access to improved drinking water sources and toilet facilities in the present study. Female-headed households were 1.18 times more likely than male-headed households to access improved drinking water sources. Similar findings were reported from Ghana, Vietnam, and Nigeria. [2, 16, 28] Gender differences may play an important role in the work division in developing countries. Most of the time women have higher household responsibilities such as fetching water, cleaning compounds, childcare, and food preparation, etc. Therefore, this might be directly linked with water and sanitation in the sense that women may be preoccupied with other daily routines than WASH.

Those households with heads having better educational status were 2.21 times more likely to access improved toilet facilities. This study finding is supported by evidence from previous studies. [14, 27, 29] Households who are led by heads who have no education had a lower probability of access to improved toilet facilities. In sub-Saharan Africa, education is a resource factor of quality health outcomes, and educated people usually are more aware of the condition that guarantees their well beings. This implies that educated household heads in this study may have utilized their resources to provide their households with improved toilet facilities.

In addition to individual level factors, community-level factors were also associated with access to improved drinking water sources and toilet facilities. When compared to households within the poorest category, households within poorer, middle, richer, and richest wealth index category were 1.48, 2.42, 3.26, and 6.97 times more likely to have access to improved sources of drinking water and 3.97, 5.82, 8.58, and 23.94 times higher odds to access improved toilet facilities, respectively. This result is consistent with results from previous studies. [13, 14, 30] People who have better incomes would intend to fulfill the necessities of life. Economically, the rich can afford the initial high cost of both water and sanitation facilities and the poor may be disproportionately underserved in the distribution of public utility, and hence consume poor quality water and use unimproved sanitation facilities.

Compared with households that got drinking water < 30 minutes, households which obtained drinking water ≥ 30 minutes were 35% less likely to access improved drinking water sources. Hence, the length of time to get drinking (proximity of a house to a drinking water source) water might make difference in access to improved sources of drinking water and coverage (%) with improved water supply (HH connection, public standpipes, protected underground water sources,

rainwater collection). This is not surprising as the physical distance is one of the reasons of WASH service inaccessibility.

The adjusted odds of access to improved drinking water sources and toilet facilities were 94.00% and 72.00% less likely among rural households as compared to urban households, respectively. The rural-urban disparity in access to improved sources of drinking water and toilet facilities have been reported by several other previous studies, too. [12, 31, 32]. The disparity might be, in sub-Saharan Africa, most of the people live in rural areas and their economic status is poor. Therefore, they do not have adequate financial resources to acquire improved drinking water sources and toilet facilities.

Furthermore, households who had improved sources of drinking water were 1.37 times more likely to access an improved toilet facilities. This study finding is consistent with an earlier study. [27] The possible explanation could be a lack of access to adequate sanitation is also linked to the limited access to water supply and households who had improved water sources may be practicing more in hygiene and sanitation.

Lastly, those households with four to six were 24% less likely access to improved toilet facilities compared to households with a family size of one to three. This is contrary to that of an earlier study. [2] The possible explanation could be the highest number of household members, the fewer resources they could have to build improved toilet facilities.

CONCLUSION

The proportion of households' access to an improved source of drinking water and sanitation facility was low in the country. Sex of household head, wealth index, time to get drinking water, residence, and region were associated with access to improved drinking water sources. Educational level of the household head, wealth index, being widowed, source of drinking water, number of household members, residence, and region were factors associated with access to improved toilet facilities. Thus, governmental and non-governmental organizations working on water, hygiene, and sanitation should consider a multi-faceted policy approach that accounts for the regions and residence variations and other identified factors to ease up the problem.

Acknowledgments

We would like to thank the Demographic and Health Survey (DHS) programme for allowing the use of Ethiopian Demographic and Health Survey (EDHS) data for this study.

Competing interests: None declared.

Patient consent for publication: Not required.

Ethics approval: The EDHS 2016 was approved by the National Research Ethics Review Committee of Ethiopia and ICF Macro International. The approval letter was obtained from the measure DHS for the use of this data, and the dataset was downloaded from www.meauredhs.com. This analysis was approved by the Department of Environmental and occupational health and safety, University of Gondar.

Funding

The author(s) received no specific funding for this work.

Availability of data and materials

The dataset analyzed during the current study available from the corresponding author upon reasonable request.

Authors' contributions

ZA wrote the analyzed data, drafted the paper, and prepared the manuscript. HD, ZNA, AAT, BD, RF, AGM, and YY drafted the paper, writing – review & editing, and commented on the manuscript. All the authors read and approved the final manuscript.

REFERENCES

1. Prüss-Ustün A, Wolf J, Bartram J, Clasen T, Cumming O, Freeman MC, et al. Burden of disease from inadequate water, sanitation and hygiene for selected adverse health outcomes: An updated analysis with a focus on low-and middle-income countries. International journal of hygiene and environmental health. 2019;222(5):765-77.
2. Agbadi P, Darkwah E, Kenney PL. A Multilevel Analysis of Regressors of Access to Improved Drinking Water and Sanitation Facilities in Ghana. Journal of environmental and public health. 2019;2019.
3. Assembly UG. Resolution on Human Right to Water and Sanitation. New York: United Nations. 2010.
4. Brookes JD, Carey CC. Ensure availability and sustainable management of water and sanitation for all. UN Chronicle. 2015;51(4):15-6.
5. Mills JE, Cumming O. The impact of water, sanitation and hygiene on key health and social outcomes. URL: https://www lshtm ac uk/sites/default/files/2017-07/WASHEvidencePaper_HighRes_01. 2016;23.
6. Saxena SK, Kumar S, Haikerwal A, Bhatt ML. Introductory chapter: Neglected tropical waterborne infectious diseases-strategies for mitigation. Water Challenges of an Urbanizing World. 2018:1.
7. Organization WH. Water, sanitation, hygiene, and waste management for the COVID-19 virus: interim guidance, 23 April 2020. World Health Organization, 2020.
8. Organization WH. Progress on drinking water, sanitation and hygiene: 2017 update and SDG baselines. 2017.
9. Organization WH. Water, sanitation, hygiene and health: a primer for health professionals. World Health Organization, 2019.
10. Organization WH. Safer water, better health. 2019.
11. UNICEF. Water, sanitation and hygiene (WASH) 2020 [cited 2020 April, 14]. Available from: https://www.unicef.org/ethiopia/water-sanitation-and-hygiene-wash.
12. Mulenga JN, Bwalya BB, Kaliba-Chishimba K. Determinants and inequalities in access to improved water sources and sanitation among the Zambian households. International Journal of Development and Sustainability. 2017;6(8):746-62.

13. Morakinyo OM, Adebowale SA, Oloruntoba EO. Wealth status and sex differential of household head: implication for source of drinking water in Nigeria. Archives of Public Health. 2015;73(1):58.

14. Simelane MS, Shongwe MC, Vermaak K, Zwane E. Determinants of Households' Access to Improved Drinking Water Sources: A Secondary Analysis of Eswatini 2010 and 2014 Multiple Indicator Cluster Surveys. Advances in Public Health. 2020;2020.

15. Wang C, Pan J, Yaya S, Yadav RB, Yao D. Geographic Inequalities in Accessing Improved Water and Sanitation Facilities in Nepal. International journal of environmental research and public health. 2019;16(7):1269.

16. Tuyet-Hanh TT, Long TK, Van Minh H, Huong LTT. Longitudinal household trends in access to improved water sources and sanitation in Chi Linh town, Hai Duong province, Viet Nam and associated factors. AIMS public health. 2016;3(4):880.

17. Organization WH, UNICEF. Progress on drinking water and sanitation: special focus on sanitation. Progress on drinking water and sanitation: special focus on sanitation2008.

18. Beyene A, Hailu T, Faris K, Kloos H. Current state and trends of access to sanitation in Ethiopia and the need to revise indicators to monitor progress in the Post-2015 era. BMC public health. 2015;15:451-.

19. Pullan RL, Freeman MC, Gething PW, Brooker SJ. Geographical inequalities in use of improved drinking water supply and sanitation across sub-Saharan Africa: mapping and spatial analysis of cross-sectional survey data. PLoS Med. 2014;11(4):e1001626.

20. Central Statistical Agency (CSA). Central Statistical Agency (CSA) [Ethiopia] and ICF Ethiopia demographic and health Survey 2016. Addis Ababa, Ethiopia, and Rockville, Maryland, USA: CSA and ICF,2017.

21. Supply WUJW, Programme SM, Organization WH, Supply WUJMPfW, Sanitation, UNICEF. Water for life: making it happen: World health organization; 2005.

22. Merlo J, Chaix B, Ohlsson H, Beckman A, Johnell K, Hjerpe P, et al. A brief conceptual tutorial of multilevel analysis in social epidemiology: using measures of clustering in multilevel logistic regression to investigate contextual phenomena. Journal of Epidemiology & Community Health. 2006;60(4):290-7.

23. Merlo J, Yang M, Chaix B, Lynch J, Råstam L. A brief conceptual tutorial on multilevel analysis in social epidemiology: investigating contextual phenomena in different groups of people. Journal of Epidemiology & Community Health. 2005;59(9):729-36.
24. Larsen K, Merlo J. Appropriate assessment of neighborhood effects on individual health: integrating random and fixed effects in multilevel logistic regression. American journal of epidemiology. 2005;161(1):81-8.
25. Spiegelhalter DJ, Best NG, Carlin BP, Van Der Linde A. Bayesian measures of model complexity and fit. Journal of the royal statistical society: Series b (statistical methodology). 2002;64(4):583-639.
26. Hair Jr JF. Multivariate Data Analysis Joseph F. Hair Jr. William C. Black Barry J. Babin Rolph E. Anderson Seventh Edition.
27. Abubakar IR. Access to sanitation facilities among Nigerian households: determinants and sustainability implications. Sustainability. 2017;9(4):547.
28. Morakinyo OM, Adebowale SA, Oloruntoba EO. Wealth status and sex differential of household head: implication for source of drinking water in Nigeria. Archives of public health = Archives belges de sante publique. 2015;73:58.
29. Akpakli DE, Manyeh AK, Akpakli JK, Kukula V, Gyapong M. Determinants of access to improved sanitation facilities in rural districts of southern Ghana: evidence from Dodowa Health and Demographic Surveillance Site. BMC Res Notes. 2018;11(1):473-.
30. Njuguna J. Progress in sanitation among poor households in Kenya: evidence from demographic and health surveys. BMC public health. 2019;19(1):135.
31. Irianti S, Prasetyoputra P, Sasimartoyo TP. Determinants of household drinking-water source in Indonesia: An analysis of the 2007 Indonesian family life survey. Cogent Medicine. 2016;3(1).
32. Prasetyoputra P, Irianti S. Access to improved sanitation facilities in indonesia: An econometric analysis of geographical and socioeconomic disparities. Journal of Applied Sciences in Environmental Sanitation. 2013;8(3).

Supplementary Table 1: Regional distribution of access to improved drinking water sources and toilet facilities in Ethiopia, EDHS, 2016.

Region	Source of drinking water		Toilet facilities	
	Unimproved	Improved	Unimproved	Improved
Tigray	410 (23.64%)	1,324 (76.36%)	1,380 (79.58%)	354 (20.42%)
Afar	627 (51.39%)	593 (48.61%)	1,032 (84.59%)	188 (15.41%)
Amhara	741 (38.96%)	1,161 (61.04%)	1,782 (93.69%)	120 (6.31%)
Oromia	746 (37.53%)	1,242 (62.47%)	1,785 (89.79%)	203 (10.21%)
Somali	884 (56.52%)	680 (43.48%)	1,145 (73.21%)	419 (26.79%)
Benishangul Gumuz	271 (21.17%)	1,009 (78.83%)	1,225 (95.70%)	55 (4.30%)
SNNPR	775 (40.85%)	1,122 (59.15%)	1,650 (86.98%)	247 (13.02%)
Gambella	246 (19.22%)	1,034 (80.78%)	1,098 (85.78%)	182 (14.22%)
Harari	179 (15.77%)	956 (84.23%)	619 (54.54%)	516 (45.46%)
Dire Dawa	117 (10.08%)	1,044 (89.92%)	404 (34.80%)	757 (65.20%)
Addis Ababa	9 (0.60%)	1,480 (99.40%)	308 (20.69%)	1,181 (79.31%)
Total	5005(30.06%)	11,645 (69.94%)	12,428 (74.64%)	4,222 (25.36%)

STROBE (Strengthening The Reporting of OBservational Studies in Epidemiology) Checklist

A checklist of items that should be included in reports of observational studies. You must report the page number in your manuscript where you consider each of the items listed in this checklist. If you have not included this information, either revise your manuscript accordingly before submitting or note N/A.

Note: An Explanation and Elaboration article discusses each checklist item and gives methodological background and published examples of transparent reporting. The STROBE checklist is best used in conjunction with this article (freely available on the Web sites of PLoS Medicine at http://www.plosmedicine.org/, Annals of Internal Medicine at http://www.annals.org/, and Epidemiology at http://www.epidem.com/). Information on the STROBE Initiative is available at www.strobe-statement.org.

Section and Item	Item No.	Recommendation	Reported on Page No.
Title and Abstract	1	(*a*) Indicate the study's design with a commonly used term in the title or the abstract	
		(*b*) Provide in the abstract an informative and balanced summary of what was done and what was found	
Introduction			
Background/Rationale	2	Explain the scientific background and rationale for the investigation being reported	
Objectives	3	State specific objectives, including any prespecified hypotheses	
Methods			
Study Design	4	Present key elements of study design early in the paper	
Setting	5	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection	
Participants	6	(*a*) *Cohort study*—Give the eligibility criteria, and the sources and methods of selection of participants. Describe methods of follow-up *Case-control study*—Give the eligibility criteria, and the sources and methods of case ascertainment and control selection. Give the rationale for the choice of cases and controls *Cross-sectional study*—Give the eligibility criteria, and the sources and methods of selection of participants	
		(*b*) *Cohort study*—For matched studies, give matching criteria and number of exposed and unexposed *Case-control study*—For matched studies, give matching criteria and the number of controls per case	
Variables	7	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable	

Section and Item	Item No.	Recommendation	Reported on Page No.
Data Sources/ Measurement	8*	For each variable of interest, give sources of data and details of methods of assessment (measurement). Describe comparability of assessment methods if there is more than one group	
Bias	9	Describe any efforts to address potential sources of bias	
Study Size	10	Explain how the study size was arrived at	
Quantitative Variables	11	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why	
Statistical Methods	12	(*a*) Describe all statistical methods, including those used to control for confounding	
		(*b*) Describe any methods used to examine subgroups and interactions	
		(*c*) Explain how missing data were addressed	
		(*d*) *Cohort study*—If applicable, explain how loss to follow-up was addressed *Case-control study*—If applicable, explain how matching of cases and controls was addressed *Cross-sectional study*—If applicable, describe analytical methods taking account of sampling strategy	
		(*e*) Describe any sensitivity analyses	
Results			
Participants	13*	(a) Report numbers of individuals at each stage of study—eg numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analysed	
		(b) Give reasons for non-participation at each stage	
		(c) Consider use of a flow diagram	
Descriptive Data	14*	(a) Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders	
		(b) Indicate number of participants with missing data for each variable of interest	
		(c) *Cohort study*—Summarise follow-up time (eg, average and total amount)	
Outcome Data	15*	*Cohort study*—Report numbers of outcome events or summary measures over time	
		Case-control study—Report numbers in each exposure category, or summary measures of exposure	
		Cross-sectional study—Report numbers of outcome events or summary measures	

Section and Item	Item No.	Recommendation	Reported on Page No.
Main Results	16	(*a*) Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (eg, 95% confidence interval). Make clear which confounders were adjusted for and why they were included	
		(*b*) Report category boundaries when continuous variables were categorized	
		(*c*) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period	
Other Analyses	17	Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses	
Discussion			
Key Results	18	Summarise key results with reference to study objectives	
Limitations	19	Discuss limitations of the study, taking into account sources of potential bias or imprecision. Discuss both direction and magnitude of any potential bias	
Interpretation	20	Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence	
Generalisability	21	Discuss the generalisability (external validity) of the study results	
Other Information			
Funding	22	Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based	

*Give information separately for cases and controls in case-control studies and, if applicable, for exposed and unexposed groups in cohort and cross-sectional studies.

Once you have completed this checklist, please save a copy and upload it as part of your submission. DO NOT include this checklist as part of the main manuscript document. It must be uploaded as a separate file.

BMJ Open

Households' access to improved drinking water sources and toilet facilities in Ethiopia: A multilevel analysis based on 2016 Ethiopian Demographic and Health Survey

Journal:	*BMJ Open*
Manuscript ID	bmjopen-2020-042071.R2
Article Type:	Original research
Date Submitted by the Author:	16-Feb-2021
Complete List of Authors:	Andualem , Zewudu ; University of Gondar College of Medicine and Health Sciences, Department of Environmental and Occupational health and Safety Dagne, Henok; University of Gondar College of Medicine and Health Sciences, Environmental and Occupational Health and Safety; University of Gondar, Environmental and Occupational Health and Safety Azene, Zelalem; University of Gondar College of Medicine and Health Sciences, Department of Women's and family health, School of Midwifery, College of Medicine and Health Sciences, University of Gondar, P. O. Box 196 Gondar, Ethiopia.; University of Gondar, Ethiopia taddese, Asefa; University of Gondar College of Medicine and Health Sciences, Epidemiology and Biostatistics Dagnew, Baye ; University of Gondar College of Medicine and Health Sciences, Human Physiology; Mr. Fisseha, Roman ; Department of Medical Microbiology, School of Biomedical and Laboratory Sciences, College of Medicine and Health Sciences, University of Gondar, P. O. Box 196 Gondar, Ethiopia. Muluneh, Atalay; University of Gondar College of Medicine and Health Sciences, Epidemiology and Bio statistics ; Yeshaw, Yigizie; University of Gondar College of Medicine and Health Sciences, Medical Physiology
Primary Subject Heading:	Public health
Secondary Subject Heading:	Occupational and environmental medicine
Keywords:	PUBLIC HEALTH, PREVENTIVE MEDICINE, Health policy < HEALTH SERVICES ADMINISTRATION & MANAGEMENT

I, the Submitting Author has the right to grant and does grant on behalf of all authors of the Work (as defined in the below author licence), an exclusive licence and/or a non-exclusive licence for contributions from authors who are: i) UK Crown employees; ii) where BMJ has agreed a CC-BY licence shall apply, and/or iii) in accordance with the terms applicable for US Federal Government officers or employees acting as part of their official duties; on a worldwide, perpetual, irrevocable, royalty-free basis to BMJ Publishing Group Ltd ("BMJ") its licensees and where the relevant Journal is co-owned by BMJ to the co-owners of the Journal, to publish the Work in this journal and any other BMJ products and to exploit all rights, as set out in our licence.

The Submitting Author accepts and understands that any supply made under these terms is made by BMJ to the Submitting Author unless you are acting as an employee on behalf of your employer or a postgraduate student of an affiliated institution which is paying any applicable article publishing charge ("APC") for Open Access articles. Where the Submitting Author wishes to make the Work available on an Open Access basis (and intends to pay the relevant APC), the terms of reuse of such Open Access shall be governed by a Creative Commons licence – details of these licences and which Creative Commons licence will apply to this Work are set out in our licence referred to above.

Other than as permitted in any relevant BMJ Author's Self Archiving Policies, I confirm this Work has not been accepted for publication elsewhere, is not being considered for publication elsewhere and does not duplicate material already published. I confirm all authors consent to publication of this Work and authorise the granting of this licence.

Households' access to improved drinking water sources and toilet facilities in Ethiopia: A multilevel analysis based on 2016 Ethiopian Demographic and Health Survey

Zewudu Andualem[1*], Henok Dagne[1], Zelalem Nigussie Azene[2], Asefa Adimasu Taddese[3], Baye Dagnew[4], Roman Fisseha[5], Atalay Goshu Muluneh[3], and Yigizie Yeshaw[4]

[1]Department of Environmental and Occupational Health and Safety, Institute of Public Health, College of Medicine and Health Sciences, University of Gondar, P. O. Box 196 Gondar, Ethiopia

[2]Department of Women's and family health, School of Midwifery, College of Medicine and Health Sciences, University of Gondar, P. O. Box 196 Gondar, Ethiopia.

[3]Department of Epidemiology and Biostatistics, Institute of Public Health, College of Medicine and Health Sciences, University of Gondar, P. O. Box 196 Gondar, Ethiopia

[4]Department of Human Physiology, School of Medicine, College of Medicine and Health Sciences, University of Gondar, P. O. Box 196 Gondar, Ethiopia

[5]Department of Medical Microbiology, School of Biomedical and Laboratory Sciences, College of Medicine and Health Sciences, University of Gondar, P. O. Box 196 Gondar, Ethiopia.

*Corresponding author

Authors' email address

[ZA] Zewudu Andualem: zewuduandualem12@gmail.com, [HD] Henok Dagne: enoch2313@gmail.com, [ZNA] Zelalem Nigussie Azene: znigussie35@gmail.com, [AAT] Asefa Adimasu Taddese: adimasuasefa@gmail.com, [BD] Baye Dagnew: bayedagnew7@gmail.com, [RF] Roman Fisseha: romanfisseha85@gmail.com, [AGM] Atalay Goshu Muluneh: atalayg1921@gmail.com, and [YY] Yigizie Yeshaw: yigizieyeshaw29@gmail.com

ABSTRACT

Objective: This study aimed to assess households' access to improved drinking water sources and sanitation facilities and their associated factors in Ethiopia

Design: Cross-sectional study

Setting: Ethiopia

Participants: Household heads

Primary outcomes: Access to improved drinking water sources and sanitation facilities

Methods: We conducted an in-depth secondary data analysis of the 2016 Ethiopian Demographic and Health Survey (EDHS). Data from a total of 16650 households and 645 clusters were included in the analysis. The households in the EDHS were selected using a stratified two-stage cluster sampling technique. Multilevel binary logistic regression analyses were performed to identify factors associated with access to an improved drinking water source and toilet facilities. Adjusted odds ratio with a 95% CI were reported. P-value < 0.05 was used to declare a significant association between the covariates and outcomes.

Results: The proportions of households' access to improved sources of drinking water and toilet facilities were 69.94%, [95% CI: (69.23, 70.63)], and 25.36%, [95% CI: (24.69, 26.03)], respectively. Female-headed households and better wealth index positively associated access improved drinking water sources, ≥ 30 minutes round trip to obtain drinking water, rural residence, and region were negatively associated with access to an improved drinking water source. Whereas higher educational status, access to an improved source of drinking water, and households with better wealth index, were positively associated with access to improved toilet facility, being

widowed, household size [4 to 6], being in rural residence, and region were negatively significantly associated with access to improved toilet facilities

Conclusion: The proportions of households' access to improved drinking water sources and toilet facilities in Ethiopia was relatively low.

Keywords: Improved toilet facilities, improved water sources, multilevel analysis, Ethiopia

Strength and limitations of the study

- The use of nationally representative data that can enhance the generalizability of the finding is one of the strength of the study.
- Due to the inherent nature of a cross-sectional study, it does not show the temporal relationship between the outcome status and predictors.
- Moreover, important variables such as culture, traditions, and social norms were not available in EDHS data which could influence the use of toilet facility type.

INTRODUCTION

Access to safe water and basic sanitation is one of the fundamental human rights, and an essential step towards improving living standards to maintain and improve health, human growth, and development. [1-3] It is one of the critical sustainable development challenges. Sustainable Development Goal (SDG) 6 aims to ensure the availability and sustainable management of water and sanitation for all by 2030. [4]

Unimproved sources of drinking water and sanitation facilities are responsible for increased risks of various infectious diseases such as; cholera, typhoid, schistosomiasis, infections of the respiratory systems, skin, and eye. [1, 5, 6] The currently available evidences also indicates that to prevent the novel coronavirus disease (COVID-19) outbreak, the provision of safe water, sanitation, and hygienic conditions is essential. [7]

Globally, 2 billion people lack basic sanitation services and 785 million people have no access to clean water. [8] More than 1.9 million deaths and 123 million disability-adjusted life-years (DALYs) could have been prevented by the provision of adequate access to water, hygiene, and sanitation (WASH) worldwide. The WASH-attributable disease burden accounts for 4.6% of global DALYs and 3.3% of global mortality. [9] The burden of under 5 mortality was 13%. [10] In Ethiopia, 60 to 80 % of communicable diseases are attributed to limited access to safe water, inadequate sanitation, and hygiene services. [11]

Regarding factors associated with improved drinking water sources and toilet facilities: Sex of household heads, region, residence, family size, and time to get to drinking water source, age of household head, educational level, and marital status of the household heads were factors associated with access to an improved drinking water source and toilet facilities based on previous studies. [2, 12-16]

In Sub-Saharan Africa, particularly in Ethiopia access to improved sources of drinking water and toilet facilities is still lacking and people are practicing open defecation. [17, 18] There was no statistical approach in the study using nationally representative data (2016 Ethiopian Demographic and Health Survey (EDHS) data), which accounts for the hierarchical nature of the data. However, in 2014 national studies conducted in Sub-Saharan African countries indicates that the spatial coverage in use of improved drinking water supply and sanitation. [19] Therefore, the current study aimed to assess access to improved drinking water sources and toilet facilities and their associated factors in Ethiopia using EDHS 2016 data.

METHODS

Patient and public involvement

This study was based on a publicly available data set (EDHS 2016). Thus, there were no patients or members of the public involved.

Study design and area

The 2016 main EDHS was a cross-sectional survey conducted from 18 January 2016 to 27 June 2016 in Ethiopia by the Ethiopian Central Statistical Agency (ECSA). For our case, we use an in-depth secondary data analysis of the survey. The 2016 EDHS survey was the fourth survey conducted in each of the 11 regions of Ethiopia (9 regional states and 2 administrative cities). Administratively, each region in Ethiopia is divided into Zones, each Zone, in turn, is divided into Woredas, and each Woreda into Kebeles (the lowest administrative units in the country). [20]

Data sources

Data were obtained from 2016 Ethiopian Demographic and Health Survey (EDHS-2016) after being registered as an authorized user. The survey collects data on key indicators of health and health-related events including access to drinking water and toilet facilities. A total of 16,650 households from 645 Enumeration Areas (EAs) were included in the survey. [20]

Sample size and sampling procedure

A two-stage stratified cluster sampling technique was employed to select study participants. Sampling frame of the 2007 Population and Housing Censuses in which EAs were the sampling units for the first stage and households for the second stage was used. A total of 18,008 households were selected for the sample, of which 17,067 were occupied. Of the occupied households, 16,650

were successfully interviewed, yielding a response rate of 98%. [20] The current study included individual-level data for 16650 household heads as well as community characteristics of 645 clusters.

Variables of the study

Outcome variables

Access to improved drinking water sources and improved toilet facilities.

Explanatory variables

The explanatory variables for this study were classified as individual, and community level factors for both access to improved drinking water sources and improved toilet facilities. The individual level factors for access to improved drinking water sources and improved toilet facilities were the sex of household head, age of household head, educational level of household head, and marital status of the household heads.

The community-level factors for access to improved drinking water sources were household wealth index, time to get to drinking water sources, family size, place of residence, and region. The community level factors for access to improved toilet facilities were household wealth index, family size, sources of drinking water, place of residence, and region. The variables were selected based on the literature review for factors affecting access to improved drinking water sources and improved toilet facilities. The basis of classification of explanatory variables into individual level, household level, and community level variables were based on previous studies [2, 21, 22] and our professional judgments.

Operational definitions

Improved sources of drinking water: a household is said to have access to an improved drinking water source if it has water piped into its dwelling, water piped to a yard/plot, a public tap/standpipe, a tube well/borehole, a protected dug well, a protected spring, rainwater, bottled water, or sachet water. [23]

Improved types of toilet facilities: a household is said to have access to improved toilet facilities if it has unshared flush/pour flush to piped sewer systems, septic tanks or pit latrines, ventilated improved pit latrines, composting toilets, or pit latrines with slabs. [23]

Data processing and analysis

Statistical analysis was performed using Stata 16.00 software. The weighted frequencies and the percentages (based on the population size of each region) were computed. The detailed weighting procedure is described elsewhere. [20]

Multilevel binary logistic regression model was used to assess the impact of individual and community-level factors on households' access to an improved source of drinking water and improved toilet facilities. The model, which is most appropriate to consider the cluster random effect in a multivariate setting and the reason to apply multilevel modeling was the nature of the data collected which have a hierarchical or clustered structure. The first level represents the individual and household and the second level factor is the clusters. Four models were tested in each of the cases (access to an improved source of drinking water and toilet facilities). **Model 0** (the null model) was fitted without explanatory variables to test random variability in the intercept and to estimate the intraclass correlation coefficient (ICC). **Model I** was used to investigate the impact of individual-level factors on the likelihood of having access to improved sources of

drinking water and toilet facilities. **Model II** was used to assess the impact of community-level factors on the likelihood of having access to improved sources of drinking water and toilet facilities. **Model III** was employed to assess the impact of individual and community-level factors altogether on access to improved sources of drinking water and toilet facilities.

The random effects (variation of effects) were measured by ICC, percentage change in variance (PCV), Median Odds Ratio (MOR), and deviance (-2log likelihood), which measure the variability between clusters in the multilevel models. The ICC explains the cluster variability, while MOR is used to quantify unexplained cluster variability (heterogeneity). The MOR was used to translate cluster variance into OR scale. [24-26] In the multilevel model, deviance can measure the total variation due to factors at the community and individual levels. [25, 27]

Adjusted odds ratio with a 95% confidence interval were reported. P-value < 0.05 was used to declare a significant association among covariates and outcome variables. A multicollinearity test was performed to rule out if there was a significant correlation between explanatory variables. If the values of variance inflation factor (VIF) was lower than 10, then the collinearity problem was considered as less likely. [28]

RESULTS

Socio-demographic characteristics of study participants

A total of 16650 study participants were included in the study. The median (±SD) age of the household heads was 40 years (± 16.22 years, range 15 - 95). Approximately, seven out of ten (69.94%) of the households had access to improved sources of drinking water and only one-fourth (25.36%) of households had access to an improved source of toilet facilities. Majority (98.37%) of respondents had no education. About 68.55% of households were male-headed. [**Table 1**].

Table 1: Socio-demographic characteristics of study participants in Ethiopia, EDHS 2016 (n= 16650)

Variables		Frequency	Percent (%)
Source of drinking water	Improved	11,645	69.94
	Unimproved	5,005	30.06
Toilet facilities	Improved	4,222	25.36
	Unimproved	12,428	74.64
Sex of household head	Male	11,413	68.55
	Female	5,237	31.45
Age of household head (years)	13 to 30	4,257	25.57
	31 to 40	4,132	24.82
	41 to 56	4,230	25.41
	≥ 57	4,031	24.21
Education level of the household head	No education	16,378	98.37
	Primary education	93	0.56
	Secondary education	114	0.68
	Higher education	65	0.39
Current marital status household head	Never married	1,046	6.29
	Married	12,064	72.50
	Widowed	2,108	12.67
	Divorced	1,423	8.55
Wealth index	Poorest	4,676	28.08
	Poorer	2,348	14.10
	Middle	2,057	12.35
	Richer	2,020	12.13
	Richest	5,549	33.33
Time to get drinking water	≤ 30 minutes	9,821	58.98
	> 30 minutes	6,829	41.02
Number of household members	1 – 3 members	6,258	37.59
	4 – 6 members	7,031	42.23

	7 members and above	3,361	20.19
Residence	Urban	5,232	31.42
	Rural	11,418	68.58
Region	Tigray	1,734	10.41
	Afar	1,220	7.33
	Amhara	1,902	11.42
	Oromia	1,988	11.94
	Somali	1,564	9.39
	Benishangul-Gumuz	1,280	7.69
	SNNPR	1,897	11.39
	Gambella	1,280	7.69
	Harari	1,135	6.82
	Dire Dawa	1,161	6.97
	Addis Ababa	1,489	8.94

Regional distribution in terms of improved drinking water and toilet facility sources in Ethiopia

Among Ethiopian regions, nearly all households in Addis Abeba (99.40%) had access to improved sources of drinking water. On the contrary, Somali (56.52%) and Afar regions (51.39%) had the least access to improved sources of drinking water. Households in Benishangul-Gumuz and Amhara regions were lowest in access to toilet facilities with 4.30% and 6.31%, respectively while households in Dire Dawa and Addis Ababa had the highest access to improved toilet facilities with 65.20% and 79.31%, respectively **[S1 Table 1].**

Factors associated with access to improved drinking water sources

The proportion of households which had access to improved sources of drinking water was 69.94% at [95% CI: (69.23, 70.63)]. Both individual-level factors and community-level factors had an

impact on accessing improved drinking water sources in this study. Among individual-level factors; sex of household head and from community-level factors; wealth index, time to get to drinking water sources, residence, and region were significantly associated with access to improved drinking water sources

Female-headed households were 1.18 [AOR = 1.18, CI: (1.01, 1.37)] times more likely to have access to improved drinking water sources than male-headed households.

Compared to poorest households, poorer [AOR = 1.48, CI: (1.26, 1.74)], middle-income [AOR = 2.42, CI: (2.03, 2.90)], richer [AOR = 3.26, CI: (2.68, 3.97)] and richest [AOR = 6.97, CI: (5.17, 9.41)] households were 1.48, 2.42, 3.26, and 6.97 times more likely to access improved drinking water sources, respectively.

In contrasted with family units who got drinking water < 30 minutes, households who got drinking water ≥ 30 minutes were 35% less likely to access drinking water [AOR = 0.65, CI: (0.58, 0.73)].

The adjusted odds of access to improved drinking water sources in rural area was 94.00% less likely compared to urban area [AOR = 0.06, CI: (0.03, 0.11)].

The likelihood of access to improved sources of drinking water were 95.00% [AOR = 0.05, (0.01, 0.21)] in Afar, 94.00% [AOR = 0.06, (0.01, 0.27)] in Amhara, 92.00% [AOR = 0.08, (0.02, 0.35)] in Oromia, 98.00% [AOR = 0.02, (0.01, 0.10)] in Somalia , 93.00% [AOR = 0.07, (0.02, 0.30)] in SNNPR, and 82.00% [AOR = 0.18 (0.04, 0.89)] in Harari as compared to improved water access in Addis Ababa city **[Table 2].**

Table 2: Multivariable multilevel logistic regression model of the effects of individual- and community-level factors on improved drinking water sources in Ethiopia, EDHS 2016

	Null Model	Model I	Model II	Model III

Variables			AOR(95% CI)	AOR(95% CI)	AOR(95% CI)
Sex of household head	Male		1		1
	Female		1.13 (0.97, 1.32)		**1.18 (1.01, 1.37)[a]**
Age of household head	13 to 30		1		1
	31 to 40		0.99 (0.85, 1.14)		1.04 (0.89, 1.22)
	41 to 56		1.07 (0.92, 1.24)		1.13 (0.96, 1.33)
	≥ 57		0.93 (0.80, 1.09)		1.00 (0.85, 1.17)
Education level of the household head	No education		1		1
	Primary		0.93 (0.50, 1.73)		0.98 (0.52, 1.83)
	Secondary		1.69 (0.82, 3.49)		1.74 (0.83, 3.65)
	Higher		1.51 (0.40, 5.70)		1.37 (0.34, 5.55)
Current marital status household head	Never married		1		1
	Married		0.74 (0.54, 1.02)		1.02 (0.72, 1.43)
	Divorced		0.71 (0.49, 1.04)		1.01 (0.68, 1.50)
	Widowed		0.72 (0.49, 1.05)		0.98 (0.66, 1.45)
Wealth index	Poorest			1	1
	Poorer			1.47 (1.25, 1.73)[b]	**1.48 (1.26, 1.74)[b]**
	Middle			2.41 (2.01, 2.88)[b]	**2.42 (2.03, 2.90)[b]**
	Richer			3.23 (2.66, 3.92)[b]	**3.26 (2.68, 3.97)[b]**
	Richest			6.84 (5.07, 9.22)[b]	**6.97 (5.17, 9.41)[b]**
Time to get drinking water	< 30 minutes			1	1
	≥ 30 minutes			0.66 (0.58, 0.74)[b]	**0.65 (0.58, 0.73)[b]**
Number of household members	1 – 3 members			1	1
	4 – 6 members			0.86 (0.77, 0.97)[a]	0.88 (0.77, 1.00)
	7^{+}			0.88 (0.76, 1.01)	0.88 (0.75, 1.04)
Residence	Urban			1	1
	Rural			0.06 (0.03, 0.10)[b]	**0.06 (0.03, 0.11)[b]**
Region	Tigray			0.26 (0.06, 1.18)	0.26 (0.06, 1.17)
	Afar			0.05 (0.01, 0.21)[b]	**0.05 (0.01, 0.21)[b]**
	Amhara			0.06 (0.01, 0.27)[b]	**0.06 (0.01, 0.27)[b]**
	Oromia			0.08 (0.02, 0.35)[b]	**0.08 (0.02, 0.35)[b]**
	Somali			0.02 (0.01, 0.10)[b]	**0.02 (0.01, 0.10)[b]**
	Benishangul Gumuz			0.39 (0.08, 1.80)	0.39 (0.08, 1.81)

	SNNPR			0.07 (0.02, 0.30)[b]	**0.07 (0.02, 0.30)[b]**
	Gambella			0.30 (0.06, 1.35)	0.29 (0.06, 1.33)
	Harari			0.18 (0.04, 0.88)[a]	**0.18 (0.04, 0.89)[a]**
	Dire Dawa			0.33 (0.07, 1.64)	0.33 (0.07, 1.63)
	Addis Ababa			1	1
Random effect	Community level variance(SE)	12.24 (1.13)[b]	12.05 (1.11)[b]	4.75 (0.42)[b]	4.73 (0.41)[b]
	ICC (%)	78.81%	78.55%	59.08%	58.97%
	MOR	9.05	8.96	5.64	5.62
	PCV	Reference	1.55%	61.19	61.36%
Model fit statistics	Log-likelihood	-5997.01	-5987.89	-5619.38	-5611.48
	Deviance	11994.02	11975.78	11238.76	11222.96

Note:

[a, b] significant at [a] $P < 0.05$; [b] $P < 0.001$;

AOR: Adjusted Odds Ratio,

CI: Confidence Interval,

Model 0- Empty (null) model

Model I- Only individual-level explanatory variables included in the model;

Model II- Only community-level explanatory variables included in the model;

Model III- Combined model; both individual-level and community-level explanatory variables

PCV: Proportional Change in Variance,

MOR: Median Odds Ratio

210

211 **Factors associated with access to improved toilet facilities**

212 The proportion of households with access to an improved source of toilet facility was 25.36% at
213 [95% CI: (24.69%, 26.03%)]. Individual-level factors such as educational level of the household
214 heads, marital status, and community level factors such as wealth index, source of drinking water,
215 number of household members, residence, and region were factors significantly associated with
216 households' access to improved toilet facilities.

Compared with households whose household heads had no education, households headed with those who attained higher education were 2.21 times more likely to have access to improved toilet facilities at [AOR = 2.21 CI: (1.12, 4.36)]. The likelihood of access to toilet facilities was 25% [AOR = 0.75, CI: (0.57, 0.98)] lower in households with widowed household heads, as compared to those who never married.

Households with poorer [AOR = 3.97 CI: (2.99, 5.29)], middle [AOR = 5.82 CI: (4.35, 7.80)], richer [AOR = 8.58 CI: (6.40, 11.50)], and richest wealth index [AOR = 23.94 CI: (17.45, 32.83)], were 3.97, 5.82, 8.58, and 23.94 times more likely to access improved toilet facilities as compared to households with the poorest wealth index, respectively.

Households who had improved sources of drinking water were 1.37 [AOR = 1.37 CI: (1.12, 1.66)] times more likely to have access to improved toilet facilities, compared with their counterparts. Compared to household which had one to three members, 24% of those with four to six members were [AOR = 0.86 (0.75, 0.98)] less likely to access improved toilet facilities.

About 72% of rural households were less likely to have access to improved toilet facilities as compared with those from urban residence [AOR = 0.28 CI: (0.20, 0.38)]. About 72.00% in Tigray [AOR = 0.28, CI: (0.17, 0.46)] , 63.00% in Afar [AOR = 0.37, CI: (0.21, 0.67)], 96.00% in Amhara [AOR = 0.04, (0.02, 0.06)], 90.00% in Oromia [AOR = 0.10, CI: (0.06, 0.17)], 95.00% in Benishangul Gumuz [AOR = 0.05 CI: (0.03, 0.10)], 80.00% in SNNPR [AOR = 0.20 CI: (0.12, 0.33)], 85% in Gambella [AOR = 0.15 CI:(0.09, 0.26)], and 60.00% in Harari [AOR = 0.40 CI: (0.24, 0.66)] households were more likely to have access to improved toilet facilities as compared to households in Addis Ababa city **[Table 3].**

Table 3: Multivariable multilevel logistic regression model of the effects of individual- and community-level factors on improved sources of toilet facilities in Ethiopia, EDHS 2016

Variables		Null Model	Model I	Model II	Model III
			AOR(95% CI)	AOR(95% CI)	AOR(95% CI)
Sex of household head	Male		1		1
	Female		1.01 (0.88, 1.16)		1.03 (0.89, 1.19)
Age of household head	13 to 30		1		1
	31 to 40		0.99 (0.85, 1.15)		1.04 (0.89, 1.21)
	41 to 56		0.98 (0.84, 1.15)		1.02 (0.86, 1.20)
	≥ 57		0.98 (0.83, 1.16)		1.08 (0.91, 1.28)
Education level of the household head	No education		1		1
	Primary		1.34 (0.67, 2.67)		1.19 (0.59, 2.40)
	Secondary		0.74 (0.40, 1.36)		0.75 (0.41, 1.38)
	Higher		2.26 (1.13, 4.54)		**2.21 (1.12, 4.36)[b]**
Current marital status household head	Never married		1		1
	Married		0.87 (0.71, 1.08)		0.99 (0.80, 1.22)
	Divorced		0.69 (0.52, 0.91)[b]		0.82 (0.62, 1.08)
	Widowed		0.66 (0.50, 0.86)[c]		**0.75 (0.57, 0.98)[b]**
Wealth index	Poorest			1	1
	Poorer			3.99 (3.00, 5.31)[c]	**3.97 (2.99, 5.29)[c]**
	Middle			5.87 (4.39, 7.86)[c]	**5.82 (4.35, 7.80)[c]**
	Richer			8.65 (6.46, 11.58)[c]	**8.58 (6.40, 11.50)[c]**
	Richest			24.76 (18.08, 33.91)[c]	**23.94 (17.45, 32.83)[c]**
Source of drinking water	Unimproved			1	1
	Improved			1.36 (1.12, 1.65)[c]	**1.37 (1.12, 1.66)[c]**
Number of household members	1 – 3 members			1	1
	4 – 6 members			0.88 (0.78, 0.99)[a]	**0.86 (0.75, 0.98)[c]**
	7^{+}			1.07 (0.91, 1.26)	1.02 (0.86, 1.22)
Residence	Urban			1	1
	Rural			0.28 (0.21, 0.39)[c]	**0.28 (0.20, 0.38)[c]**
Region	Tigray			0.27 (0.16, 0.45)[c]	**0.28 (0.17, 0.46)[c]**
	Afar			0.38 (0.21, 0.68)[c]	**0.37 (0.21, 0.67)[c]**
	Amhara			0.04 (0.02, 0.06)[c]	**0.04 (0.02, 0.06)[c]**
	Oromia			0.10 (0.06, 0.17)[c]	**0.10 (0.06, 0.17)[c]**
	Somali			1.33 (0.79, 2.22)	1.32 (0.79, 2.21)

	Benishangul G.			0.05 (0.03, 0.10) [c]	**0.05 (0.03, 0.10) [c]**
	SNNPR			0.20 (0.12, 0.34) [c]	**0.20 (0.12, 0.33) [c]**
	Gambella			0.15 (0.09, 0.26) [c]	**0.15 (0.09, 0.26) [c]**
	Harari			0.40 (0.24, 0.66) [c]	**0.40 (0.24, 0.66) [c]**
	Dire Dawa			1.13 (0.69, 1.87)	1.14 (0.69, 1.89)
	Addis Ababa			1	1
Random effect	Community level variance(SE)	8.66 (0.73)[c]	8.71 (0.74)[c]	1.21 (0.12)[c]	1.22 (0.12)[c]
	ICC (%)	72.46%	72.58%	26.95%	27.08%
	MOR	16.37	16.50	2.84	2.86
	PCV	reference	-1.07%	86.03	85.91%
Model fit statistics	Log-likelihood	-5621.74	-5603.26	-5029.24	-5018.39
	Deviance	11243.48	11206.52	11036.78	10058.48

Note:

[a, b, c] significant at [a] P < 0.05; [b] p < 0.01, [c] P < 0.001;

AOR: Adjusted Odds Ratio,

CI: Confidence Interval,

Model 0- Empty (null) model

Model I- Only individual-level explanatory variables included in the model;

Model II- Only community-level explanatory variables included in the model;

Model III- Combined model; both individual-level and community-level explanatory variables

PCV: Proportional Change in Variance,

MOR: Median Odds Ratio

Random-effects analysis

The prevalence rate of access to improved drinking water sources varied across communities (community-level variance = 12.24, p = <0.001) **[Table 2]**. The null model revealed that 78.81% of the total variance in the odds of access to improved drinking water sources was accounted by between-cluster variation of characteristics (ICC = 0.7881). The inter-cluster variability declined over successive models, from 78.81% in the null model to 78.55% in the only individual-level, 59.08% in the only community-level, and 58.97% in the final (combined) models. The proportional

change in variance indicated that the addition of predictors to the empty model explained an increased proportion of variation in access to improved drinking water sources. The combined model showed that a higher PCV, i.e., 61.36% of the variance in access to improved drinking water sources could be explained by the combined factors at the individual- and community-levels.

In [**Table 3]** the final model (**Model III**), ICC value of 0.2708 indicates that 27.08% of the total variation in access to improved toilet facilities is accounted for the community-level factors. The remaining 72.92% variation is therefore triggered by the individual- level and other unknown factors. The proportional change in variance indicated that the addition of predictors to the empty model explained an increased proportion of variation in access to improved toilet facilities. The combined model showed a higher PCV, i.e., 85.91% of the variance in access to improved toilet facilities could be explained by the combined factors at the individual- and community-levels.

Model fit statistics

As shown in [**Tables 2 & 3**] (model fit statistics), the values of log-likelihood and Deviance showed a subsequent reduction which indicates that each model represents a significant improvement over the previous model and it points to the goodness of fit for the final model built in the analysis.

DISCUSSION

In this study, we aimed to assess access to improved drinking water sources and sanitation facilities and their associated factors in Ethiopia. Accordingly, the proportion of households' access to improved drinking water sources was 69.94%, [95% CI: (69.23, 70.63)]. This finding is lower than reports from studies conducted in Ghana,[2] Viet Nam,[16], and Eswatini. [14] Whereas, it is higher than a reported proportion from a study conducted in Nepal. [15] The proportion of households' access to toilet facilities was 25.36%, [95% CI: (24.69, 26.03)]. This result is higher than the one reported from Ghana,[2] However, lower than studies from Nigeria,[29] and Viet Nam. [16] The variation could be the disparities in GDP status and literacy rate among countries, study period, and setting.

Individual-level factors were associated with access to improved drinking water sources and toilet facilities in the present study. Female-headed households were 1.18 times more likely than male-headed households to access improved drinking water sources. Similar findings were reported from Ghana, Vietnam, and Nigeria. [2, 16, 30] Gender differences may play an important role in the work division in developing countries. Most of the time women have higher household responsibilities such as fetching water, cleaning compounds, childcare, and food preparation, etc. Therefore, this might be directly linked with water and sanitation in the sense that women may be preoccupied with other daily routines than WASH.

Those households with heads having better educational status were 2.21 times more likely to access improved toilet facilities. This study finding is supported by evidence from previous studies. [14, 29, 31] Households who are led by heads who have no education had a lower probability of access to improved toilet facilities. In sub-Saharan Africa, education is a resource factor of quality health

outcomes, and educated people usually are more aware of the condition that guarantees their well beings. This implies that educated household heads in this study may have utilized their resources to provide their households with improved toilet facilities.

In addition to individual level factors, community-level factors were also associated with access to improved drinking water sources and toilet facilities. When compared to households within the poorest category, households within poorer, middle, richer, and richest wealth index category were 1.48, 2.42, 3.26, and 6.97 times more likely to have access to improved sources of drinking water and 3.97, 5.82, 8.58, and 23.94 times higher odds to access improved toilet facilities, respectively. This result is consistent with results from previous studies. [13, 14, 32] People who have better incomes would intend to fulfill the necessities of life. Economically, the rich can afford the initial high cost of both water and sanitation facilities and the poor may be disproportionately underserved in the distribution of public utility, and hence consume poor quality water and use unimproved sanitation facilities.

Compared with households that got drinking water < 30 minutes, households which obtained drinking water ≥ 30 minutes were 35% less likely to access improved drinking water sources. Hence, the length of time to get drinking (proximity of a house to a drinking water source) water might make difference in access to improved sources of drinking water and coverage (%) with improved water supply (HH connection, public standpipes, protected underground water sources, rainwater collection). This is not surprising as the physical distance is one of the reasons of WASH service inaccessibility.

The adjusted odds of access to improved drinking water sources and toilet facilities were 94.00% and 72.00% less likely among rural households as compared to urban households, respectively. The rural-urban disparity in access to improved sources of drinking water and toilet facilities have

been reported by several other previous studies, too. [12, 33, 34]. The disparity might be, in sub-Saharan Africa, most of the people live in rural areas and their economic status is poor. Therefore, they do not have adequate financial resources to acquire improved drinking water sources and toilet facilities.

Furthermore, households who had improved sources of drinking water were 1.37 times more likely to access an improved toilet facilities. This study finding is consistent with an earlier study. [29] The possible explanation could be a lack of access to adequate sanitation is also linked to the limited access to water supply and households who had improved water sources may be practicing more in hygiene and sanitation.

Lastly, those households with four to six were 24% less likely access to improved toilet facilities compared to households with a family size of one to three. This is contrary to that of an earlier study. [2] The possible explanation could be the highest number of household members, the fewer resources they could have to build improved toilet facilities.

CONCLUSIONS

The proportion of households' access to an improved source of drinking water and sanitation facility was low in the country. Sex of household head, wealth index, time to get drinking water, residence, and region were associated with access to improved drinking water sources. Educational level of the household head, wealth index, being widowed, source of drinking water, number of household members, residence, and region were factors associated with access to improved toilet facilities. Thus, governmental and non-governmental organizations working on water, hygiene, and sanitation should consider a multi-faceted policy approach that accounts for the regions and residence variations and other identified factors to ease up the problem.

Acknowledgments

We would like to thank the Demographic and Health Survey (DHS) programme for allowing the use of Ethiopian Demographic and Health Survey (EDHS) data for this study.

Competing interests: None declared.

Patient consent for publication: Not required.

Ethics approval: The EDHS 2016 was approved by the National Research Ethics Review Committee of Ethiopia and ICF Macro International. The approval letter was obtained from the measure DHS for the use of this data, and the dataset was downloaded from www.meauredhs.com. This analysis was approved by the Department of Environmental and occupational health and safety, University of Gondar.

Funding

The author(s) received no specific funding for this work.

Availability of data and materials

The dataset analyzed during the current study available from the corresponding author upon reasonable request.

Authors' contributions

ZA wrote the analyzed data, drafted the paper, and prepared the manuscript. HD, ZNA, AAT, BD, RF, AGM, and YY drafted the paper, writing – review & editing, and commented on the manuscript. All the authors read and approved the final manuscript.

REFERENCES

1. Prüss-Ustün A, Wolf J, Bartram J, Clasen T, Cumming O, Freeman MC, et al. Burden of disease from inadequate water, sanitation and hygiene for selected adverse health outcomes: An updated analysis with a focus on low-and middle-income countries. International journal of hygiene and environmental health. 2019;222(5):765-77.
2. Agbadi P, Darkwah E, Kenney PL. A Multilevel Analysis of Regressors of Access to Improved Drinking Water and Sanitation Facilities in Ghana. Journal of environmental and public health. 2019;2019.
3. Assembly UG. Resolution on Human Right to Water and Sanitation. New York: United Nations. 2010.
4. Brookes JD, Carey CC. Ensure availability and sustainable management of water and sanitation for all. UN Chronicle. 2015;51(4):15-6.
5. Mills JE, Cumming O. The impact of water, sanitation and hygiene on key health and social outcomes. URL: https://www lshtm ac uk/sites/default/files/2017-07/WASHEvidencePaper_HighRes_01. 2016;23.
6. Saxena SK, Kumar S, Haikerwal A, Bhatt ML. Introductory chapter: Neglected tropical waterborne infectious diseases-strategies for mitigation. Water Challenges of an Urbanizing World. 2018:1.
7. Organization WH. Water, sanitation, hygiene, and waste management for the COVID-19 virus: interim guidance, 23 April 2020. World Health Organization, 2020.
8. Organization WH. Progress on drinking water, sanitation and hygiene: 2017 update and SDG baselines. 2017.
9. Organization WH. Water, sanitation, hygiene and health: a primer for health professionals. World Health Organization, 2019.
10. Organization WH. Safer water, better health. 2019.
11. UNICEF. Water, sanitation and hygiene (WASH) 2020 [cited 2020 April, 14]. Available from: https://www.unicef.org/ethiopia/water-sanitation-and-hygiene-wash.
12. Mulenga JN, Bwalya BB, Kaliba-Chishimba K. Determinants and inequalities in access to improved water sources and sanitation among the Zambian households. International Journal of Development and Sustainability. 2017;6(8):746-62.

13. Morakinyo OM, Adebowale SA, Oloruntoba EO. Wealth status and sex differential of household head: implication for source of drinking water in Nigeria. Archives of Public Health. 2015;73(1):58.

14. Simelane MS, Shongwe MC, Vermaak K, Zwane E. Determinants of Households' Access to Improved Drinking Water Sources: A Secondary Analysis of Eswatini 2010 and 2014 Multiple Indicator Cluster Surveys. Advances in Public Health. 2020;2020.

15. Wang C, Pan J, Yaya S, Yadav RB, Yao D. Geographic Inequalities in Accessing Improved Water and Sanitation Facilities in Nepal. International journal of environmental research and public health. 2019;16(7):1269.

16. Tuyet-Hanh TT, Long TK, Van Minh H, Huong LTT. Longitudinal household trends in access to improved water sources and sanitation in Chi Linh town, Hai Duong province, Viet Nam and associated factors. AIMS public health. 2016;3(4):880.

17. Organization WH, UNICEF. Progress on drinking water and sanitation: special focus on sanitation. Progress on drinking water and sanitation: special focus on sanitation2008.

18. Beyene A, Hailu T, Faris K, Kloos H. Current state and trends of access to sanitation in Ethiopia and the need to revise indicators to monitor progress in the Post-2015 era. BMC Public Health. 2015;15:451-.

19. Pullan RL, Freeman MC, Gething PW, Brooker SJ. Geographical inequalities in use of improved drinking water supply and sanitation across sub-Saharan Africa: mapping and spatial analysis of cross-sectional survey data. PLoS Med. 2014;11(4):e1001626.

20. Central Statistical Agency (CSA). Central Statistical Agency (CSA) [Ethiopia] and ICF Ethiopia demographic and health Survey 2016. Addis Ababa, Ethiopia, and Rockville, Maryland, USA: CSA and ICF,2017.

21. Simelane M, Shongwe M, Vermaak K, Zwane E. Determinants of Households' Access to Improved Drinking Water Sources: A Secondary Analysis of Eswatini 2010 and 2014 Multiple Indicator Cluster Surveys. 2020;2020.

22. Ribeiro Sarmento MPH D. An Analysis of Access to Improved Drinking Water and Sanitation and Distance to the Water Source in a Newly Independent Country, Timor-Leste: Assessing Geographical and Socioeconomic Disparities. 2015.

23. Supply WUJW, Programme SM, Organization WH, Supply WUJMPfW, Sanitation, UNICEF. Water for life: making it happen: World health organization; 2005.

24. Merlo J, Chaix B, Ohlsson H, Beckman A, Johnell K, Hjerpe P, et al. A brief conceptual tutorial of multilevel analysis in social epidemiology: using measures of clustering in multilevel logistic regression to investigate contextual phenomena. Journal of Epidemiology & Community Health. 2006;60(4):290-7.

25. Merlo J, Yang M, Chaix B, Lynch J, Råstam L. A brief conceptual tutorial on multilevel analysis in social epidemiology: investigating contextual phenomena in different groups of people. Journal of Epidemiology & Community Health. 2005;59(9):729-36.

26. Larsen K, Merlo J. Appropriate assessment of neighborhood effects on individual health: integrating random and fixed effects in multilevel logistic regression. American journal of epidemiology. 2005;161(1):81-8.

27. Spiegelhalter DJ, Best NG, Carlin BP, Van Der Linde A. Bayesian measures of model complexity and fit. Journal of the royal statistical society: Series b (statistical methodology). 2002;64(4):583-639.

28. Joseph F. Hair, Jr. William, Black Barry J., Babin Rolph, E. Anderson. Multivariate Data Analysis Edition S, editor2018.

29. Abubakar IR. Access to sanitation facilities among Nigerian households: determinants and sustainability implications. Sustainability. 2017;9(4):547.

30. Morakinyo OM, Adebowale SA, Oloruntoba EO. Wealth status and sex differential of household head: implication for source of drinking water in Nigeria. Archives of public health = Archives belges de sante publique. 2015;73:58.

31. Akpakli DE, Manyeh AK, Akpakli JK, Kukula V, Gyapong M. Determinants of access to improved sanitation facilities in rural districts of southern Ghana: evidence from Dodowa Health and Demographic Surveillance Site. BMC Res Notes. 2018;11(1):473-.

32. Njuguna J. Progress in sanitation among poor households in Kenya: evidence from demographic and health surveys. BMC Public Health. 2019;19(1):135.

33. Irianti S, Prasetyoputra P, Sasimartoyo TP. Determinants of household drinking-water source in Indonesia: An analysis of the 2007 Indonesian family life survey. Cogent Medicine. 2016;3(1).

34. Prasetyoputra P, Irianti S. Access to improved sanitation facilities in indonesia: An econometric analysis of geographical and socioeconomic disparities. Journal of Applied Sciences in Environmental Sanitation. 2013;8(3).

Supplementary Table 1: Regional distribution of access to improved drinking water sources and toilet facilities in Ethiopia, EDHS, 2016.

Region	Source of drinking water		Toilet facilities	
	Unimproved	Improved	Unimproved	Improved
Tigray	410 (23.64%)	1,324 (76.36%)	1,380 (79.58%)	354 (20.42%)
Afar	627 (51.39%)	593 (48.61%)	1,032 (84.59%)	188 (15.41%)
Amhara	741 (38.96%)	1,161 (61.04%)	1,782 (93.69%)	120 (6.31%)
Oromia	746 (37.53%)	1,242 (62.47%)	1,785 (89.79%)	203 (10.21%)
Somali	884 (56.52%)	680 (43.48%)	1,145 (73.21%)	419 (26.79%)
Benishangul Gumuz	271 (21.17%)	1,009 (78.83%)	1,225 (95.70%)	55 (4.30%)
SNNPR	775 (40.85%)	1,122 (59.15%)	1,650 (86.98%)	247 (13.02%)
Gambella	246 (19.22%)	1,034 (80.78%)	1,098 (85.78%)	182 (14.22%)
Harari	179 (15.77%)	956 (84.23%)	619 (54.54%)	516 (45.46%)
Dire Dawa	117 (10.08%)	1,044 (89.92%)	404 (34.80%)	757 (65.20%)
Addis Ababa	9 (0.60%)	1,480 (99.40%)	308 (20.69%)	1,181 (79.31%)
Total	5005(30.06%)	11,645 (69.94%)	12,428 (74.64%)	4,222 (25.36%)

STROBE (Strengthening The Reporting of OBservational Studies in Epidemiology) Checklist

A checklist of items that should be included in reports of observational studies. You must report the page number in your manuscript where you consider each of the items listed in this checklist. If you have not included this information, either revise your manuscript accordingly before submitting or note N/A.

Note: An Explanation and Elaboration article discusses each checklist item and gives methodological background and published examples of transparent reporting. The STROBE checklist is best used in conjunction with this article (freely available on the Web sites of PLoS Medicine at http://www.plosmedicine.org/, Annals of Internal Medicine at http://www.annals.org/, and Epidemiology at http://www.epidem.com/). Information on the STROBE Initiative is available at www.strobe-statement.org.

Section and Item	Item No.	Recommendation	Reported on Page No.
Title and Abstract	1	(*a*) Indicate the study's design with a commonly used term in the title or the abstract	
		(*b*) Provide in the abstract an informative and balanced summary of what was done and what was found	
Introduction			
Background/Rationale	2	Explain the scientific background and rationale for the investigation being reported	
Objectives	3	State specific objectives, including any prespecified hypotheses	
Methods			
Study Design	4	Present key elements of study design early in the paper	
Setting	5	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection	
Participants	6	(*a*) *Cohort study*—Give the eligibility criteria, and the sources and methods of selection of participants. Describe methods of follow-up *Case-control study*—Give the eligibility criteria, and the sources and methods of case ascertainment and control selection. Give the rationale for the choice of cases and controls *Cross-sectional study*—Give the eligibility criteria, and the sources and methods of selection of participants	
		(*b*) *Cohort study*—For matched studies, give matching criteria and number of exposed and unexposed *Case-control study*—For matched studies, give matching criteria and the number of controls per case	
Variables	7	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable	

Section and Item	Item No.	Recommendation	Reported on Page No.
Data Sources/ Measurement	8*	For each variable of interest, give sources of data and details of methods of assessment (measurement). Describe comparability of assessment methods if there is more than one group	
Bias	9	Describe any efforts to address potential sources of bias	
Study Size	10	Explain how the study size was arrived at	
Quantitative Variables	11	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why	
Statistical Methods	12	(*a*) Describe all statistical methods, including those used to control for confounding	
		(*b*) Describe any methods used to examine subgroups and interactions	
		(*c*) Explain how missing data were addressed	
		(*d*) *Cohort study*—If applicable, explain how loss to follow-up was addressed *Case-control study*—If applicable, explain how matching of cases and controls was addressed *Cross-sectional study*—If applicable, describe analytical methods taking account of sampling strategy	
		(*e*) Describe any sensitivity analyses	
Results			
Participants	13*	(a) Report numbers of individuals at each stage of study—eg numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analysed	
		(b) Give reasons for non-participation at each stage	
		(c) Consider use of a flow diagram	
Descriptive Data	14*	(a) Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders	
		(b) Indicate number of participants with missing data for each variable of interest	
		(c) *Cohort study*—Summarise follow-up time (eg, average and total amount)	
Outcome Data	15*	*Cohort study*—Report numbers of outcome events or summary measures over time	
		Case-control study—Report numbers in each exposure category, or summary measures of exposure	
		Cross-sectional study—Report numbers of outcome events or summary measures	

Section and Item	Item No.	Recommendation	Reported on Page No.
Main Results	16	(*a*) Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (eg, 95% confidence interval). Make clear which confounders were adjusted for and why they were included	
		(*b*) Report category boundaries when continuous variables were categorized	
		(*c*) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period	
Other Analyses	17	Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses	
Discussion			
Key Results	18	Summarise key results with reference to study objectives	
Limitations	19	Discuss limitations of the study, taking into account sources of potential bias or imprecision. Discuss both direction and magnitude of any potential bias	
Interpretation	20	Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence	
Generalisability	21	Discuss the generalisability (external validity) of the study results	
Other Information			
Funding	22	Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based	

*Give information separately for cases and controls in case-control studies and, if applicable, for exposed and unexposed groups in cohort and cross-sectional studies.

Once you have completed this checklist, please save a copy and upload it as part of your submission. DO NOT include this checklist as part of the main manuscript document. It must be uploaded as a separate file.

BMJ Open

Households' access to improved drinking water sources and toilet facilities in Ethiopia: A multilevel analysis based on 2016 Ethiopian Demographic and Health Survey

Journal:	*BMJ Open*
Manuscript ID	bmjopen-2020-042071.R3
Article Type:	Original research
Date Submitted by the Author:	26-Feb-2021
Complete List of Authors:	Andualem , Zewudu ; University of Gondar College of Medicine and Health Sciences, Department of Environmental and Occupational health and Safety Dagne, Henok; University of Gondar College of Medicine and Health Sciences, Environmental and Occupational Health and Safety; University of Gondar, Environmental and Occupational Health and Safety Azene, Zelalem; University of Gondar College of Medicine and Health Sciences, Department of Women's and family health, School of Midwifery, College of Medicine and Health Sciences, University of Gondar, P. O. Box 196 Gondar, Ethiopia.; University of Gondar, Ethiopia taddese, Asefa; University of Gondar College of Medicine and Health Sciences, Epidemiology and Biostatistics Dagnew, Baye ; University of Gondar College of Medicine and Health Sciences, Human Physiology; Mr. Fisseha, Roman ; Department of Medical Microbiology, School of Biomedical and Laboratory Sciences, College of Medicine and Health Sciences, University of Gondar, P. O. Box 196 Gondar, Ethiopia. Muluneh, Atalay; University of Gondar College of Medicine and Health Sciences, Epidemiology and Bio statistics ; Yeshaw, Yigizie; University of Gondar College of Medicine and Health Sciences, Medical Physiology
Primary Subject Heading:	Public health
Secondary Subject Heading:	Occupational and environmental medicine
Keywords:	PUBLIC HEALTH, PREVENTIVE MEDICINE, Health policy < HEALTH SERVICES ADMINISTRATION & MANAGEMENT

I, the Submitting Author has the right to grant and does grant on behalf of all authors of the Work (as defined in the below author licence), an exclusive licence and/or a non-exclusive licence for contributions from authors who are: i) UK Crown employees; ii) where BMJ has agreed a CC-BY licence shall apply, and/or iii) in accordance with the terms applicable for US Federal Government officers or employees acting as part of their official duties; on a worldwide, perpetual, irrevocable, royalty-free basis to BMJ Publishing Group Ltd ("BMJ") its licensees and where the relevant Journal is co-owned by BMJ to the co-owners of the Journal, to publish the Work in this journal and any other BMJ products and to exploit all rights, as set out in our licence.

The Submitting Author accepts and understands that any supply made under these terms is made by BMJ to the Submitting Author unless you are acting as an employee on behalf of your employer or a postgraduate student of an affiliated institution which is paying any applicable article publishing charge ("APC") for Open Access articles. Where the Submitting Author wishes to make the Work available on an Open Access basis (and intends to pay the relevant APC), the terms of reuse of such Open Access shall be governed by a Creative Commons licence – details of these licences and which Creative Commons licence will apply to this Work are set out in our licence referred to above.

Other than as permitted in any relevant BMJ Author's Self Archiving Policies, I confirm this Work has not been accepted for publication elsewhere, is not being considered for publication elsewhere and does not duplicate material already published. I confirm all authors consent to publication of this Work and authorise the granting of this licence.

Households access to improved drinking water sources and toilet facilities in Ethiopia: A multilevel analysis based on 2016 Ethiopian Demographic and Health Survey

Zewudu Andualem[1*], Henok Dagne[1], Zelalem Nigussie Azene[2], Asefa Adimasu Taddese[3], Baye Dagnew[4], Roman Fisseha[5], Atalay Goshu Muluneh[3], and Yigizie Yeshaw [4]

[1]Department of Environmental and Occupational Health and Safety, Institute of Public Health, College of Medicine and Health Sciences, University of Gondar, P. O. Box 196 Gondar, Ethiopia

[2]Department of Women's and Family Health, School of Midwifery, College of Medicine and Health Sciences, University of Gondar, P. O. Box 196 Gondar, Ethiopia.

[3]Department of Epidemiology and Biostatistics, Institute of Public Health, College of Medicine and Health Sciences, University of Gondar, P. O. Box 196 Gondar, Ethiopia

[4]Department of Human Physiology, School of Medicine, College of Medicine and Health Sciences, University of Gondar, P. O. Box 196 Gondar, Ethiopia

[5]Department of Medical Microbiology, School of Biomedical and Laboratory Sciences, College of Medicine and Health Sciences, University of Gondar, P. O. Box 196 Gondar, Ethiopia.

*Corresponding author

Authors' email address

[ZA] Zewudu Andualem: zewuduandualem12@gmail.com, [HD] Henok Dagne: enoch2313@gmail.com, [ZNA] Zelalem Nigussie Azene: znigussie35@gmail.com, [AAT] Asefa Adimasu Taddese: adimasuasefa@gmail.com, [BD] Baye Dagnew: bayedagnew7@gmail.com, [RF] Roman Fisseha: romanfisseha85@gmail.com, [AGM] Atalay Goshu Muluneh: atalayg1921@gmail.com, and [YY] Yigizie Yeshaw: yigizieyeshaw29@gmail.com

ABSTRACT

Objective: This study aimed to assess households access to improved drinking water sources and sanitation facilities and their associated factors in Ethiopia.

Design: Cross-sectional study

Setting: Ethiopia

Participants: Household heads

Primary outcomes: Access to improved drinking water sources and toilet facilities

Methods: We conducted an in-depth secondary data analysis of 2016 Ethiopian Demographic and Health Survey (EDHS). Data from a total of 16650 households and 645 clusters were included in the analysis. The households were selected using a stratified two-stage cluster sampling technique. Multilevel binary logistic regression analyses were performed to identify factors associated with access to an improved drinking water source and toilet facilities. Adjusted odds ratio with a 95% CI was reported with p-value < 0.05 was used to declare a significant association between the covariates and the outcome variables.

Results: The proportions of households' access to improved sources of drinking water and toilet facilities were 69.94%, [95% CI: (69.23, 70.63)], and 25.36%, [95% CI: (24.69, 26.03)], respectively. Households headed by females and households with a better wealth index were positively associated with access to improved drinking water sources. Whereas rural households, ≥ 30 minutes round trip to obtain drinking water and region were factors negatively associated with households access to improved drinking water sources. A higher probability of having access to improved toilet facilities: households with heads who had attained higher education, households

having better access to improved sources of drinking water, and households with better wealth index. While the following households were less likely to have access to improved toilet facilities: households with heads were widowed, households with four to six members, rural households, and region

Conclusion: The study found that the proportions of households' access to improved drinking water sources and toilet facilities in Ethiopia were relatively low, which demands the need to tailor strategies to increase the coverage of access to improved drinking water sources and toilet facilities.

Keywords: Improved toilet facilities, improved water sources, multilevel analysis, Ethiopia

Strength and limitations of the study

- The use of nationally representative data that can enhance the generalizability of the findings is one of the strengths of this study.
- This study used data from a cross-sectional survey; as a result, the results from analyzing the data cannot establish causal relationships.
- Moreover, important variables such as culture, traditions, and social norms were not available in EDHS data which could influence the use of toilet facility type.

INTRODUCTION

Access to safe water and basic sanitation is one of the fundamental human rights, and an essential step towards improving living standards to maintain and improve health, human growth, and development. [1-3] It is one of the critical sustainable development challenges. Sustainable Development Goal (SDG) 6 aims to ensure the availability and sustainable management of water and sanitation for all by 2030. [4]

Unimproved sources of drinking water and sanitation facilities are responsible for increased risks of various infectious diseases such as; cholera, typhoid, schistosomiasis, infections of the respiratory systems, skin, and eye. [1, 5, 6] The currently available evidences also indicate that to prevent the novel coronavirus disease (COVID-19) outbreak, the provision of safe water, sanitation, and hygienic conditions is crucial. [7]

Globally, 2 billion people lack basic sanitation services and 785 million people have no access to clean water. [8] More than 1.9 million deaths and 123 million disability-adjusted life-years (DALYs) could have been prevented by the provision of adequate access to water, hygiene, and sanitation (WASH) worldwide. The WASH-attributable disease burden accounts for 4.6% of global DALYs and 3.3% of global mortality. [9] 13% of under 5 mortality was accounted by WASH-attributable disease. [10] In Ethiopia, 60 to 80 % of communicable diseases are attributed to limited access to safe water, inadequate sanitation, and hygiene services. [11]

Regarding factors associated with improved drinking water sources and toilet facilities: Sex of household heads, region, residence, family size, and time to get to drinking water source, age of household head, educational level, and marital status of the household heads were predictors linked to access to improved drinking water sources and toilet facilities reported by previous studies. [2, 12-16]

In Sub-Saharan Africa, particularly in Ethiopia, access to improved sources of drinking water and toilet facilities is still lacking and people are practicing open defecation. [17, 18] There is no study in Ethiopia using nationally representative data (2016 Ethiopian Demographic and Health Survey (EDHS) data), which accounts for the hierarchical nature of the data. However, national studies conducted in Sub-Saharan African countries in 2014 indicated the spatial variation in the coverage of households' use of improved drinking water supply and sanitation. [19] Therefore, the current study aimed to assess access to improved drinking water sources and toilet facilities and their associated factors in Ethiopia using EDHS 2016 data.

METHODS

Patient and public involvement

This study was based on a publicly available data set (EDHS 2016). Thus, there were no patients or members of the public involved.

Study design and area

The 2016 main EDHS was a cross-sectional survey conducted from 18 January 2016 to 27 June 2016 in Ethiopia by the Ethiopian Central Statistical Agency (ECSA). For our case, we used an in-depth secondary data analysis of the survey. It was the fourth survey conducted in each of the 11 regions of Ethiopia (9 regional states and 2 administrative cities). Administratively, each region in Ethiopia is divided into Zones, each Zone, in turn, is divided into Woredas, and each Woreda into Kebeles (the lowest administrative units in the country). [20]

Data sources

Data were obtained from 2016 Ethiopian Demographic and Health Survey (EDHS-2016) after being registered as an authorized user. The survey collects data on key indicators of health and health-related events including access to improved drinking water sources and toilet facilities. A total of 16,650 households from 645 Enumeration Areas (EAs) were included in the survey. [20]

Sample size and sampling procedure

A two-stage stratified cluster sampling technique was employed to select study participants. Sampling frame of the 2007 Population and Housing Censuses in which EAs were the sampling units for the first stage and households for the second stage was used. A total of 18,008 households were selected for the sample, of which 17,067 were occupied. Of the occupied households, 16,650

were successfully interviewed, yielding a response rate of 98%. [20] The current study included individual-level data for 16650 household heads as well as community characteristics of 645 clusters.

Variables of the study

Outcome variables

Access to improved drinking water sources and improved toilet facilities.

Explanatory variables

The explanatory variables for this study were classified as individual and community level factors for both outcome variables. . The individual-level factors for the outcome variables were; Sex, age, educational level, and marital status of the household head. Whereas, the community-level factors for the first outcome variable (access to improved drinking water sources) were; household wealth index, time to get to drinking water sources, family size, place of residence, and region. While, for the second outcome variable (access to improved toilet facilities) the community-level factors were household wealth index, household size, sources of drinking water, place of residence, and region. The variables were selected based on the literature review for factors affecting access to improved drinking water sources and improved toilet facilities. The basis of the classification of explanatory variables into the individual level, household level, and community level variables were based on previous studies [2, 21, 22] and our professional judgments.

Operational definitions

Improved sources of drinking water: a household is said to have access to an improved drinking water source if it has water piped into its dwelling, water piped to a yard/plot, a public tap/standpipe, a tube well/borehole, a protected dug well, a protected spring, rainwater, bottled water, or sachet water. [23]

Improved types of toilet facilities: a household is said to have access to improved toilet facilities if it has unshared flush/pour flush to piped sewer systems, septic tanks or pit latrines, ventilated improved pit latrines, composting toilets, or pit latrines with slabs. [23]

Data processing and analysis

Statistical analysis was performed using Stata 16.00 software. The weighted frequencies and the percentages (based on the population size of each region) were computed. The detailed weighting procedure is described elsewhere. [20]

Multilevel binary logistic regression model was used to assess the impact of individual and community-level factors on households' access to improved sources of drinking water and improved toilet facilities. The model, which is most appropriate to consider the cluster random effect in a multivariate setting and the reason to apply multilevel modeling was the nature of the data collected which have a hierarchical or clustered structure. The first level represents the individual and household and the second level factor is the clusters. Four models were tested in each of the cases (access to improved sources of drinking water and toilet facilities). **Model 0** (the null model) was fitted without explanatory variables to test random variability in the intercept and to estimate the intraclass correlation coefficient (ICC). **Model I** was used to investigate the impact of individual-level factors on the likelihood of having access to improved sources of drinking water

and toilet facilities. **Model II** was used to assess the impact of community-level factors on the likelihood of having access to improved sources of drinking water and toilet facilities. **Model III** was employed to assess the impact of individual and community-level factors altogether on access to improved sources of drinking water and toilet facilities.

The random effects (variation of effects) were measured by ICC, percentage change in variance (PCV), Median Odds Ratio (MOR), and deviance (-2log likelihood), which measure the variability between clusters in the multilevel models. The ICC explains the cluster variability, while MOR is used to quantify unexplained cluster variability (heterogeneity). The MOR was used to translate cluster variance into OR scale. [24-26] In the multilevel model, deviance can measure the total variation due to factors at the community and individual levels. [25, 27]

Adjusted odds ratio with a 95% confidence interval was reported with p-value < 0.05 was used to declare a significant association among covariates and outcome variables. A multicollinearity test was performed to rule out if there was a significant correlation between explanatory variables. If the values of variance inflation factor (VIF) was lower than 10, then the collinearity problem was considered less likely. [28]

RESULTS

Socio-demographic characteristics of the study participants

A total of 16650 study participants were included in the study. The median (±SD) age of the household heads was 40 years (± 16.22 years, range 15 - 95). Approximately, seven out of ten (69.94%) of the households had access to improved sources of drinking water and only one-fourth (25.36%) of households had access to improved sources of toilet facilities. Majority (98.37%) of respondents had no formal education. About 68.55% of households were male-headed. [**Table 1**].

Table 1: Socio-demographic characteristics of the study participants in Ethiopia, EDHS 2016 (n= 16650)

Variables		Frequency	Percent (%)
Source of drinking water	Improved	11,645	69.94
	Unimproved	5,005	30.06
Toilet facilities	Improved	4,222	25.36
	Unimproved	12,428	74.64
Sex of household head	Male	11,413	68.55
	Female	5,237	31.45
Age of household head (years)	13 to 30	4,257	25.57
	31 to 40	4,132	24.82
	41 to 56	4,230	25.41
	□ 57	4,031	24.21
Education level of the household head	No education	16,378	98.37
	Primary education	93	0.56
	Secondary education	114	0.68
	Higher education	65	0.39
Current marital status household head	Never married	1,046	6.29
	Married	12,064	72.50
	Widowed	2,108	12.67
	Divorced	1,423	8.55
Wealth index	Poorest	4,676	28.08
	Poorer	2,348	14.10
	Middle	2,057	12.35
	Richer	2,020	12.13
	Richest	5,549	33.33
Time to get drinking water	≤ 30 minutes	9,821	58.98
	> 30 minutes	6,829	41.02
Number of household members	1 – 3 members	6,258	37.59
	4 – 6 members	7,031	42.23

	7 members and above	3,361	20.19
Residence	Urban	5,232	31.42
	Rural	11,418	68.58
Region	Tigray	1,734	10.41
	Afar	1,220	7.33
	Amhara	1,902	11.42
	Oromia	1,988	11.94
	Somali	1,564	9.39
	Benishangul-Gumuz	1,280	7.69
	SNNPR	1,897	11.39
	Gambella	1,280	7.69
	Harari	1,135	6.82
	Dire Dawa	1,161	6.97
	Addis Ababa	1,489	8.94

Regional distribution in terms of improved drinking water and toilet facility sources in Ethiopia

Among Ethiopian regions, nearly all households in Addis Abeba (99.40%) had access to improved sources of drinking water. On the contrary, Somali (56.52%) and Afar regions (51.39%) had the least access to improved sources of drinking water. Households in Benishangul-Gumuz and Amhara regions were lowest in access to toilet facilities with 4.30% and 6.31%, respectively while households in Dire Dawa and Addis Ababa had the highest access to improved toilet facilities with 65.20% and 79.31%, respectively **[S1 Table 1].**

Factors associated with access to improved drinking water sources

The proportion of households which had access to improved sources of drinking water was 69.94% at [95% CI: (69.23, 70.63)]. Both individual-level and community-level factors had an impact on

accessing improved drinking water sources in this study. Among individual-level factors; sex of the household head and from community-level factors; wealth index, time to get to drinking water sources, residence, and region were significantly associated with access to improved drinking water sources.

Female-headed households were 1.18 [AOR = 1.18, CI: (1.01, 1.37)] times more likely to have access to improved drinking water sources than male-headed households.

Compared to poorest households, poorer [AOR = 1.48, CI: (1.26, 1.74)], middle-income [AOR = 2.42, CI: (2.03, 2.90)], richer [AOR = 3.26, CI: (2.68, 3.97)] and richest [AOR = 6.97, CI: (5.17, 9.41)] households were 1.48, 2.42, 3.26, and 6.97 times higher probability to have access to improved drinking water sources, respectively.

In contrast to households who got drinking water in □ 30 minutes, households who got drinking water □ 30 minutes were 35% less likely to access to improved drinking water sources [AOR = 0.65, CI: (0.58, 0.73)].

The adjusted odds of access to improved drinking water sources in rural households was 94.00% less likely compared to urban households [AOR = 0.06, CI: (0.03, 0.11)].

The likelihood of access to improved sources of drinking water was 95.00% [AOR = 0.05, (0.01, 0.21)] in Afar, 94.00% [AOR = 0.06, (0.01, 0.27)] in Amhara, 92.00% [AOR = 0.08, (0.02, 0.35)] in Oromia, 98.00% [AOR = 0.02, (0.01, 0.10)] in Somalia , 93.00% [AOR = 0.07, (0.02, 0.30)] in SNNPR, and 82.00% [AOR = 0.18 (0.04, 0.89)] in Harari compared to access to improved water sources in Addis Ababa city **[Table 2].**

Table 2: Multivariable multilevel logistic regression model of the effects of individual- and community-level factors on improved drinking water sources in Ethiopia, EDHS 2016

Variables		Null Model	Model I	Model II	Model III
			AOR(95% CI)	AOR(95% CI)	AOR(95% CI)
Sex of household head	Male		1		1
	Female		1.13 (0.97, 1.32)		**1.18 (1.01, 1.37)[a]**
Age of household head	13 to 30		1		1
	31 to 40		0.99 (0.85, 1.14)		1.04 (0.89, 1.22)
	41 to 56		1.07 (0.92, 1.24)		1.13 (0.96, 1.33)
	□ 57		0.93 (0.80, 1.09)		1.00 (0.85, 1.17)
Education level of the household head	No education		1		1
	Primary		0.93 (0.50, 1.73)		0.98 (0.52, 1.83)
	Secondary		1.69 (0.82, 3.49)		1.74 (0.83, 3.65)
	Higher		1.51 (0.40, 5.70)		1.37 (0.34, 5.55)
Current marital status household head	Never married		1		1
	Married		0.74 (0.54, 1.02)		1.02 (0.72, 1.43)
	Divorced		0.71 (0.49, 1.04)		1.01 (0.68, 1.50)
	Widowed		0.72 (0.49, 1.05)		0.98 (0.66, 1.45)
Wealth index	Poorest			1	1
	Poorer			1.47 (1.25, 1.73)[b]	**1.48 (1.26, 1.74)[b]**
	Middle			2.41 (2.01, 2.88)[b]	**2.42 (2.03, 2.90)[b]**
	Richer			3.23 (2.66, 3.92)[b]	**3.26 (2.68, 3.97)[b]**
	Richest			6.84 (5.07, 9.22)[b]	**6.97 (5.17, 9.41)[b]**
Time to get drinking water	□ 30 minutes			1	1
	□ 30 minutes			0.66 (0.58, 0.74)[b]	**0.65 (0.58, 0.73)[b]**
Number of household members	1 – 3 members			1	1
	4 – 6 members			0.86 (0.77, 0.97)[a]	0.88 (0.77, 1.00)
	7^{+}			0.88 (0.76, 1.01)	0.88 (0.75, 1.04)
Residence	Urban			1	1
	Rural			0.06 (0.03, 0.10)[b]	**0.06 (0.03, 0.11)[b]**
Region	Tigray			0.26 (0.06, 1.18)	0.26 (0.06, 1.17)
	Afar			0.05 (0.01, 0.21)[b]	**0.05 (0.01, 0.21)[b]**
	Amhara			0.06 (0.01, 0.27)[b]	**0.06 (0.01, 0.27)[b]**
	Oromia			0.08 (0.02, 0.35)[b]	**0.08 (0.02, 0.35)[b]**
	Somali			0.02 (0.01, 0.10)[b]	**0.02 (0.01, 0.10)[b]**

		Benishangul Gumuz			0.39 (0.08, 1.80)	0.39 (0.08, 1.81)
		SNNPR			0.07 (0.02, 0.30)[b]	**0.07 (0.02, 0.30)[b]**
		Gambella			0.30 (0.06, 1.35)	0.29 (0.06, 1.33)
		Harari			0.18 (0.04, 0.88)[a]	**0.18 (0.04, 0.89)[a]**
		Dire Dawa			0.33 (0.07, 1.64)	0.33 (0.07, 1.63)
		Addis Ababa			1	1
Random effect	Community level variance(SE)		12.24 (1.13)[b]	12.05 (1.11)[b]	4.75 (0.42)[b]	4.73 (0.41)[b]
	ICC (%)		78.81%	78.55%	59.08%	58.97%
	MOR		9.05	8.96	5.64	5.62
	PCV		Reference	1.55%	61.19	61.36%
Model fit statistics	Log-likelihood		-5997.01	-5987.89	-5619.38	-5611.48
	Deviance		11994.02	11975.78	11238.76	11222.96

Note:

[a, b] significant at [a] $P < 0.05$; [b] $P < 0.001$;

AOR: Adjusted Odds Ratio,

CI: Confidence Interval,

Model 0- Empty (null) model

Model I- Only individual-level explanatory variables included in the model;

Model II- Only community-level explanatory variables included in the model;

Model III- Combined model; both individual-level and community-level explanatory variables

PCV: Proportional Change in Variance,

MOR: Median Odds Ratio

Factors associated with access to improved toilet facilities

The proportion of households with access to an improved sources of toilet facility was 25.36% at [95% CI: (24.69%, 26.03%)]. Individual-level factors such as educational level and marital status of the household head, and community level factors such as wealth index, sources of drinking water, number of household members, residence, and region were factors significantly impacting households' access to improved toilet facilities.

Compared to household heads that had no formal education, households with heads who attained higher education were 2.21 times more likely to have access to improved toilet facilities at [AOR = 2.21 CI: (1.12, 4.36)]. The likelihood of access to improved toilet facilities was 25% [AOR = 0.75, CI: (0.57, 0.98)] lower in households with heads who were widowed compared to those who never married.

Compared to poorest households' access to improved toilet facilities, households with the following wealth indices have the following positive associations: poor households had [AOR = 3.97 CI: (2.99, 5.29 higher probability, middle households had a [AOR = 5.82 CI: (4.35, 7.80)] higher probability, richer households had a [AOR = 8.58 CI: (6.40, 11.50)] higher probability, and richest households had an [AOR = 23.94 CI: (17.45, 32.83) higher probability.

Households who had improved sources of drinking water were 1.37 [AOR = 1.37 CI: (1.12, 1.66)] times more likely to have access to improved toilet facilities compared to their counterparts.

Households with more members were less likely to have access to improved toilet facilities. Compared to households with one to three members, households with four to six members had a 24% [AOR = 0.86 (0.75, 0.98)] lower probability to have access to improved toilet facilities.

In this study, a decrease in the probability of access to improved toilet facilities was observed for rural households contrary to urban households by 72% [AOR = 0.28 CI: (0.20, 0.38)].

About 72.00% in Tigray [AOR = 0.28, CI: (0.17, 0.46)] , 63.00% in Afar [AOR = 0.37, CI: (0.21, 0.67)], 96.00% in Amhara [AOR = 0.04, (0.02, 0.06)], 90.00% in Oromia [AOR = 0.10, CI: (0.06, 0.17)], 95.00% in Benishangul Gumuz [AOR = 0.05 CI: (0.03, 0.10)], 80.00% in SNNPR [AOR = 0.20 CI: (0.12, 0.33)], 85% in Gambella [AOR = 0.15 CI:(0.09, 0.26)], and 60.00% in Harari [AOR = 0.40 CI: (0.24, 0.66)] households had a higher probability to have access to improved toilet facilities as compared to households in Addis Ababa city **[Table 3].**

Table 3: Multivariable multilevel logistic regression model of the effects of individual- and community-level factors on improved sources of toilet facilities in Ethiopia, EDHS 2016

Variables		Null Model	Model I	Model II	Model III
			AOR(95% CI)	AOR(95% CI)	AOR(95% CI)
Sex of the household head	Male		1		1
	Female		1.01 (0.88, 1.16)		1.03 (0.89, 1.19)
Age of the household head	13 to 30		1		1
	31 to 40		0.99 (0.85, 1.15)		1.04 (0.89, 1.21)
	41 to 56		0.98 (0.84, 1.15)		1.02 (0.86, 1.20)
	□ 57		0.98 (0.83, 1.16)		1.08 (0.91, 1.28)
Education level of the household head	No education		1		1
	Primary		1.34 (0.67, 2.67)		1.19 (0.59, 2.40)
	Secondary		0.74 (0.40, 1.36)		0.75 (0.41, 1.38)
	Higher		2.26 (1.13, 4.54)		**2.21 (1.12, 4.36)[b]**
Current marital status of the household head	Never married		1		1
	Married		0.87 (0.71, 1.08)		0.99 (0.80, 1.22)
	Divorced		0.69 (0.52, 0.91)[b]		0.82 (0.62, 1.08)
	Widowed		0.66 (0.50, 0.86)[c]		**0.75 (0.57, 0.98)[b]**
Household wealth index	Poorest			1	1
	Poor			3.99 (3.00, 5.31)[c]	**3.97 (2.99, 5.29)[c]**
	Middle			5.87 (4.39, 7.86)[c]	**5.82 (4.35, 7.80)[c]**
	Richer			8.65 (6.46, 11.58)[c]	**8.58 (6.40, 11.50)[c]**
	Richest			24.76 (18.08, 33.91)[c]	**23.94 (17.45, 32.83)[c]**
Source of drinking water	Unimproved			1	1
	Improved			1.36 (1.12, 1.65)[c]	**1.37 (1.12, 1.66)[c]**
Household size	1 – 3 members			1	1
	4 – 6 members			0.88 (0.78, 0.99)[a]	**0.86 (0.75, 0.98)[c]**
	7+			1.07 (0.91, 1.26)	1.02 (0.86, 1.22)
Place of residence	Urban			1	1
	Rural			0.28 (0.21, 0.39)[c]	**0.28 (0.20, 0.38)[c]**
Region	Tigray			0.27 (0.16, 0.45)[c]	**0.28 (0.17, 0.46)[c]**
	Afar			0.38 (0.21, 0.68)[c]	**0.37 (0.21, 0.67)[c]**

	Amhara			0.04 (0.02, 0.06) [c]	**0.04 (0.02, 0.06) [c]**
	Oromia			0.10 (0.06, 0.17) [c]	**0.10 (0.06, 0.17) [c]**
	Somali			1.33 (0.79, 2.22)	1.32 (0.79, 2.21)
	Benishangul G.			0.05 (0.03, 0.10) [c]	**0.05 (0.03, 0.10) [c]**
	SNNPR			0.20 (0.12, 0.34) [c]	**0.20 (0.12, 0.33) [c]**
	Gambella			0.15 (0.09, 0.26) [c]	**0.15 (0.09, 0.26) [c]**
	Harari			0.40 (0.24, 0.66) [c]	**0.40 (0.24, 0.66) [c]**
	Dire Dawa			1.13 (0.69, 1.87)	1.14 (0.69, 1.89)
	Addis Ababa			1	1
Random effect	Community level variance(SE)	8.66 (0.73)[c]	8.71 (0.74)[c]	1.21 (0.12)[c]	1.22 (0.12)[c]
	ICC (%)	72.46%	72.58%	26.95%	27.08%
	MOR	16.37	16.50	2.84	2.86
	PCV	reference	-1.07%	86.03	85.91%
Model fit statistics	Log-likelihood	-5621.74	-5603.26	-5029.24	-5018.39
	Deviance	11243.48	11206.52	11036.78	10058.48

Note:

[a, b, c] significant at [a] P < 0.05; [b] p < 0.01, [c] P < 0.001;

AOR: Adjusted Odds Ratio,

CI: Confidence Interval,

Model 0- Empty (null) model

Model I- Only individual-level explanatory variables included in the model;

Model II- Only community-level explanatory variables included in the model;

Model III- Combined model; both individual-level and community-level explanatory variables

PCV: Proportional Change in Variance,

MOR: Median Odds Ratio

Random-effects analysis

The prevalence of access to improved drinking water sources varied across communities (community-level variance = 12.24, p = <0.001) **[Table 2]**. The null model (Model 0) revealed that 78.81% of the total variance in the odds of access to improved drinking water sources was accounted by between-cluster variation of characteristics (ICC = 0.7881). The inter-cluster

variability declined over successive models, from 78.81% in the null model to 78.55% in the only individual-level, 59.08% in the only community-level, and 58.97% in the final (combined) models. The proportional change in variance indicated that the addition of predictors to the empty model explained an increased proportion of variation in access to improved drinking water sources. The combined model showed that a higher PCV, i.e., 61.36% of the variance in access to improved drinking water sources could be explained by the combined factors at the individual- and community-level factors.

In [**Table 3]** the final model (**Model III**), ICC value of 0.2708 displayed that 27.08% of the total variation in access to improved toilet facilities is accounted for the community-level factors. The remaining 72.92% variation is therefore triggered by the individual- level and other unknown factors. The proportional change in variance indicated that the addition of predictors to the empty model explained an increased proportion of variation in access to improved toilet facilities. The combined model showed a higher PCV, i.e., 85.91% of the variance in access to improved toilet facilities could be explained by the combined factors at the individual- and community-level factors.

Model fit statistics

As shown in [**Tables 2 & 3**] (model fit statistics), the values of log-likelihood and Deviance showed a subsequent reduction which demonstrated that each model represents a significant improvement over the previous model and it points to the goodness of fit for the final model built in the analysis.

DISCUSSION

In this study, we aimed to assess access to improved drinking water sources and toilet facilities and their associated factors in Ethiopia. Accordingly, the proportion of households' access to improved drinking water sources was 69.94%, [95% CI: (69.23, 70.63)]. This finding is lower than reports from studies conducted in Ghana,[2] Viet Nam,[16], and Eswatini. [14] Whereas, it is higher than a reported proportion from a study conducted in Nepal. [15] The proportion of households' access to toilet facilities was 25.36%, [95% CI: (24.69, 26.03)]. This result is higher than the one reported from Ghana,[2] However, lower than studies from Nigeria [29] and Viet Nam. [16] The variation could be the disparities in GDP status and literacy rate among countries, study period, and setting.

Individual-level factors were associated with both access to improved drinking water sources and toilet facilities in the present study. Female-headed households were 1.18 times more likely than male-headed households to access improved drinking water sources. Similar findings were reported from Ghana, Vietnam, and Nigeria. [2, 16, 30] Gender differences may play an important role in the work division in developing countries. Most of the time women have higher household responsibilities such as fetching water, cleaning compounds, childcare, and food preparation, etc. Therefore, this might be directly linked with water and sanitation in the sense that women may be preoccupied with other daily routines than WASH.

Those households with heads having better educational status were 2.21 times more likely to access improved toilet facilities. This study finding is supported by evidences from previous studies. [14, 29, 31] Households who are led by heads who have no education had a lower probability of access to improved toilet facilities. In sub-Saharan Africa, education is a resource factor of

quality health outcomes, and educated people usually are more aware of the condition that guarantees their well beings. This implies that educated household heads in this study may have utilized their resources to provide their households with improved toilet facilities.

In addition to individual-level factors, community-level factors were also a significant factor in determining access to improved drinking water sources and toilet facilities. Compared to households within the poorest category, households within the poor, middle, richer, and richest wealth index category were 1.48, 2.42, 3.26, and 6.97 times more likely to have access to improved sources of drinking water and 3.97, 5.82, 8.58, and 23.94 times higher odds to access to improved toilet facilities, respectively. This result is consistent with results from previous studies. [13, 14, 32] People who have better incomes would intend to fulfill the necessities of life. Economically, the rich can afford the initial high cost of both water and sanitation facilities and the poor may be disproportionately underserved in the distribution of public utility, and hence consume poor quality water and use unimproved toilet facilities.

Compared to households that got drinking water < 30 minutes, households which obtained drinking water ≥ 30 minutes were 35% less likely to access improved drinking water sources. Hence, the length of time to get drinking (proximity of a house to a drinking water sources) water might make difference in access to improved sources of drinking water and coverage (%) with improved water supply (HH connection, public standpipes, protected underground water sources, rainwater collection). This is not surprising as physical distance is one of the reasons of WASH service inaccessibility.

The adjusted odds of access to improved drinking water sources and toilet facilities were 94.00% and 72.00% less likely among rural households as compared to urban households, respectively. The rural-urban disparity in access to improved sources of drinking water and toilet facilities have

been reported by several other previous studies, too. [12, 33, 34]. The disparity might be, in Sub-Saharan Africa, most of the people live in rural areas and their economic status is poor. Therefore, they do not have adequate financial resources to acquire improved drinking water sources and toilet facilities.

Furthermore, households who had improved sources of drinking water were 1.37 times more likely to access an improved toilet facilities. This study finding is consistent with an earlier study. [29] The possible explanation could be a lack of access to adequate sanitation is also linked to the limited access to water supply and households who had improved water sources may be practicing more in hygiene and sanitation.

Lastly, those households with four to six members were 24% less likely to have access to improved toilet facilities compared to households with one to three members. This is contrary to that of an earlier study. [2] The possible explanation could be the highest number of household members, the fewer resources they could have to build improved toilet facilities.

The results of our study should be interpreted with the following limitations. Since the information is recorded retrospectively, it might be prone to recall bias, and the analyses were conducted using data collected in a cross-sectional survey, which prevents causal inferences.

CONCLUSIONS

The proportion of households' access to an improved sources of drinking water and toilet facilities was low in Ethiopia. Sex of the household head, household wealth index, time to get drinking water, place of household/ urban/ rural residence, and region were factors impacting access to improved drinking water sources. Educational level of the household head, household wealth index, marital status of the household head (widowed), sources of drinking water, number of household members, household or rural/urban residence, and region were factors associated with access to improved toilet facilities. Thus, we authors recommend governmental and non-governmental organizations working on water, hygiene, and sanitation should consider a multi-faceted policy approach that accounts for the regions and residence variations and other identified factors to ease up the problem.

Acknowledgments

We would like to thank the Demographic and Health Survey (DHS) programme for allowing the use of Ethiopian Demographic and Health Survey (EDHS) data for this study.

Competing interests: None declared.

Patient consent for publication: Not required.

Ethics approval: The EDHS 2016 was approved by the National Research Ethics Review Committee of Ethiopia and ICF Macro International. The approval letter was obtained from the measure DHS for the use of this data, and the dataset was downloaded from www.meauredhs.com. This analysis was approved by the Department of Environmental and occupational health and safety, University of Gondar.

Funding

The author(s) received no specific funding for this work.

Availability of data and materials

The dataset analyzed during the current study available from the corresponding author upon reasonable request.

Authors' contributions

ZA wrote the analyzed data, drafted the manuscript, and prepared the manuscript. HD, ZNA, AAT, BD, RF, AGM, and YY involved in drafting, writing – review & editing, and commenting the manuscript. All authors read and approved the final manuscript.

REFERENCES

1. Prüss-Ustün A, Wolf J, Bartram J, Clasen T, Cumming O, Freeman MC, et al. Burden of disease from inadequate water, sanitation and hygiene for selected adverse health outcomes: An updated analysis with a focus on low-and middle-income countries. International journal of hygiene and environmental health. 2019;222(5):765-77.
2. Agbadi P, Darkwah E, Kenney PL. A Multilevel Analysis of Regressors of Access to Improved Drinking Water and Sanitation Facilities in Ghana. Journal of environmental and public health. 2019;2019.
3. Assembly UG. Resolution on Human Right to Water and Sanitation. New York: United Nations. 2010.
4. Brookes JD, Carey CC. Ensure availability and sustainable management of water and sanitation for all. UN Chronicle. 2015;51(4):15-6.
5. Mills JE, Cumming O. The impact of water, sanitation and hygiene on key health and social outcomes. URL: https://www lshtm ac uk/sites/default/files/2017-07/WASHEvidencePaper_HighRes_01. 2016;23.
6. Saxena SK, Kumar S, Haikerwal A, Bhatt ML. Introductory chapter: Neglected tropical waterborne infectious diseases-strategies for mitigation. Water Challenges of an Urbanizing World. 2018:1.
7. Organization WH. Water, sanitation, hygiene, and waste management for the COVID-19 virus: interim guidance, 23 April 2020. World Health Organization, 2020.
8. Organization WH. Progress on drinking water, sanitation and hygiene: 2017 update and SDG baselines. 2017.
9. Organization WH. Water, sanitation, hygiene and health: a primer for health professionals. World Health Organization, 2019.
10. Organization WH. Safer water, better health. 2019.
11. UNICEF. Water, sanitation and hygiene (WASH) 2020 [cited 2020 April, 14]. Available from: https://www.unicef.org/ethiopia/water-sanitation-and-hygiene-wash.
12. Mulenga JN, Bwalya BB, Kaliba-Chishimba K. Determinants and inequalities in access to improved water sources and sanitation among the Zambian households. International Journal of Development and Sustainability. 2017;6(8):746-62.

13. Morakinyo OM, Adebowale SA, Oloruntoba EO. Wealth status and sex differential of household head: implication for source of drinking water in Nigeria. Archives of Public Health. 2015;73(1):58.

14. Simelane MS, Shongwe MC, Vermaak K, Zwane E. Determinants of Households' Access to Improved Drinking Water Sources: A Secondary Analysis of Eswatini 2010 and 2014 Multiple Indicator Cluster Surveys. Advances in Public Health. 2020;2020.

15. Wang C, Pan J, Yaya S, Yadav RB, Yao D. Geographic Inequalities in Accessing Improved Water and Sanitation Facilities in Nepal. International journal of environmental research and public health. 2019;16(7):1269.

16. Tuyet-Hanh TT, Long TK, Van Minh H, Huong LTT. Longitudinal household trends in access to improved water sources and sanitation in Chi Linh town, Hai Duong province, Viet Nam and associated factors. AIMS public health. 2016;3(4):880.

17. Organization WH, UNICEF. Progress on drinking water and sanitation: special focus on sanitation. Progress on drinking water and sanitation: special focus on sanitation2008.

18. Beyene A, Hailu T, Faris K, Kloos H. Current state and trends of access to sanitation in Ethiopia and the need to revise indicators to monitor progress in the Post-2015 era. BMC Public Health. 2015;15:451-.

19. Pullan RL, Freeman MC, Gething PW, Brooker SJ. Geographical inequalities in use of improved drinking water supply and sanitation across sub-Saharan Africa: mapping and spatial analysis of cross-sectional survey data. PLoS Med. 2014;11(4):e1001626.

20. Central Statistical Agency (CSA). Central Statistical Agency (CSA) [Ethiopia] and ICF Ethiopia demographic and health Survey 2016. Addis Ababa, Ethiopia, and Rockville, Maryland, USA: CSA and ICF,2017.

21. Simelane M, Shongwe M, Vermaak K, Zwane E. Determinants of Households' Access to Improved Drinking Water Sources: A Secondary Analysis of Eswatini 2010 and 2014 Multiple Indicator Cluster Surveys. 2020;2020.

22. Ribeiro Sarmento MPH D. An Analysis of Access to Improved Drinking Water and Sanitation and Distance to the Water Source in a Newly Independent Country, Timor-Leste: Assessing Geographical and Socioeconomic Disparities. 2015.

23. Supply WUJW, Programme SM, Organization WH, Supply WUJMPfW, Sanitation, UNICEF. Water for life: making it happen: World health organization; 2005.

24. Merlo J, Chaix B, Ohlsson H, Beckman A, Johnell K, Hjerpe P, et al. A brief conceptual tutorial of multilevel analysis in social epidemiology: using measures of clustering in multilevel logistic regression to investigate contextual phenomena. Journal of Epidemiology & Community Health. 2006;60(4):290-7.

25. Merlo J, Yang M, Chaix B, Lynch J, Råstam L. A brief conceptual tutorial on multilevel analysis in social epidemiology: investigating contextual phenomena in different groups of people. Journal of Epidemiology & Community Health. 2005;59(9):729-36.

26. Larsen K, Merlo J. Appropriate assessment of neighborhood effects on individual health: integrating random and fixed effects in multilevel logistic regression. American journal of epidemiology. 2005;161(1):81-8.

27. Spiegelhalter DJ, Best NG, Carlin BP, Van Der Linde A. Bayesian measures of model complexity and fit. Journal of the royal statistical society: Series b (statistical methodology). 2002;64(4):583-639.

28. Joseph F. Hair, Jr. William, Black Barry J., Babin Rolph, E. Anderson. Multivariate Data Analysis Edition S, editor2018.

29. Abubakar IR. Access to sanitation facilities among Nigerian households: determinants and sustainability implications. Sustainability. 2017;9(4):547.

30. Morakinyo OM, Adebowale SA, Oloruntoba EO. Wealth status and sex differential of household head: implication for source of drinking water in Nigeria. Archives of public health = Archives belges de sante publique. 2015;73:58.

31. Akpakli DE, Manyeh AK, Akpakli JK, Kukula V, Gyapong M. Determinants of access to improved sanitation facilities in rural districts of southern Ghana: evidence from Dodowa Health and Demographic Surveillance Site. BMC Res Notes. 2018;11(1):473-.

32. Njuguna J. Progress in sanitation among poor households in Kenya: evidence from demographic and health surveys. BMC Public Health. 2019;19(1):135.

33. Irianti S, Prasetyoputra P, Sasimartoyo TP. Determinants of household drinking-water source in Indonesia: An analysis of the 2007 Indonesian family life survey. Cogent Medicine. 2016;3(1).

34. Prasetyoputra P, Irianti S. Access to improved sanitation facilities in indonesia: An econometric analysis of geographical and socioeconomic disparities. Journal of Applied Sciences in Environmental Sanitation. 2013;8(3).

Supplementary Table 1: Regional distribution of access to improved drinking water sources and toilet facilities in Ethiopia, EDHS, 2016.

Region	Source of drinking water		Toilet facilities	
	Unimproved	Improved	Unimproved	Improved
Tigray	410 (23.64%)	1,324 (76.36%)	1,380 (79.58%)	354 (20.42%)
Afar	627 (51.39%)	593 (48.61%)	1,032 (84.59%)	188 (15.41%)
Amhara	741 (38.96%)	1,161 (61.04%)	1,782 (93.69%)	120 (6.31%)
Oromia	746 (37.53%)	1,242 (62.47%)	1,785 (89.79%)	203 (10.21%)
Somali	884 (56.52%)	680 (43.48%)	1,145 (73.21%)	419 (26.79%)
Benishangul Gumuz	271 (21.17%)	1,009 (78.83%)	1,225 (95.70%)	55 (4.30%)
SNNPR	775 (40.85%)	1,122 (59.15%)	1,650 (86.98%)	247 (13.02%)
Gambella	246 (19.22%)	1,034 (80.78%)	1,098 (85.78%)	182 (14.22%)
Harari	179 (15.77%)	956 (84.23%)	619 (54.54%)	516 (45.46%)
Dire Dawa	117 (10.08%)	1,044 (89.92%)	404 (34.80%)	757 (65.20%)
Addis Ababa	9 (0.60%)	1,480 (99.40%)	308 (20.69%)	1,181 (79.31%)
Total	5005(30.06%)	11,645 (69.94%)	12,428 (74.64%)	4,222 (25.36%)

STROBE (Strengthening The Reporting of OBservational Studies in Epidemiology) Checklist

A checklist of items that should be included in reports of observational studies. You must report the page number in your manuscript where you consider each of the items listed in this checklist. If you have not included this information, either revise your manuscript accordingly before submitting or note N/A.

Note: An Explanation and Elaboration article discusses each checklist item and gives methodological background and published examples of transparent reporting. The STROBE checklist is best used in conjunction with this article (freely available on the Web sites of PLoS Medicine at http://www.plosmedicine.org/, Annals of Internal Medicine at http://www.annals.org/, and Epidemiology at http://www.epidem.com/). Information on the STROBE Initiative is available at www.strobe-statement.org.

Section and Item	Item No.	Recommendation	Reported on Page No.
Title and Abstract	1	(*a*) Indicate the study's design with a commonly used term in the title or the abstract	
		(*b*) Provide in the abstract an informative and balanced summary of what was done and what was found	
Introduction			
Background/Rationale	2	Explain the scientific background and rationale for the investigation being reported	
Objectives	3	State specific objectives, including any prespecified hypotheses	
Methods			
Study Design	4	Present key elements of study design early in the paper	
Setting	5	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection	
Participants	6	(*a*) *Cohort study*—Give the eligibility criteria, and the sources and methods of selection of participants. Describe methods of follow-up *Case-control study*—Give the eligibility criteria, and the sources and methods of case ascertainment and control selection. Give the rationale for the choice of cases and controls *Cross-sectional study*—Give the eligibility criteria, and the sources and methods of selection of participants	
		(*b*) *Cohort study*—For matched studies, give matching criteria and number of exposed and unexposed *Case-control study*—For matched studies, give matching criteria and the number of controls per case	
Variables	7	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable	

Section and Item	Item No.	Recommendation	Reported on Page No.
Data Sources/ Measurement	8*	For each variable of interest, give sources of data and details of methods of assessment (measurement). Describe comparability of assessment methods if there is more than one group	
Bias	9	Describe any efforts to address potential sources of bias	
Study Size	10	Explain how the study size was arrived at	
Quantitative Variables	11	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why	
Statistical Methods	12	(*a*) Describe all statistical methods, including those used to control for confounding	
		(*b*) Describe any methods used to examine subgroups and interactions	
		(*c*) Explain how missing data were addressed	
		(*d*) *Cohort study*—If applicable, explain how loss to follow-up was addressed *Case-control study*—If applicable, explain how matching of cases and controls was addressed *Cross-sectional study*—If applicable, describe analytical methods taking account of sampling strategy	
		(*e*) Describe any sensitivity analyses	
Results			
Participants	13*	(a) Report numbers of individuals at each stage of study—eg numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analysed	
		(b) Give reasons for non-participation at each stage	
		(c) Consider use of a flow diagram	
Descriptive Data	14*	(a) Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders	
		(b) Indicate number of participants with missing data for each variable of interest	
		(c) *Cohort study*—Summarise follow-up time (eg, average and total amount)	
Outcome Data	15*	*Cohort study*—Report numbers of outcome events or summary measures over time	
		Case-control study—Report numbers in each exposure category, or summary measures of exposure	
		Cross-sectional study—Report numbers of outcome events or summary measures	

Section and Item	Item No.	Recommendation	Reported on Page No.
Main Results	16	(*a*) Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (eg, 95% confidence interval). Make clear which confounders were adjusted for and why they were included	
		(*b*) Report category boundaries when continuous variables were categorized	
		(*c*) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period	
Other Analyses	17	Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses	
Discussion			
Key Results	18	Summarise key results with reference to study objectives	
Limitations	19	Discuss limitations of the study, taking into account sources of potential bias or imprecision. Discuss both direction and magnitude of any potential bias	
Interpretation	20	Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence	
Generalisability	21	Discuss the generalisability (external validity) of the study results	
Other Information			
Funding	22	Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based	

*Give information separately for cases and controls in case-control studies and, if applicable, for exposed and unexposed groups in cohort and cross-sectional studies.

Once you have completed this checklist, please save a copy and upload it as part of your submission. DO NOT include this checklist as part of the main manuscript document. It must be uploaded as a separate file.