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

Journal:	<i>BMJ Open</i>
Manuscript ID	bmjopen-2020-042071
Article Type:	Original research
Date Submitted by the Author:	30-Jul-2020
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Keywords:	PUBLIC HEALTH, PREVENTIVE MEDICINE, Health policy < HEALTH SERVICES ADMINISTRATION & MANAGEMENT

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

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3 [AOR =1.37, 95% CI: (1.12, 1.66)], household size [4 to 6] [AOR = 0.86, 95% CI: (0.75, 0.98)],
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5 rural residence [AOR = 0.28, 95% CI: (0.20, 0.38)], households with better wealth index, and
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7 region were significantly associated with access to improved toilet facilities
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11 **Conclusion:** The proportions of households' access to improved drinking water sources and toilet
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13 facilities in Ethiopia was relatively low.
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17 **Keywords:** Improved toilet facilities, Improved water sources, Multilevel analysis, Ethiopia
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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)

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

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3 procedure is presented elsewhere. ⁽¹⁹⁾ The current study included individual-level data for 16650
4 household heads as well as community characteristics of 645 clusters.
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8 **Variables of the study**

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

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24 **Improved sources of drinking water:** a household is said to have access to an improved drinking
25 water source if it has water piped into its dwelling, water piped to a yard/plot, a public
26 tap/standpipe, a tube well/borehole, a protected dug well, a protected spring, rainwater, bottled
27 water, or sachet water. ⁽²⁰⁾
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34 **Improved types of toilet facilities:** a household is said to have access to improved toilet facilities
35 if it has unshared flush/pour flush to piped sewer systems, septic tanks or pit latrines, ventilated
36 improved pit latrines, composting toilets, or pit latrines with slabs. ⁽²⁰⁾
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41 **Data processing and analysis**

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43 Statistical analysis was performed using Stata 16.00 software. The weighted frequencies and the
44 percentages (based on the population size of each region) were computed. The detailed weighting
45 procedure is described elsewhere. ⁽¹⁹⁾
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51 Multilevel binary logistic regression model was used to assess the impact of individual and
52 community-level factors on households' access to an improved source of drinking water and
53 improved toilet facilities. The model, which is most appropriate to consider the cluster random
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3 effect in a multivariate setting and the reason to apply multilevel modeling was the nature of the
4 data collected which have a hierarchical or clustered structure. The first level represents the
5 individual and household and the second level factor is the clusters. Four models were tested in
6 each of the cases (access to an improved source of drinking water and toilet facilities). **Model 0**
7 (the null model) was fitted without explanatory variables to test random variability in the intercept
8 and to estimate the intraclass correlation coefficient (ICC). **Model I** was used to investigate the
9 impact of individual-level factors on the likelihood of having access to improved sources of
10 drinking water and toilet facilities. **Model II** was used to assess the impact of community-level
11 factors on the likelihood of having access to improved sources of drinking water and toilet
12 facilities. **Model III** was employed to assess the impact of individual and community-level factors
13 altogether on access to improved sources of drinking water and toilet facilities.
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29 The random effects (variation of effects) were measured by ICC, percentage change in variance
30 (PCV), Median Odds Ratio (MOR), and deviance (-2log likelihood), which measure the variability
31 between clusters in the multilevel models. The ICC explains the cluster variability, while MOR
32 used to quantify unexplained cluster variability (heterogeneity). The MOR was used to translate
33 cluster variance into OR scale. (21-23) In the multilevel model, deviance can measure the total
34 variation due to factors at the community and individual level. (22, 24)
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44 Adjusted odds ratio with a 95% confidence interval were reported. P-value < 0.05 was used to
45 declare a significant association among covariates and outcome variables. A multicollinearity test
46 was performed to rule out if there was a significant correlation between explanatory variables. If
47 the values of variance inflation factor (VIF) was lower than 10, then the collinearity problem was
48 considered as less likely. (25)
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RESULTS

Sociodemographic characteristics of study participants

A total of 16650 study participants were included in the study. The median (\pm SD) age of the household heads was 40 years (\pm 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
	\geq 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

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3 least access to an improved sources of drinking water. Households in Benishangul-Gumuz and
4 Amhara regions were lowest in access to toilet facilities with 4.30% and 6.31%, respectively while
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7 households in Dire Dawa and Addis Ababa had the highest access to improved toilet facilities with
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10 65.20% and 79.31%, respectively [S1 Table 1].
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12 13 **Factors associated with access to improved drinking water sources** 14

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16 The proportion of households which had access to an improved sources of drinking water was
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18 69.94% at [95% CI: (69.23, 70.63)]. Both individual-level factors and community-level factors
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20 had an impact on accessing improved drinking water sources in this study. Among individual-level
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22 factors; sex of household head and from community-level factors; wealth index, time to get to
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24 drinking water sources, residence and region were significantly associated with access to improved
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26 drinking water sources
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30 Female-headed households were 1.18 [AOR = 1.18, CI: (1.01, 1.37)] times more likely to have
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32 access to improved drinking water sources than male-headed households.
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35 Compared to poorest households, poorer [AOR = 1.48, CI: (1.26, 1.74)], middle-income [AOR =
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37 2.42, CI: (2.03, 2.90)], richer [AOR = 3.26, CI: (2.68, 3.97)] and richest [AOR = 6.97, CI: (5.17,
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39 9.41)] households were 1.48, 2.42, 3.26, and 6.97 times more likely to access improved drinking
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41 water sources at, respectively.
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45 In contrasted with family units who got drinking water < 30 minutes, households who got drinking
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47 water \geq 30 minutes were 35% less likely to access drinking water [AOR = 0.65, CI: (0.58, 0.73)].
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51 The adjusted odds of access to improved drinking water sources in rural area was 94.00% less
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53 likely compared to urban area [AOR = 0.06, CI: (0.03, 0.11)].
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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

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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

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3	Number of household members	1 – 3 members			1	1
4		4 – 6 members			0.88 (0.78, 0.99) ^a	0.86 (0.75, 0.98)^c
5		7+			1.07 (0.91, 1.26)	1.02 (0.86, 1.22)
6	Residence	Urban			1	1
7		Rural			0.28 (0.21, 0.39) ^c	0.28 (0.20, 0.38)^c
8	Region	Tigray			0.27 (0.16, 0.45) ^c	0.28 (0.17, 0.46)^c
9		Afar			0.38 (0.21, 0.68) ^c	0.37 (0.21, 0.67)^c
10		Amhara			0.04 (0.02, 0.06) ^c	0.04 (0.02, 0.06)^c
11		Oromia			0.10 (0.06, 0.17) ^c	0.10 (0.06, 0.17)^c
12		Somali			1.33 (0.79, 2.22)	1.32 (0.79, 2.21)
13		Benishangul G.			0.05 (0.03, 0.10) ^c	0.05 (0.03, 0.10)^c
14		SNNPR			0.20 (0.12, 0.34) ^c	0.20 (0.12, 0.33)^c
15		Gambella			0.15 (0.09, 0.26) ^c	0.15 (0.09, 0.26)^c
16		Harari			0.40 (0.24, 0.66) ^c	0.40 (0.24, 0.66)^c
17		Dire Dawa			1.13 (0.69, 1.87)	1.14 (0.69, 1.89)
18	Addis Ababa			1	1	
19	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
20		ICC (%)	72.46%	72.58%	26.95%	27.08%
21		MOR	16.37	16.50	2.84	2.86
22		PCV	reference	-1.07%	86.03	85.91%
23	Model fit statistics	Log-likelihood	-5621.74	-5603.26	-5029.24	-5018.39
24		Deviance	11243.48	11206.52	11036.78	10058.48

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Note:
^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

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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

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3 improvement over the previous model and it points to the goodness of fit for the final model built
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5 in the analysis.
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10 **DISCUSSION**

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13 In this study, we aimed to assess access to improved drinking water sources and sanitation facilities
14 and their associated factors in Ethiopia. Accordingly, the proportion of households' access to
15 improved drinking water sources was 69.94%, [95% CI: (69.23, 70.63)]. This finding is lower than
16 reports from studies conducted in Ghana,⁽²⁾ Viet Nam,⁽¹⁶⁾ and Eswatini. ⁽¹⁴⁾ Whereas, it is higher
17 than a reported proportion from a study conducted in Nepal. ⁽¹⁵⁾ The proportion of households'
18 access to toilet facilities was 25.36%, [95% CI: (24.69, 26.03)]. This result is higher than the one
19 reported from Ghana,⁽²⁾ However, lower than studies from Nigeria,⁽²⁶⁾ and Viet Nam. ⁽¹⁶⁾ The
20 variation could be the disparities in GDP status and literacy rate among countries, study period,
21 and setting.
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35 Individual-level factors were associated with access to improved drinking water sources and toilet
36 facilities in the present study. Female-headed households were 1.18 times more likely than male-
37 headed households to access improved drinking water sources. Similar findings were reported
38 from Ghana, Vietnam, and Nigeria. ^(2, 16, 27) Gender differences may play an important role in the
39 work division in developing countries. Most of the time women have higher household
40 responsibilities such as fetching water, cleaning compound, childcare, and food preparation, etc.
41 Therefore, this might be directly linked with water and sanitation in the sense that women may be
42 preoccupied with other daily routines than WASH.
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3 Those households with heads having better educational status were 2.21 times more likely to
4 access improved toilet facilities. This finding supported by evidence from previous studies.^{(14, 26,}
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8 ²⁸⁾ Households who are led by heads who have no education had a lower probability of access to
9 improved toilet facilities. In sub-Saharan Africa, education is a resource factor of quality health
10 outcomes, and educated people usually are more aware of the condition that guarantees their well
11 beings. This implies that educated household heads in this study may have utilized their resources
12 to provide their households with improved toilet facilities.
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20 In addition to individual level factors, community-level factors were also associated with access
21 to improved drinking water sources and toilet facilities. When compared to households within a
22 poorest category, households within poorer, middle, richer and richest wealth index category were
23 1.48, 2.42, 3.26, and 6.97 times more likely to have access to improved sources of drinking water
24 and 3.97, 5.82, 8.58, and 23.94 times higher odds to access improved toilet facilities, respectively.
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31 This result is consistent with results from previous studies.^(13, 14, 29) People who have better income
32 would intend to fulfill the necessities of life. Economically, the rich can afford the initial high cost
33 of both water and sanitation facilities and the poor may be disproportionately underserved in the
34 distribution of public utility, and hence consume poor quality water and use unimproved sanitation
35 facilities.
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44 Compared with households that got drinking water < 30 minutes, households which obtained
45 drinking water \geq 30 minutes were 35% less likely to access improved drinking water sources.
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47 Hence, the length of time to get drinking (proximity of a house to a drinking water source) water
48 might make difference in access to improved sources of drinking water and coverage (%) with
49 improved water supply (HH connection, public standpipes, protected underground water sources,
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3 rainwater collection). This is not surprising as physical distance is one of the reasons of WASH
4 service in accessibilities.
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8 The adjusted odds of access to improved drinking water sources and toilet facilities were 94.00%
9 and 72.00% less likely among rural households as compared to urban households, respectively.
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12 The rural-urban disparity in access to improved sources of drinking water and toilet facilities have
13 been reported by several other previous studies, too. (12, 30, 31). The disparity might be, in sub-
14 Saharan Africa, most of the people live in rural areas and their economic status is poor. Therefore,
15 they do not have adequate financial resources to acquire improved drinking water sources and
16 toilet facilities.
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25 Furthermore, households who had improved sources of drinking water were 1.37 times more likely
26 to access an improved toilet facilities. This study finding is consistent with an earlier study. (26)
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29 The possible explanation could be a lack of access to adequate sanitation is also linked to the
30 limited access to water supply and households who had improved water sources may be practicing
31 more in hygiene and sanitation.
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37 Lastly, those households with four to six were 24% less likely access to improved toilet facilities
38 compared to households with a family size of one to three. This is contrary to that of an earlier
39 study. (2) The possible explanation could be the highest number of household members, the fewer
40 resources they could have to build improved toilet facilities.
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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.measuredhs.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.

- 1
2
3 9. Organization WH. Water, sanitation, hygiene and health: a primer for health professionals.
4
5 World Health Organization, 2019.
6
- 7
8 10. Organization WH. Safer water, better health. 2019.
9
- 10 11. UNICEF. Water, sanitation and hygiene (WASH) 2020 [cited 2020 April, 14]. Available
11
12 from: <https://www.unicef.org/ethiopia/water-sanitation-and-hygiene-wash>.
13
- 14
15 12. Mulenga JN, Bwalya BB, Kaliba-Chishimba K. Determinants and inequalities in access to
16
17 improved water sources and sanitation among the Zambian households. International Journal of
18
19 Development and Sustainability. 2017;6(8):746-62.
20
- 21
22 13. Morakinyo OM, Adebawale SA, Oloruntoba EO. Wealth status and sex differential of
23
24 household head: implication for source of drinking water in Nigeria. Archives of Public Health.
25
26 2015;73(1):58.
27
- 28
29 14. Simelane MS, Shongwe MC, Vermaak K, Zwane E. Determinants of Households' Access
30
31 to Improved Drinking Water Sources: A Secondary Analysis of Eswatini 2010 and 2014 Multiple
32
33 Indicator Cluster Surveys. Advances in Public Health. 2020;2020.
34
- 35
36 15. Wang C, Pan J, Yaya S, Yadav RB, Yao D. Geographic Inequalities in Accessing Improved
37
38 Water and Sanitation Facilities in Nepal. International journal of environmental research and
39
40 public health. 2019;16(7):1269.
41
- 42
43 16. Tuyet-Hanh TT, Long TK, Van Minh H, Huong LTT. Longitudinal household trends in
44
45 access to improved water sources and sanitation in Chi Linh town, Hai Duong province, Viet Nam
46
47 and associated factors. AIMS public health. 2016;3(4):880.
48
- 49
50 17. Organization WH, UNICEF. Progress on drinking water and sanitation: special focus on
51
52 sanitation. Progress on drinking water and sanitation: special focus on sanitation2008.
53
54
55
56
57
58
59

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.

- 1
2
3 26. Abubakar IR. Access to sanitation facilities among Nigerian households: determinants and
4 sustainability implications. *Sustainability*. 2017;9(4):547.
5
6
7
8 27. Morakinyo OM, Adebawale SA, Oloruntoba EO. Wealth status and sex differential of
9 household head: implication for source of drinking water in Nigeria. *Archives of public health =*
10 *Archives belges de sante publique*. 2015;73:58.
11
12
13
14 28. Akpakli DE, Manyeh AK, Akpakli JK, Kukula V, Gyapong M. Determinants of access to
15 improved sanitation facilities in rural districts of southern Ghana: evidence from Dodowa Health
16 and Demographic Surveillance Site. *BMC Res Notes*. 2018;11(1):473-.
17
18
19
20 29. Njuguna J. Progress in sanitation among poor households in Kenya: evidence from
21 demographic and health surveys. *BMC public health*. 2019;19(1):135.
22
23
24
25 30. Irianti S, Prasetyoputra P, Sasimartoyo TP. Determinants of household drinking-water
26 source in Indonesia: An analysis of the 2007 Indonesian family life survey. *Cogent Medicine*.
27 2016;3(1).
28
29
30
31 31. Prasetyoputra P, Irianti S. Access to improved sanitation facilities in indonesia: An
32 econometric analysis of geographical and socioeconomic disparities. *Journal of Applied Sciences*
33 *in Environmental Sanitation*. 2013;8(3).
34
35
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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) <i>Cohort study</i> —Give the eligibility criteria, and the sources and methods of selection of participants. Describe methods of follow-up <i>Case-control study</i> —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 <i>Cross-sectional study</i> —Give the eligibility criteria, and the sources and methods of selection of participants	
		(b) <i>Cohort study</i> —For matched studies, give matching criteria and number of exposed and unexposed <i>Case-control study</i> —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) <i>Cohort study</i> —If applicable, explain how loss to follow-up was addressed <i>Case-control study</i> —If applicable, explain how matching of cases and controls was addressed <i>Cross-sectional study</i> —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) <i>Cohort study</i> —Summarise follow-up time (eg, average and total amount)	
Outcome Data	15*	<i>Cohort study</i> —Report numbers of outcome events or summary measures over time	
		<i>Case-control study</i> —Report numbers in each exposure category, or summary measures of exposure	
		<i>Cross-sectional study</i> —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.

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

Journal:	<i>BMJ Open</i>
Manuscript ID	bmjopen-2020-042071.R1
Article Type:	Original research
Date Submitted by the Author:	11-Jan-2021
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Primary Subject Heading:	Public health
Secondary Subject Heading:	Occupational and environmental medicine
Keywords:	PUBLIC HEALTH, PREVENTIVE MEDICINE, Health policy < HEALTH SERVICES ADMINISTRATION & MANAGEMENT

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3 **1 Households' access to improved drinking water sources and toilet facilities in Ethiopia: A**
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5 **2 multilevel analysis based on 2016 Ethiopian Demographic and Health Survey**
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3 24 **ABSTRACT**
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6 25 **Objective:** This study aimed to assess households' access to improved drinking water sources
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8 26 and sanitation facilities and their associated factors in Ethiopia
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11 27 **Design:** Cross-sectional study
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14 28 **Setting:** Ethiopia
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17 29 **Participants:** Household heads
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20 30 **Primary outcomes:** Access to improved drinking water sources and sanitation facilities
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23 31 **Methods:** We conducted an in-depth secondary data analysis of 2016 Ethiopian Demographic and
24
25 32 Health Survey (EDHS). Data from a total of 16650 households and 645 clusters were included in
26
27 33 the analysis. The households in the EDHS were selected using a stratified two-stage cluster
28
29 34 sampling technique. Multilevel binary logistic regression analyses were performed to identify
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31 35 factors associated with access to an improved drinking water source and toilet facilities. Adjusted
32
33 36 odds ratio with a 95% CI were reported. P-value < 0.05 was used to declare a significant
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35 37 association between the covariates and outcomes.
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39 38 **Results:** The proportions of households' access to improved sources of drinking water and toilet
40
41 39 facilities were 69.94%, [95% CI: (69.23, 70.63)], and 25.36%, [95% CI: (24.69, 26.03)],
42
43 40 respectively. Female headed households [AOR = 1.18, 95% CI: (1.01, 1.37)] and better wealth
44
45 41 index, ≥ 30 minutes time to obtain drinking water [AOR = 0.65, 95% CI: (0.58, 0.73)], rural
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47 42 residence [AOR = 0.06, 95% CI: (0.03, 0.11)] and region were factors associated with access to
48
49 43 improved drinking water source. Whereas, higher educational status [AOR = 2.21, 95% CI: (1.12,
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51 44 4.36)], being widowed [AOR = 0.75, 95% CI: (0.57, 0.98)], improved source of drinking water
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3 45 [AOR =1.37, 95% CI: (1.12, 1.66)], household size [4 to 6] [AOR = 0.86, 95% CI: (0.75, 0.98)],
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5 46 rural residence [AOR = 0.28, 95% CI: (0.20, 0.38)], households with better wealth index, and
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7 47 region were significantly associated with access to improved toilet facilities
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10 48 **Conclusion:** The proportions of households' access to improved drinking water sources and toilet
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12 49 facilities in Ethiopia was relatively low.
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16 50 **Keywords:** Improved toilet facilities, improved water sources, multilevel analysis, Ethiopia
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3 **53 Strength and limitations of the study**
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6 54 ☞ The use of nationally representative data that can enhance the generalizability of the finding
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8 is one of the strength of the study.
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10 56 ☞ Due to the inherent nature of a cross-sectional study, it does not show the temporal
11
12 relationship between the outcome status and predictors.
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15 58 ☞ Moreover, important variables such as culture, traditions, and social norms were not
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17 available in EDHS data which could influence the use of toilet facility type.
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61 INTRODUCTION

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

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

72 Globally, 2 billion people lack basic sanitation services and 785 million people have no access to
73 clean water. ⁽⁸⁾ More than 1.9 million deaths and 123 million disability-adjusted life-years
74 (DALYs) could have been prevented by the provision of adequate access to water, hygiene, and
75 sanitation (WASH) worldwide. The WASH-attributable disease burden accounts to 4.6% of global
76 DALYs and 3.3% of global mortality. ⁽⁹⁾ The burden of under 5 mortality was 13%. ⁽¹⁰⁾ In Ethiopia,
77 60 to 80 % of communicable diseases are attributed to limited access to safe water, inadequate
78 sanitation, and hygiene services. ⁽¹¹⁾

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

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3 84 In Sub-Saharan Africa, particularly in Ethiopia access to improved sources of drinking water and
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5 85 toilet facilities is still lacking and people are practicing open defecation. (17, 18) There was no
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8 86 statistical approach in the study using nationally representative data (2016 EDHS data), which
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10 87 accounts for the hierarchical nature of the data. However, in 2014 national studies conducted in
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12 88 Sub-Saharan African countries indicates that the spatial coverage in use of improved drinking
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14 89 water supply and sanitation. (19) Therefore, the current study aimed to assess access to improved
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17 90 drinking water sources and toilet facilities and their associated factors in Ethiopia using EDHS
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19 91 2016 data.
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92 **METHODS**

93 **Patient and public involvement**

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

96 **Study design and area**

97 The 2016 main EDHS was a cross-sectional survey conducted from 18 January 2016 to 27 June
19 2016 in Ethiopia by the Ethiopian Central Statistical Agency (ECSA). For our case, we use an in-
20 21 depth secondary data analysis of the survey. The 2016 EDHS survey was the fourth survey
22 23 conducted in each of the 11 regions of Ethiopia (9 regional states and 2 administrative cities).
24 100 Administratively, each region in Ethiopia is divided into Zones, each Zone, in turn, is divided into
25 26 Woredas, and each Woreda into Kebeles (the lowest administrative units in the country). (20)

103 **Data sources**

104 Data were obtained from 2016 Ethiopian Demographic and Health Survey (EDHS-2016) after
35 36 being registered as an authorized user. The survey collects data on key indicators of health and
37 105 health-related events including access to drinking water and toilet facilities. A total of 16,650
38 39 106 households from 645 Enumeration Areas (EAs) were included in the survey. (20)

108 **Sample size and sampling procedure**

109 A two-stage stratified cluster sampling technique was employed to select study participants.
48 49 Sampling frame of the 2007 Population and Housing Censuses in which EAs were the sampling
50 51 units for the first stage and households for the second stage was used. A total of 18,008 households
52 53 111 were selected for the sample, of which 17,067 were occupied. Of the occupied households, 16,650
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3 113 were successfully interviewed, yielding a response rate of 98%. (20) The current study included
4
5 114 individual-level data for 16650 household heads as well as community characteristics of 645
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8 115 clusters.

11 116 **Variables of the study**

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14 117 The outcome variables are; access to improved drinking water sources and improved toilet
15
16 118 facilities. The explanatory variables; include sex, age, educational level, marital status of the
17
18 119 household heads, household wealth index, time to get to drinking water sources, family size,
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21 120 religion, media use, place of residence, and region.

23 121 **Operational definitions**

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25
26 122 **Improved sources of drinking water:** a household is said to have access to an improved drinking
27
28 123 water source if it has water piped into its dwelling, water piped to a yard/plot, a public
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30 124 tap/standpipe, a tube well/borehole, a protected dug well, a protected spring, rainwater, bottled
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32 125 water, or sachet water. (21)

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36 126 **Improved types of toilet facilities:** a household is said to have access to improved toilet facilities
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38 127 if it has unshared flush/pour flush to piped sewer systems, septic tanks or pit latrines, ventilated
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40 128 improved pit latrines, composting toilets, or pit latrines with slabs. (21)

42 129 **Data processing and analysis**

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45 130 Statistical analysis was performed using Stata 16.00 software. The weighted frequencies and the
46
47 131 percentages (based on the population size of each region) were computed. The detailed weighting
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49 132 procedure is described elsewhere. (20)

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53 133 Multilevel binary logistic regression model was used to assess the impact of individual and
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55 134 community-level factors on households' access to an improved source of drinking water and

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3 135 improved toilet facilities. The model, which is most appropriate to consider the cluster random
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5 136 effect in a multivariate setting and the reason to apply multilevel modeling was the nature of the
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8 137 data collected which have a hierarchical or clustered structure. The first level represents the
9
10 138 individual and household and the second level factor is the clusters. Four models were tested in
11
12 139 each of the cases (access to an improved source of drinking water and toilet facilities). **Model 0**
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14 140 (the null model) was fitted without explanatory variables to test random variability in the intercept
15
16 141 and to estimate the intraclass correlation coefficient (ICC). **Model I** was used to investigate the
17
18 142 impact of individual-level factors on the likelihood of having access to improved sources of
19
20 143 drinking water and toilet facilities. **Model II** was used to assess the impact of community-level
21
22 144 factors on the likelihood of having access to improved sources of drinking water and toilet
23
24 145 facilities. **Model III** was employed to assess the impact of individual and community-level factors
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26 146 altogether on access to improved sources of drinking water and toilet facilities.

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31 147 The random effects (variation of effects) were measured by ICC, percentage change in variance
32
33 148 (PCV), Median Odds Ratio (MOR), and deviance ($-2\log$ likelihood), which measure the variability
34
35 149 between clusters in the multilevel models. The ICC explains the cluster variability, while MOR is
36
37 150 used to quantify unexplained cluster variability (heterogeneity). The MOR was used to translate
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39 151 cluster variance into OR scale. ⁽²²⁻²⁴⁾ In the multilevel model, deviance can measure the total
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41 152 variation due to factors at the community and individual levels. ^(23, 25)

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46 153 Adjusted odds ratio with a 95% confidence interval were reported. P-value < 0.05 was used to
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48 154 declare a significant association among covariates and outcome variables. A multicollinearity test
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50 155 was performed to rule out if there was a significant correlation between explanatory variables. If
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52 156 the values of variance inflation factor (VIF) was lower than 10, then the collinearity problem was
53
54 157 considered as less likely. ⁽²⁶⁾

158 **RESULTS**

159 **Socio-demographic characteristics of study participants**

160 A total of 16650 study participants were included in the study. The median (\pm SD) age of the
 161 household heads was 40 years (\pm 16.22 years, range 15 - 95). Approximately, seven out of ten
 162 (69.94%) of the households had access to improved sources of drinking water and only one-fourth
 163 (25.36%) of households had access to an improved source of toilet facilities. Majority (98.37%)
 164 of respondents had no education. About 68.55% of households were male-headed. [Table 1].

165 Table 1: Socio-demographic characteristics of study participants in Ethiopia, EDHS 2016 (n=
 166 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
	\geq 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	

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

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

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3 171 least access to improved sources of drinking water. Households in Benishangul-Gumuz and
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5 172 Amhara regions were lowest in access to toilet facilities with 4.30% and 6.31%, respectively while
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8 173 households in Dire Dawa and Addis Ababa had the highest access to improved toilet facilities with
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10 174 65.20% and 79.31%, respectively [S1 Table 1].
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13 175 **Factors associated with access to improved drinking water sources**

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16 176 The proportion of households which had access to improved sources of drinking water was 69.94%
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18 177 at [95% CI: (69.23, 70.63)]. Both individual-level factors and community-level factors had an
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21 178 impact on accessing improved drinking water sources in this study. Among individual-level
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23 179 factors; sex of household head and from community-level factors; wealth index, time to get to
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25 180 drinking water sources, residence, and region were significantly associated with access to
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28 181 improved drinking water sources
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31 182 Female-headed households were 1.18 [AOR = 1.18, CI: (1.01, 1.37)] times more likely to have
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33 183 access to improved drinking water sources than male-headed households.
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36 184 Compared to poorest households, poorer [AOR = 1.48, CI: (1.26, 1.74)], middle-income [AOR =
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38 185 2.42, CI: (2.03, 2.90)], richer [AOR = 3.26, CI: (2.68, 3.97)] and richest [AOR = 6.97, CI: (5.17,
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40 186 9.41)] households were 1.48, 2.42, 3.26, and 6.97 times more likely to access improved drinking
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43 187 water sources, respectively.
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46 188 In contrasted with family units who got drinking water < 30 minutes, households who got drinking
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48 189 water ≥ 30 minutes were 35% less likely to access drinking water [AOR = 0.65, CI: (0.58, 0.73)].
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51 190 The adjusted odds of access to improved drinking water sources in rural area was 94.00% less
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53 191 likely compared to urban area [AOR = 0.06, CI: (0.03, 0.11)].
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192 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].

197 **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

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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

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

201 The proportion of households with access to an improved source of toilet facility was 25.36% at
202 [95% CI: (24.69%, 26.03%)]. Individual-level factors such as educational level of the household
203 heads, marital status, and community level factors such as wealth index, source of drinking water,
204 number of household members, residence, and region were factors significantly associated with
205 households' access to improved toilet facilities.

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

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

215 Households who had improved sources of drinking water were 1.37 [AOR = 1.37 CI: (1.12, 1.66)]
216 times more likely to have access to improved toilet facilities, compared with their counterparts. Compared
217 to household which had one to three members, 24% of those with four to six members were [AOR = 0.86
218 (0.75, 0.98)] less likely to access improved toilet facilities.

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

222 [AOR = 0.04, (0.02, 0.06)], 90.00% in Oromia [AOR = 0.10, CI: (0.06, 0.17)], 95.00% in
 223 Benishangul Gumuz [AOR = 0.05 CI: (0.03, 0.10)], 80.00% in SNNPR [AOR = 0.20 CI: (0.12,
 224 0.33)], 85% in Gambella [AOR = 0.15 CI:(0.09, 0.26)], and 60.00% in Harari [AOR = 0.40 CI:
 225 (0.24, 0.66)] households were more likely to have access to improved toilet facilities as compared
 226 to households in Addis Ababa city [Table 3].

227 **Table 3:** Multivariable multilevel logistic regression model of the effects of individual- and
 228 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 of 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

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3	water	Improved			1.36 (1.12, 1.65) ^c	1.37 (1.12, 1.66)^c
4	5 Number of household 6 members	1 – 3 members			1	1
7		4 – 6 members			0.88 (0.78, 0.99) ^a	0.86 (0.75, 0.98)^c
8		7+			1.07 (0.91, 1.26)	1.02 (0.86, 1.22)
9	10 Residence	Urban			1	1
11		Rural			0.28 (0.21, 0.39) ^c	0.28 (0.20, 0.38)^c
12	13 Region	Tigray			0.27 (0.16, 0.45) ^c	0.28 (0.17, 0.46)^c
14		Afar			0.38 (0.21, 0.68) ^c	0.37 (0.21, 0.67)^c
15		Amhara			0.04 (0.02, 0.06) ^c	0.04 (0.02, 0.06)^c
16		Oromia			0.10 (0.06, 0.17) ^c	0.10 (0.06, 0.17)^c
17		Somali			1.33 (0.79, 2.22)	1.32 (0.79, 2.21)
18		Benishangul G.			0.05 (0.03, 0.10) ^c	0.05 (0.03, 0.10)^c
19		SNNPR			0.20 (0.12, 0.34) ^c	0.20 (0.12, 0.33)^c
20		Gambella			0.15 (0.09, 0.26) ^c	0.15 (0.09, 0.26)^c
21		Harari			0.40 (0.24, 0.66) ^c	0.40 (0.24, 0.66)^c
22		Dire Dawa			1.13 (0.69, 1.87)	1.14 (0.69, 1.89)
23	Addis Ababa			1	1	
24	31 Random 32 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
25		ICC (%)	72.46%	72.58%	26.95%	27.08%
26		MOR	16.37	16.50	2.84	2.86
27		PCV	reference	-1.07%	86.03	85.91%
28	37 Model fit 38 statistics	Log-likelihood	-5621.74	-5603.26	-5029.24	-5018.39
29		Deviance	11243.48	11206.52	11036.78	10058.48

40 Note:

41 ^a, ^b, ^c significant at ^a P < 0.05; ^b p < 0.01, ^c P < 0.001;42 **AOR:** Adjusted Odds Ratio,43 **CI:** Confidence Interval,44 **Model 0-** Empty (null) model45 **Model I-** Only individual-level explanatory variables included in the model;46 **Model II-** Only community-level explanatory variables included in the model;47 **Model III-** Combined model; both individual-level and community-level explanatory variables48 **PCV:** Proportional Change in Variance,49 **MOR:** Median Odds Ratio

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230 **Random-effects analysis**

231 The prevalence rate of access to improved drinking water sources varied across communities
232 (community-level variance = 12.24, $p = <0.001$) [Table 2]. The null model revealed that 78.81%
233 of the total variance in the odds of access to improved drinking water sources was accounted by
234 between-cluster variation of characteristics (ICC = 0.7881). The inter-cluster variability declined
235 over successive models, from 78.81% in the null model to 78.55% in the only individual-level,
236 59.08% in the only community-level, and 58.97% in the final (combined) models. The proportional
237 change in variance indicated that the addition of predictors to the empty model explained an
238 increased proportion of variation in access to improved drinking water sources. The combined
239 model showed that a higher PCV, i.e., 61.36% of the variance in access to improved drinking water
240 sources could be explained by the combined factors at the individual- and community-levels.

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

249 **Model fit statistics**

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

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3 252 improvement over the previous model and it points to the goodness of fit for the final model built
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5 253 in the analysis.
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10 255 **DISCUSSION**

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14 256 In this study, we aimed to assess access to improved drinking water sources and sanitation facilities
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16 257 and their associated factors in Ethiopia. Accordingly, the proportion of households' access to
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18 258 improved drinking water sources was 69.94%, [95% CI: (69.23, 70.63)]. This finding is lower than
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20 259 reports from studies conducted in Ghana,⁽²⁾ Viet Nam,⁽¹⁶⁾ and Eswatini. ⁽¹⁴⁾ Whereas, it is higher
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22 260 than a reported proportion from a study conducted in Nepal. ⁽¹⁵⁾ The proportion of households'
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24 261 access to toilet facilities was 25.36%, [95% CI: (24.69, 26.03)]. This result is higher than the one
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26 262 reported from Ghana,⁽²⁾ However, lower than studies from Nigeria,⁽²⁷⁾ and Viet Nam. ⁽¹⁶⁾ The
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28 263 variation could be the disparities in GDP status and literacy rate among countries, study period,
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30 264 and setting.
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35 265 Individual-level factors were associated with access to improved drinking water sources and toilet
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37 266 facilities in the present study. Female-headed households were 1.18 times more likely than male-
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39 267 headed households to access improved drinking water sources. Similar findings were reported
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41 268 from Ghana, Vietnam, and Nigeria. ^(2, 16, 28) Gender differences may play an important role in the
42
43 269 work division in developing countries. Most of the time women have higher household
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45 270 responsibilities such as fetching water, cleaning compounds, childcare, and food preparation, etc.
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47 271 Therefore, this might be directly linked with water and sanitation in the sense that women may be
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49 272 preoccupied with other daily routines than WASH.
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3 273 Those households with heads having better educational status were 2.21 times more likely to
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5 274 access improved toilet facilities. This study finding is supported by evidence from previous studies.
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8 275 (14, 27, 29) Households who are led by heads who have no education had a lower probability of access
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10 276 to improved toilet facilities. In sub-Saharan Africa, education is a resource factor of quality health
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12 277 outcomes, and educated people usually are more aware of the condition that guarantees their well
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14 278 beings. This implies that educated household heads in this study may have utilized their resources
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17 279 to provide their households with improved toilet facilities.
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20 280 In addition to individual level factors, community-level factors were also associated with access
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22 281 to improved drinking water sources and toilet facilities. When compared to households within the
23
24 282 poorest category, households within poorer, middle, richer, and richest wealth index category were
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27 283 1.48, 2.42, 3.26, and 6.97 times more likely to have access to improved sources of drinking water
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29 284 and 3.97, 5.82, 8.58, and 23.94 times higher odds to access improved toilet facilities, respectively.
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31 285 This result is consistent with results from previous studies. (13, 14, 30) People who have better
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33 286 incomes would intend to fulfill the necessities of life. Economically, the rich can afford the initial
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36 287 high cost of both water and sanitation facilities and the poor may be disproportionately
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38 288 underserved in the distribution of public utility, and hence consume poor quality water and use
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41 289 unimproved sanitation facilities.
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44 290 Compared with households that got drinking water < 30 minutes, households which obtained
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46 291 drinking water \geq 30 minutes were 35% less likely to access improved drinking water sources.
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48 292 Hence, the length of time to get drinking (proximity of a house to a drinking water source) water
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50 293 might make difference in access to improved sources of drinking water and coverage (%) with
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53 294 improved water supply (HH connection, public standpipes, protected underground water sources,
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3 295 rainwater collection). This is not surprising as the physical distance is one of the reasons of WASH
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5 296 service inaccessibility.
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8 297 The adjusted odds of access to improved drinking water sources and toilet facilities were 94.00%
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10 298 and 72.00% less likely among rural households as compared to urban households, respectively.
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13 299 The rural-urban disparity in access to improved sources of drinking water and toilet facilities have
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15 300 been reported by several other previous studies, too. (12, 31, 32). The disparity might be, in sub-
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17 301 Saharan Africa, most of the people live in rural areas and their economic status is poor. Therefore,
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19 302 they do not have adequate financial resources to acquire improved drinking water sources and
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21 303 toilet facilities.
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25 304 Furthermore, households who had improved sources of drinking water were 1.37 times more likely
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27 305 to access an improved toilet facilities. This study finding is consistent with an earlier study. (27)
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30 306 The possible explanation could be a lack of access to adequate sanitation is also linked to the
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32 307 limited access to water supply and households who had improved water sources may be practicing
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34 308 more in hygiene and sanitation.
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37 309 Lastly, those households with four to six were 24% less likely access to improved toilet facilities
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39 310 compared to households with a family size of one to three. This is contrary to that of an earlier
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41 311 study. (2) The possible explanation could be the highest number of household members, the fewer
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43 312 resources they could have to build improved toilet facilities.
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3 314 **CONCLUSION**
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6 315 The proportion of households' access to an improved source of drinking water and sanitation
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8 316 facility was low in the country. Sex of household head, wealth index, time to get drinking water,
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10 317 residence, and region were associated with access to improved drinking water sources. Educational
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12 318 level of the household head, wealth index, being widowed, source of drinking water, number of
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14 319 household members, residence, and region were factors associated with access to improved toilet
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16 320 facilities. Thus, governmental and non-governmental organizations working on water, hygiene,
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18 321 and sanitation should consider a multi-faceted policy approach that accounts for the regions and
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20 322 residence variations and other identified factors to ease up the problem.
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3 324 **Acknowledgments**
4

5 325 We would like to thank the Demographic and Health Survey (DHS) programme for allowing the
6
7 326 use of Ethiopian Demographic and Health Survey (EDHS) data for this study.

9
10 327 **Competing interests:** None declared.

11
12 328 **Patient consent for publication:** Not required.

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14
15 329 **Ethics approval:** The EDHS 2016 was approved by the National Research Ethics Review
16
17 330 Committee of Ethiopia and ICF Macro International. The approval letter was obtained from the
18
19 331 measure DHS for the use of this data, and the dataset was downloaded from www.measuredhs.com.

20
21 332 This analysis was approved by the Department of Environmental and occupational health and
22
23 333 safety, University of Gondar.

24
25
26 334 **Funding**
27

28 335 The author(s) received no specific funding for this work.

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31 336 **Availability of data and materials**
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33 337 The dataset analyzed during the current study available from the corresponding author upon
34
35 338 reasonable request.

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38 339 **Authors' contributions**
39

40 340 ZA wrote the analyzed data, drafted the paper, and prepared the manuscript. HD, ZNA, AAT, BD,
41
42 341 RF, AGM, and YY drafted the paper, writing – review & editing, and commented on the
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44 342 manuscript. All the authors read and approved the final manuscript.
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344 **REFERENCES**

- 345 1. Prüss-Ustün A, Wolf J, Bartram J, Clasen T, Cumming O, Freeman MC, et al. Burden of
346 disease from inadequate water, sanitation and hygiene for selected adverse health outcomes: An
347 updated analysis with a focus on low-and middle-income countries. *International journal of*
348 *hygiene and environmental health*. 2019;222(5):765-77.
- 349 2. Agbadi P, Darkwah E, Kenney PL. A Multilevel Analysis of Regressors of Access to
350 Improved Drinking Water and Sanitation Facilities in Ghana. *Journal of environmental and*
351 *public health*. 2019;2019.
- 352 3. Assembly UG. Resolution on Human Right to Water and Sanitation. New York: United
353 Nations. 2010.
- 354 4. Brookes JD, Carey CC. Ensure availability and sustainable management of water and
355 sanitation for all. *UN Chronicle*. 2015;51(4):15-6.
- 356 5. Mills JE, Cumming O. The impact of water, sanitation and hygiene on key health and
357 social outcomes. URL: [https://www.lshtm.ac.uk/sites/default/files/2017-](https://www.lshtm.ac.uk/sites/default/files/2017-07/WASHEvidencePaper_HighRes_01)
358 [07/WASHEvidencePaper_HighRes_01](https://www.lshtm.ac.uk/sites/default/files/2017-07/WASHEvidencePaper_HighRes_01). 2016;23.
- 359 6. Saxena SK, Kumar S, Haikerwal A, Bhatt ML. Introductory chapter: Neglected tropical
360 waterborne infectious diseases-strategies for mitigation. *Water Challenges of an Urbanizing*
361 *World*. 2018:1.
- 362 7. Organization WH. Water, sanitation, hygiene, and waste management for the COVID-19
363 virus: interim guidance, 23 April 2020. World Health Organization, 2020.
- 364 8. Organization WH. Progress on drinking water, sanitation and hygiene: 2017 update and
365 SDG baselines. 2017.
- 366 9. Organization WH. Water, sanitation, hygiene and health: a primer for health
367 professionals. World Health Organization, 2019.
- 368 10. Organization WH. Safer water, better health. 2019.
- 369 11. UNICEF. Water, sanitation and hygiene (WASH) 2020 [cited 2020 April, 14]. Available
370 from: <https://www.unicef.org/ethiopia/water-sanitation-and-hygiene-wash>.
- 371 12. Mulenga JN, Bwalya BB, Kaliba-Chishimba K. Determinants and inequalities in access
372 to improved water sources and sanitation among the Zambian households. *International Journal*
373 *of Development and Sustainability*. 2017;6(8):746-62.

- 1
2
3 374 13. Morakinyo OM, Adebowale SA, Oloruntoba EO. Wealth status and sex differential of
4 375 household head: implication for source of drinking water in Nigeria. *Archives of Public Health*.
5 376 2015;73(1):58.
- 6
7
8 377 14. Simelane MS, Shongwe MC, Vermaak K, Zwane E. Determinants of Households'
9 378 Access to Improved Drinking Water Sources: A Secondary Analysis of Eswatini 2010 and 2014
10 379 Multiple Indicator Cluster Surveys. *Advances in Public Health*. 2020;2020.
- 11
12 380 15. Wang C, Pan J, Yaya S, Yadav RB, Yao D. Geographic Inequalities in Accessing
13 381 Improved Water and Sanitation Facilities in Nepal. *International journal of environmental*
14 382 *research and public health*. 2019;16(7):1269.
- 15
16 383 16. Tuyet-Hanh TT, Long TK, Van Minh H, Huong LTT. Longitudinal household trends in
17 384 access to improved water sources and sanitation in Chi Linh town, Hai Duong province, Viet
18 385 Nam and associated factors. *AIMS public health*. 2016;3(4):880.
- 19
20 386 17. Organization WH, UNICEF. Progress on drinking water and sanitation: special focus on
21 387 sanitation. *Progress on drinking water and sanitation: special focus on sanitation*2008.
- 22
23 388 18. Beyene A, Hailu T, Faris K, Kloos H. Current state and trends of access to sanitation in
24 389 Ethiopia and the need to revise indicators to monitor progress in the Post-2015 era. *BMC public*
25 390 *health*. 2015;15:451-.
- 26
27 391 19. Pullan RL, Freeman MC, Gething PW, Brooker SJ. Geographical inequalities in use of
28 392 improved drinking water supply and sanitation across sub-Saharan Africa: mapping and spatial
29 393 analysis of cross-sectional survey data. *PLoS Med*. 2014;11(4):e1001626.
- 30
31 394 20. Central Statistical Agency (CSA). Central Statistical Agency (CSA) [Ethiopia] and ICF
32 395 Ethiopia demographic and health Survey 2016. Addis Ababa, Ethiopia, and Rockville, Maryland,
33 396 USA: CSA and ICF,2017.
- 34
35 397 21. Supply WUJW, Programme SM, Organization WH, Supply WUJMPfW, Sanitation,
36 398 UNICEF. *Water for life: making it happen: World health organization*; 2005.
- 37
38 399 22. Merlo J, Chaix B, Ohlsson H, Beckman A, Johnell K, Hjerpe P, et al. A brief conceptual
39 400 tutorial of multilevel analysis in social epidemiology: using measures of clustering in multilevel
40 401 logistic regression to investigate contextual phenomena. *Journal of Epidemiology & Community*
41 402 *Health*. 2006;60(4):290-7.
- 42
43
44
45
46
47
48
49
50
51
52
53
54
55
56
57
58
59
60

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2
3 403 23. Merlo J, Yang M, Chaix B, Lynch J, Råstam L. A brief conceptual tutorial on multilevel
4 404 analysis in social epidemiology: investigating contextual phenomena in different groups of
5 405 people. *Journal of Epidemiology & Community Health*. 2005;59(9):729-36.
6
7
8 406 24. Larsen K, Merlo J. Appropriate assessment of neighborhood effects on individual health:
9 407 integrating random and fixed effects in multilevel logistic regression. *American journal of*
10 408 *epidemiology*. 2005;161(1):81-8.
11
12
13 409 25. Spiegelhalter DJ, Best NG, Carlin BP, Van Der Linde A. Bayesian measures of model
14 410 complexity and fit. *Journal of the royal statistical society: Series b (statistical methodology)*.
15 411 2002;64(4):583-639.
16
17
18 412 26. Hair Jr JF. *Multivariate Data Analysis* Joseph F. Hair Jr. William C. Black Barry J. Babin
19 413 Rolph E. Anderson Seventh Edition.
20
21
22 414 27. Abubakar IR. Access to sanitation facilities among Nigerian households: determinants
23 415 and sustainability implications. *Sustainability*. 2017;9(4):547.
24
25
26 416 28. Morakinyo OM, Adebowale SA, Oloruntoba EO. Wealth status and sex differential of
27 417 household head: implication for source of drinking water in Nigeria. *Archives of public health =*
28 418 *Archives belges de sante publique*. 2015;73:58.
29
30
31 419 29. Akpakli DE, Manyeh AK, Akpakli JK, Kukula V, Gyapong M. Determinants of access to
32 420 improved sanitation facilities in rural districts of southern Ghana: evidence from Dodowa Health
33 421 and Demographic Surveillance Site. *BMC Res Notes*. 2018;11(1):473-.
34
35
36 422 30. Njuguna J. Progress in sanitation among poor households in Kenya: evidence from
37 423 demographic and health surveys. *BMC public health*. 2019;19(1):135.
38
39
40 424 31. Irianti S, Prasetyoputra P, Sasimartoyo TP. Determinants of household drinking-water
41 425 source in Indonesia: An analysis of the 2007 Indonesian family life survey. *Cogent Medicine*.
42 426 2016;3(1).
43
44
45 427 32. Prasetyoputra P, Irianti S. Access to improved sanitation facilities in indonesia: An
46 428 econometric analysis of geographical and socioeconomic disparities. *Journal of Applied Sciences*
47 429 *in Environmental Sanitation*. 2013;8(3).
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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) <i>Cohort study</i> —Give the eligibility criteria, and the sources and methods of selection of participants. Describe methods of follow-up <i>Case-control study</i> —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 <i>Cross-sectional study</i> —Give the eligibility criteria, and the sources and methods of selection of participants	
		(b) <i>Cohort study</i> —For matched studies, give matching criteria and number of exposed and unexposed <i>Case-control study</i> —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) <i>Cohort study</i> —If applicable, explain how loss to follow-up was addressed <i>Case-control study</i> —If applicable, explain how matching of cases and controls was addressed <i>Cross-sectional study</i> —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) <i>Cohort study</i> —Summarise follow-up time (eg, average and total amount)	
Outcome Data	15*	<i>Cohort study</i> —Report numbers of outcome events or summary measures over time	
		<i>Case-control study</i> —Report numbers in each exposure category, or summary measures of exposure	
		<i>Cross-sectional study</i> —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.

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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:	<i>BMJ Open</i>
Manuscript ID	bmjopen-2020-042071.R2
Article Type:	Original research
Date Submitted by the Author:	16-Feb-2021
Complete List of Authors:	<p>Andualem , Zewudu ; University of Gondar College of Medicine and Health Sciences, Department of Environmental and Occupational health and Safety</p> <p>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</p> <p>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</p> <p>taddese, Asefa; University of Gondar College of Medicine and Health Sciences, Epidemiology and Biostatistics</p> <p>Dagne, Baye ; University of Gondar College of Medicine and Health Sciences, Human Physiology; Mr.</p> <p>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.</p> <p>Muluneh, Atalay; University of Gondar College of Medicine and Health Sciences, Epidemiology and Bio statistics ;</p> <p>Yeshaw, Yigizie; University of Gondar College of Medicine and Health Sciences, Medical Physiology</p>
Primary Subject Heading:	Public health
Secondary Subject Heading:	Occupational and environmental medicine
Keywords:	PUBLIC HEALTH, PREVENTIVE MEDICINE, Health policy < HEALTH SERVICES ADMINISTRATION & MANAGEMENT

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3 **1 Households' access to improved drinking water sources and toilet facilities in Ethiopia: A**
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5 **2 multilevel analysis based on 2016 Ethiopian Demographic and Health Survey**
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3 24 **ABSTRACT**
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6 25 **Objective:** This study aimed to assess households' access to improved drinking water sources
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8 26 and sanitation facilities and their associated factors in Ethiopia
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11 27 **Design:** Cross-sectional study
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14 28 **Setting:** Ethiopia
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17 29 **Participants:** Household heads
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20 30 **Primary outcomes:** Access to improved drinking water sources and sanitation facilities
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23 31 **Methods:** We conducted an in-depth secondary data analysis of the 2016 Ethiopian Demographic
24
25 32 and Health Survey (EDHS). Data from a total of 16650 households and 645 clusters were included
26
27 33 in the analysis. The households in the EDHS were selected using a stratified two-stage cluster
28
29 34 sampling technique. Multilevel binary logistic regression analyses were performed to identify
30
31 35 factors associated with access to an improved drinking water source and toilet facilities. Adjusted
32
33 36 odds ratio with a 95% CI were reported. P-value < 0.05 was used to declare a significant
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35 37 association between the covariates and outcomes.
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39 38 **Results:** The proportions of households' access to improved sources of drinking water and toilet
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41 39 facilities were 69.94%, [95% CI: (69.23, 70.63)], and 25.36%, [95% CI: (24.69, 26.03)],
42
43 40 respectively. Female-headed households and better wealth index positively associated access
44
45 41 improved drinking water sources, ≥ 30 minutes round trip to obtain drinking water, rural residence,
46
47 42 and region were negatively associated with access to an improved drinking water source. Whereas
48
49 43 higher educational status, access to an improved source of drinking water, and households with
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51 44 better wealth index, were positively associated with access to improved toilet facility, being
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3 45 widowed, household size [4 to 6], being in rural residence, and region were negatively significantly
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5 46 associated with access to improved toilet facilities
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8 47 **Conclusion:** The proportions of households' access to improved drinking water sources and toilet
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10 48 facilities in Ethiopia was relatively low.
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13 49 **Keywords:** Improved toilet facilities, improved water sources, multilevel analysis, Ethiopia
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18 19 51 **Strength and limitations of the study**

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22 52 ☞ The use of nationally representative data that can enhance the generalizability of the finding
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24 53 is one of the strength of the study.
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27 54 ☞ Due to the inherent nature of a cross-sectional study, it does not show the temporal
28
29 55 relationship between the outcome status and predictors.
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32 56 ☞ Moreover, important variables such as culture, traditions, and social norms were not
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34 57 available in EDHS data which could influence the use of toilet facility type.
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59 INTRODUCTION

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

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

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

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

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3 82 In Sub-Saharan Africa, particularly in Ethiopia access to improved sources of drinking water and
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5 83 toilet facilities is still lacking and people are practicing open defecation. (17, 18) There was no
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8 84 statistical approach in the study using nationally representative data (2016 Ethiopian Demographic
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10 85 and Health Survey (EDHS) data), which accounts for the hierarchical nature of the data. However,
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12 86 in 2014 national studies conducted in Sub-Saharan African countries indicates that the spatial
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14 87 coverage in use of improved drinking water supply and sanitation. (19) Therefore, the current study
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16 88 aimed to assess access to improved drinking water sources and toilet facilities and their associated
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18 89 factors in Ethiopia using EDHS 2016 data.
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90 **METHODS**

91 **Patient and public involvement**

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

94 **Study design and area**

95 The 2016 main EDHS was a cross-sectional survey conducted from 18 January 2016 to 27 June
96 2016 in Ethiopia by the Ethiopian Central Statistical Agency (ECSA). For our case, we use an in-
97 depth secondary data analysis of the survey. The 2016 EDHS survey was the fourth survey
98 conducted in each of the 11 regions of Ethiopia (9 regional states and 2 administrative cities).
99 Administratively, each region in Ethiopia is divided into Zones, each Zone, in turn, is divided into
100 Woredas, and each Woreda into Kebeles (the lowest administrative units in the country). ⁽²⁰⁾

101 **Data sources**

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

106 **Sample size and sampling procedure**

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

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3 111 were successfully interviewed, yielding a response rate of 98%. (20) The current study included
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5 112 individual-level data for 16650 household heads as well as community characteristics of 645
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7
8 113 clusters.

10 114 **Variables of the study**

13 115 **Outcome variables**

16 116 Access to improved drinking water sources and improved toilet facilities.

19 117 **Explanatory variables**

22 118 The explanatory variables for this study were classified as individual, and community level factors
23
24 119 for both access to improved drinking water sources and improved toilet facilities. The individual
25
26 120 level factors for access to improved drinking water sources and improved toilet facilities were the
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28 121 sex of household head, age of household head, educational level of household head, and marital
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30 122 status of the household heads.

33 123 The community-level factors for access to improved drinking water sources were household
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35 124 wealth index, time to get to drinking water sources, family size, place of residence, and region.

37 125 The community level factors for access to improved toilet facilities were household wealth index,
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39 126 family size, sources of drinking water, place of residence, and region. The variables were selected
40
41 127 based on the literature review for factors affecting access to improved drinking water sources and
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43 128 improved toilet facilities. The basis of classification of explanatory variables into individual level,
44
45 129 household level, and community level variables were based on previous studies (2, 21, 22) and our
46
47 130 professional judgments.

49 131

132 **Operational definitions**

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

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

140 **Data processing and analysis**

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

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

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3 154 drinking water and toilet facilities. **Model II** was used to assess the impact of community-level
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5 155 factors on the likelihood of having access to improved sources of drinking water and toilet
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8 156 facilities. **Model III** was employed to assess the impact of individual and community-level factors
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10 157 altogether on access to improved sources of drinking water and toilet facilities.

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13 158 The random effects (variation of effects) were measured by ICC, percentage change in variance
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15 159 (PCV), Median Odds Ratio (MOR), and deviance (-2log likelihood), which measure the variability
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17 160 between clusters in the multilevel models. The ICC explains the cluster variability, while MOR is
18
19 161 used to quantify unexplained cluster variability (heterogeneity). The MOR was used to translate
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21 162 cluster variance into OR scale. (24-26) In the multilevel model, deviance can measure the total
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23 163 variation due to factors at the community and individual levels. (25, 27)

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27 164 Adjusted odds ratio with a 95% confidence interval were reported. P-value < 0.05 was used to
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29 165 declare a significant association among covariates and outcome variables. A multicollinearity test
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31 166 was performed to rule out if there was a significant correlation between explanatory variables. If
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33 167 the values of variance inflation factor (VIF) was lower than 10, then the collinearity problem was
34
35 168 considered as less likely. (28)

36 37 38 39 169 **RESULTS**

40 41 42 170 **Socio-demographic characteristics of study participants**

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44
45 171 A total of 16650 study participants were included in the study. The median (\pm SD) age of the
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47 172 household heads was 40 years (\pm 16.22 years, range 15 - 95). Approximately, seven out of ten
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49 173 (69.94%) of the households had access to improved sources of drinking water and only one-fourth
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51 174 (25.36%) of households had access to an improved source of toilet facilities. Majority (98.37%)
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54 175 of respondents had no education. About 68.55% of households were male-headed. [Table 1].

176 Table 1: Socio-demographic characteristics of study participants in Ethiopia, EDHS 2016 (n=
177 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	

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

180 Among Ethiopian regions, nearly all households in Addis Abeba (99.40%) had access to improved
 181 sources of drinking water. On the contrary, Somali (56.52%) and Afar regions (51.39%) had the
 182 least access to improved sources of drinking water. Households in Benishangul-Gumuz and
 183 Amhara regions were lowest in access to toilet facilities with 4.30% and 6.31%, respectively while
 184 households in Dire Dawa and Addis Ababa had the highest access to improved toilet facilities with
 185 65.20% and 79.31%, respectively [S1 Table 1].

186 **Factors associated with access to improved drinking water sources**

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

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

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

195 Compared to poorest households, poorer [AOR = 1.48, CI: (1.26, 1.74)], middle-income [AOR =
 196 2.42, CI: (2.03, 2.90)], richer [AOR = 3.26, CI: (2.68, 3.97)] and richest [AOR = 6.97, CI: (5.17,
 197 9.41)] households were 1.48, 2.42, 3.26, and 6.97 times more likely to access improved drinking
 198 water sources, respectively.

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

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

203 The likelihood of access to improved sources of drinking water were 95.00% [AOR = 0.05, (0.01,
 204 0.21)] in Afar, 94.00% [AOR = 0.06, (0.01, 0.27)] in Amhara, 92.00% [AOR = 0.08, (0.02, 0.35)]
 205 in Oromia, 98.00% [AOR = 0.02, (0.01, 0.10)] in Somalia, 93.00% [AOR = 0.07, (0.02, 0.30)] in
 206 SNNPR, and 82.00% [AOR = 0.18 (0.04, 0.89)] in Harari as compared to improved water access
 207 in Addis Ababa city [Table 2].

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

	Null Model	Model I	Model II	Model III
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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)

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	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

21 Note:

22 ^{a, b} significant at ^a P < 0.05; ^b P < 0.001;23 **AOR:** Adjusted Odds Ratio,24 **CI:** Confidence Interval,25 **Model 0-** Empty (null) model26 **Model I-** Only individual-level explanatory variables included in the model;27 **Model II-** Only community-level explanatory variables included in the model;28 **Model III-** Combined model; both individual-level and community-level explanatory variables29 **PCV:** Proportional Change in Variance,30 **MOR:** Median Odds Ratio

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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.

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3 217 Compared with households whose household heads had no education, households headed with
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5 218 those who attained higher education were 2.21 times more likely to have access to improved toilet
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7 219 facilities at [AOR = 2.21 CI: (1.12, 4.36)]. The likelihood of access to toilet facilities was 25%
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9 220 [AOR = 0.75, CI: (0.57, 0.98)] lower in households with widowed household heads, as compared to those
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11 221 who never married.

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15 222 Households with poorer [AOR = 3.97 CI: (2.99, 5.29)], middle [AOR = 5.82 CI: (4.35, 7.80)],
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17 223 richer [AOR = 8.58 CI: (6.40, 11.50)], and richest wealth index [AOR = 23.94 CI: (17.45, 32.83)],
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19 224 were 3.97, 5.82, 8.58, and 23.94 times more likely to access improved toilet facilities as compared
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21 225 to households with the poorest wealth index, respectively.

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25 226 Households who had improved sources of drinking water were 1.37 [AOR = 1.37 CI: (1.12, 1.66)]
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27 227 times more likely to have access to improved toilet facilities, compared with their counterparts. Compared
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29 228 to household which had one to three members, 24% of those with four to six members were [AOR = 0.86
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31 229 (0.75, 0.98)] less likely to access improved toilet facilities.

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34 230 About 72% of rural households were less likely to have access to improved toilet facilities as
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36 231 compared with those from urban residence [AOR = 0.28 CI: (0.20, 0.38)]. About 72.00% in Tigray
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38 232 [AOR = 0.28, CI: (0.17, 0.46)], 63.00% in Afar [AOR = 0.37, CI: (0.21, 0.67)], 96.00% in Amhara
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40 233 [AOR = 0.04, (0.02, 0.06)], 90.00% in Oromia [AOR = 0.10, CI: (0.06, 0.17)], 95.00% in
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42 234 Benishangul Gumuz [AOR = 0.05 CI: (0.03, 0.10)], 80.00% in SNNPR [AOR = 0.20 CI: (0.12,
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44 235 0.33)], 85% in Gambella [AOR = 0.15 CI:(0.09, 0.26)], and 60.00% in Harari [AOR = 0.40 CI:
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46 236 (0.24, 0.66)] households were more likely to have access to improved toilet facilities as compared
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48 237 to households in Addis Ababa city [Table 3].

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53 238 **Table 3:** Multivariable multilevel logistic regression model of the effects of individual- and
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55 239 community-level factors on improved sources of toilet facilities in Ethiopia, EDHS 2016

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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)

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	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

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241 Random-effects analysis

242 The prevalence rate of access to improved drinking water sources varied across communities
 243 (community-level variance = 12.24, p = <0.001) [Table 2]. The null model revealed that 78.81%
 244 of the total variance in the odds of access to improved drinking water sources was accounted by
 245 between-cluster variation of characteristics (ICC = 0.7881). The inter-cluster variability declined
 246 over successive models, from 78.81% in the null model to 78.55% in the only individual-level,
 247 59.08% in the only community-level, and 58.97% in the final (combined) models. The proportional

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3 248 change in variance indicated that the addition of predictors to the empty model explained an
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5 249 increased proportion of variation in access to improved drinking water sources. The combined
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8 250 model showed that a higher PCV, i.e., 61.36% of the variance in access to improved drinking water
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10 251 sources could be explained by the combined factors at the individual- and community-levels.

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13 252 In [Table 3] the final model (**Model III**), ICC value of 0.2708 indicates that 27.08% of the total
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15 253 variation in access to improved toilet facilities is accounted for the community-level factors. The
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17 254 remaining 72.92% variation is therefore triggered by the individual- level and other unknown
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19 255 factors. The proportional change in variance indicated that the addition of predictors to the empty
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21 256 model explained an increased proportion of variation in access to improved toilet facilities. The
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23 257 combined model showed a higher PCV, i.e., 85.91% of the variance in access to improved toilet
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25 258 facilities could be explained by the combined factors at the individual- and community-levels.
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29 **Model fit statistics**

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34 261 As shown in [Tables 2 & 3] (model fit statistics), the values of log-likelihood and Deviance
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36 262 showed a subsequent reduction which indicates that each model represents a significant
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38 263 improvement over the previous model and it points to the goodness of fit for the final model built
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40 264 in the analysis.
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267 **DISCUSSION**

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

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

285 Those households with heads having better educational status were 2.21 times more likely to
286 access improved toilet facilities. This study finding is supported by evidence from previous studies.
287 ^(14, 29, 31) Households who are led by heads who have no education had a lower probability of access
288 to improved toilet facilities. In sub-Saharan Africa, education is a resource factor of quality health

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3 289 outcomes, and educated people usually are more aware of the condition that guarantees their well
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5 290 beings. This implies that educated household heads in this study may have utilized their resources
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8 291 to provide their households with improved toilet facilities.
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11 292 In addition to individual level factors, community-level factors were also associated with access
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13 293 to improved drinking water sources and toilet facilities. When compared to households within the
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15 294 poorest category, households within poorer, middle, richer, and richest wealth index category were
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17 295 1.48, 2.42, 3.26, and 6.97 times more likely to have access to improved sources of drinking water
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19 296 and 3.97, 5.82, 8.58, and 23.94 times higher odds to access improved toilet facilities, respectively.
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22 297 This result is consistent with results from previous studies. (13, 14, 32) People who have better
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24 298 incomes would intend to fulfill the necessities of life. Economically, the rich can afford the initial
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27 299 high cost of both water and sanitation facilities and the poor may be disproportionately
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29 300 underserved in the distribution of public utility, and hence consume poor quality water and use
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31 301 unimproved sanitation facilities.
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34 302 Compared with households that got drinking water < 30 minutes, households which obtained
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36 303 drinking water \geq 30 minutes were 35% less likely to access improved drinking water sources.
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39 304 Hence, the length of time to get drinking (proximity of a house to a drinking water source) water
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41 305 might make difference in access to improved sources of drinking water and coverage (%) with
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43 306 improved water supply (HH connection, public standpipes, protected underground water sources,
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46 307 rainwater collection). This is not surprising as the physical distance is one of the reasons of WASH
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48 308 service inaccessibility.
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51 309 The adjusted odds of access to improved drinking water sources and toilet facilities were 94.00%
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53 310 and 72.00% less likely among rural households as compared to urban households, respectively.
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56 311 The rural-urban disparity in access to improved sources of drinking water and toilet facilities have
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3 312 been reported by several other previous studies, too. (12, 33, 34). The disparity might be, in sub-
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5 313 Saharan Africa, most of the people live in rural areas and their economic status is poor. Therefore,
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7 314 they do not have adequate financial resources to acquire improved drinking water sources and
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9 315 toilet facilities.

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13 316 Furthermore, households who had improved sources of drinking water were 1.37 times more likely
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15 317 to access an improved toilet facilities. This study finding is consistent with an earlier study. (29)
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17 318 The possible explanation could be a lack of access to adequate sanitation is also linked to the
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19 319 limited access to water supply and households who had improved water sources may be practicing
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21 320 more in hygiene and sanitation.

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25 321 Lastly, those households with four to six were 24% less likely access to improved toilet facilities
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27 322 compared to households with a family size of one to three. This is contrary to that of an earlier
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29 323 study. (2) The possible explanation could be the highest number of household members, the fewer
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31 324 resources they could have to build improved toilet facilities.

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3 326 **CONCLUSIONS**
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6 327 The proportion of households' access to an improved source of drinking water and sanitation
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8 328 facility was low in the country. Sex of household head, wealth index, time to get drinking water,
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10 329 residence, and region were associated with access to improved drinking water sources. Educational
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12 330 level of the household head, wealth index, being widowed, source of drinking water, number of
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14 331 household members, residence, and region were factors associated with access to improved toilet
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16 332 facilities. Thus, governmental and non-governmental organizations working on water, hygiene,
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18 333 and sanitation should consider a multi-faceted policy approach that accounts for the regions and
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20 334 residence variations and other identified factors to ease up the problem.
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3 336 **Acknowledgments**
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5 337 We would like to thank the Demographic and Health Survey (DHS) programme for allowing the
6
7
8 338 use of Ethiopian Demographic and Health Survey (EDHS) data for this study.
9

10 339 **Competing interests:** None declared.
11

12 340 **Patient consent for publication:** Not required.
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15 341 **Ethics approval:** The EDHS 2016 was approved by the National Research Ethics Review
16
17 342 Committee of Ethiopia and ICF Macro International. The approval letter was obtained from the
18
19 343 measure DHS for the use of this data, and the dataset was downloaded from www.measuredhs.com.
20

21 344 This analysis was approved by the Department of Environmental and occupational health and
22
23 345 safety, University of Gondar.
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25

26 346 **Funding**
27

28 347 The author(s) received no specific funding for this work.
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31 348 **Availability of data and materials**
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33 349 The dataset analyzed during the current study available from the corresponding author upon
34
35 350 reasonable request.
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38 351 **Authors' contributions**
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40 352 ZA wrote the analyzed data, drafted the paper, and prepared the manuscript. HD, ZNA, AAT, BD,
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42 353 RF, AGM, and YY drafted the paper, writing – review & editing, and commented on the
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44 354 manuscript. All the authors read and approved the final manuscript.
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356 **REFERENCES**

- 357 1. Prüss-Ustün A, Wolf J, Bartram J, Clasen T, Cumming O, Freeman MC, et al. Burden of
358 disease from inadequate water, sanitation and hygiene for selected adverse health outcomes: An
359 updated analysis with a focus on low-and middle-income countries. *International journal of
360 hygiene and environmental health.* 2019;222(5):765-77.
- 361 2. Agbadi P, Darkwah E, Kenney PL. A Multilevel Analysis of Regressors of Access to
362 Improved Drinking Water and Sanitation Facilities in Ghana. *Journal of environmental and
363 public health.* 2019;2019.
- 364 3. Assembly UG. Resolution on Human Right to Water and Sanitation. New York: United
365 Nations. 2010.
- 366 4. Brookes JD, Carey CC. Ensure availability and sustainable management of water and
367 sanitation for all. *UN Chronicle.* 2015;51(4):15-6.
- 368 5. Mills JE, Cumming O. The impact of water, sanitation and hygiene on key health and
369 social outcomes. URL: [https://www.lshtm.ac.uk/sites/default/files/2017-
370 07/WASHEvidencePaper_HighRes_01](https://www.lshtm.ac.uk/sites/default/files/2017-07/WASHEvidencePaper_HighRes_01). 2016;23.
- 371 6. Saxena SK, Kumar S, Haikerwal A, Bhatt ML. Introductory chapter: Neglected tropical
372 waterborne infectious diseases-strategies for mitigation. *Water Challenges of an Urbanizing
373 World.* 2018:1.
- 374 7. Organization WH. Water, sanitation, hygiene, and waste management for the COVID-19
375 virus: interim guidance, 23 April 2020. World Health Organization, 2020.
- 376 8. Organization WH. Progress on drinking water, sanitation and hygiene: 2017 update and
377 SDG baselines. 2017.
- 378 9. Organization WH. Water, sanitation, hygiene and health: a primer for health
379 professionals. World Health Organization, 2019.
- 380 10. Organization WH. Safer water, better health. 2019.
- 381 11. UNICEF. Water, sanitation and hygiene (WASH) 2020 [cited 2020 April, 14]. Available
382 from: <https://www.unicef.org/ethiopia/water-sanitation-and-hygiene-wash>.
- 383 12. Mulenga JN, Bwalya BB, Kaliba-Chishimba K. Determinants and inequalities in access
384 to improved water sources and sanitation among the Zambian households. *International Journal
385 of Development and Sustainability.* 2017;6(8):746-62.

- 1
2
3 386 13. Morakinyo OM, Adebowale SA, Oloruntoba EO. Wealth status and sex differential of
4 387 household head: implication for source of drinking water in Nigeria. Archives of Public Health.
5 388 2015;73(1):58.
6
7
8 389 14. Simelane MS, Shongwe MC, Vermaak K, Zwane E. Determinants of Households'
9 390 Access to Improved Drinking Water Sources: A Secondary Analysis of Eswatini 2010 and 2014
10 391 Multiple Indicator Cluster Surveys. Advances in Public Health. 2020;2020.
11
12 392 15. Wang C, Pan J, Yaya S, Yadav RB, Yao D. Geographic Inequalities in Accessing
13 393 Improved Water and Sanitation Facilities in Nepal. International journal of environmental
14 394 research and public health. 2019;16(7):1269.
15
16 395 16. Tuyet-Hanh TT, Long TK, Van Minh H, Huong LTT. Longitudinal household trends in
17 396 access to improved water sources and sanitation in Chi Linh town, Hai Duong province, Viet
18 397 Nam and associated factors. AIMS public health. 2016;3(4):880.
19
20 398 17. Organization WH, UNICEF. Progress on drinking water and sanitation: special focus on
21 399 sanitation. Progress on drinking water and sanitation: special focus on sanitation2008.
22
23 400 18. Beyene A, Hailu T, Faris K, Kloos H. Current state and trends of access to sanitation in
24 401 Ethiopia and the need to revise indicators to monitor progress in the Post-2015 era. BMC Public
25 402 Health. 2015;15:451-.
26
27 403 19. Pullan RL, Freeman MC, Gething PW, Brooker SJ. Geographical inequalities in use of
28 404 improved drinking water supply and sanitation across sub-Saharan Africa: mapping and spatial
29 405 analysis of cross-sectional survey data. PLoS Med. 2014;11(4):e1001626.
30
31 406 20. Central Statistical Agency (CSA). Central Statistical Agency (CSA) [Ethiopia] and ICF
32 407 Ethiopia demographic and health Survey 2016. Addis Ababa, Ethiopia, and Rockville, Maryland,
33 408 USA: CSA and ICF,2017.
34
35 409 21. Simelane M, Shongwe M, Vermaak K, Zwane E. Determinants of Households' Access to
36 410 Improved Drinking Water Sources: A Secondary Analysis of Eswatini 2010 and 2014 Multiple
37 411 Indicator Cluster Surveys. 2020;2020.
38
39 412 22. Ribeiro Sarmiento MPH D. An Analysis of Access to Improved Drinking Water and
40 413 Sanitation and Distance to the Water Source in a Newly Independent Country, Timor-Leste:
41 414 Assessing Geographical and Socioeconomic Disparities. 2015.
42
43 415 23. Supply WUJW, Programme SM, Organization WH, Supply WUJMPfW, Sanitation,
44 416 UNICEF. Water for life: making it happen: World health organization; 2005.
45
46
47
48
49
50
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54
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56
57
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59
60

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2
3 417 24. Merlo J, Chaix B, Ohlsson H, Beckman A, Johnell K, Hjerpe P, et al. A brief conceptual
4 418 tutorial of multilevel analysis in social epidemiology: using measures of clustering in multilevel
5 419 logistic regression to investigate contextual phenomena. *Journal of Epidemiology & Community*
6 420 *Health*. 2006;60(4):290-7.
- 7
8 421 25. Merlo J, Yang M, Chaix B, Lynch J, Råstam L. A brief conceptual tutorial on multilevel
9 422 analysis in social epidemiology: investigating contextual phenomena in different groups of
10 423 people. *Journal of Epidemiology & Community Health*. 2005;59(9):729-36.
- 11
12 424 26. Larsen K, Merlo J. Appropriate assessment of neighborhood effects on individual health:
13 425 integrating random and fixed effects in multilevel logistic regression. *American journal of*
14 426 *epidemiology*. 2005;161(1):81-8.
- 15
16 427 27. Spiegelhalter DJ, Best NG, Carlin BP, Van Der Linde A. Bayesian measures of model
17 428 complexity and fit. *Journal of the royal statistical society: Series b (statistical methodology)*.
18 429 2002;64(4):583-639.
- 19
20 430 28. Joseph F. Hair, Jr. William, Black Barry J., Babin Rolph, E. Anderson. *Multivariate Data*
21 431 *Analysis Edition S, editor*2018.
- 22
23 432 29. Abubakar IR. Access to sanitation facilities among Nigerian households: determinants
24 433 and sustainability implications. *Sustainability*. 2017;9(4):547.
- 25
26 434 30. Morakinyo OM, Adebowale SA, Oloruntoba EO. Wealth status and sex differential of
27 435 household head: implication for source of drinking water in Nigeria. *Archives of public health =*
28 436 *Archives belges de sante publique*. 2015;73:58.
- 29
30 437 31. Akpakli DE, Manyeh AK, Akpakli JK, Kukula V, Gyapong M. Determinants of access to
31 438 improved sanitation facilities in rural districts of southern Ghana: evidence from Dodowa Health
32 439 and Demographic Surveillance Site. *BMC Res Notes*. 2018;11(1):473-.
- 33
34 440 32. Njuguna J. Progress in sanitation among poor households in Kenya: evidence from
35 441 demographic and health surveys. *BMC Public Health*. 2019;19(1):135.
- 36
37 442 33. Irianti S, Prasetyoputra P, Sasimartoyo TP. Determinants of household drinking-water
38 443 source in Indonesia: An analysis of the 2007 Indonesian family life survey. *Cogent Medicine*.
39 444 2016;3(1).
- 40
41 445 34. Prasetyoputra P, Irianti S. Access to improved sanitation facilities in indonesia: An
42 446 econometric analysis of geographical and socioeconomic disparities. *Journal of Applied Sciences*
43 447 *in Environmental Sanitation*. 2013;8(3).
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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) <i>Cohort study</i> —Give the eligibility criteria, and the sources and methods of selection of participants. Describe methods of follow-up <i>Case-control study</i> —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 <i>Cross-sectional study</i> —Give the eligibility criteria, and the sources and methods of selection of participants	
		(b) <i>Cohort study</i> —For matched studies, give matching criteria and number of exposed and unexposed <i>Case-control study</i> —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) <i>Cohort study</i> —If applicable, explain how loss to follow-up was addressed <i>Case-control study</i> —If applicable, explain how matching of cases and controls was addressed <i>Cross-sectional study</i> —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) <i>Cohort study</i> —Summarise follow-up time (eg, average and total amount)	
Outcome Data	15*	<i>Cohort study</i> —Report numbers of outcome events or summary measures over time	
		<i>Case-control study</i> —Report numbers in each exposure category, or summary measures of exposure	
		<i>Cross-sectional study</i> —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.

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

Journal:	<i>BMJ Open</i>
Manuscript ID	bmjopen-2020-042071.R3
Article Type:	Original research
Date Submitted by the Author:	26-Feb-2021
Complete List of Authors:	<p>Andualem , Zewudu ; University of Gondar College of Medicine and Health Sciences, Department of Environmental and Occupational health and Safety</p> <p>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</p> <p>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</p> <p>taddese, Asefa; University of Gondar College of Medicine and Health Sciences, Epidemiology and Biostatistics</p> <p>Dagne, Baye ; University of Gondar College of Medicine and Health Sciences, Human Physiology; Mr.</p> <p>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.</p> <p>Mulneh, Atalay; University of Gondar College of Medicine and Health Sciences, Epidemiology and Bio statistics ;</p> <p>Yeshaw, Yigizie; University of Gondar College of Medicine and Health Sciences, Medical Physiology</p>
Primary Subject Heading:	Public health
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3 **1 Households access to improved drinking water sources and toilet facilities in Ethiopia: A**
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5 **2 multilevel analysis based on 2016 Ethiopian Demographic and Health Survey**
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3 24 **ABSTRACT**
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6 25 **Objective:** This study aimed to assess households access to improved drinking water sources and
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8 26 sanitation facilities and their associated factors in Ethiopia.
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11 27 **Design:** Cross-sectional study
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14 28 **Setting:** Ethiopia
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17 29 **Participants:** Household heads
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20 30 **Primary outcomes:** Access to improved drinking water sources and toilet facilities
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23 31 **Methods:** We conducted an in-depth secondary data analysis of 2016 Ethiopian Demographic and
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25 32 Health Survey (EDHS). Data from a total of 16650 households and 645 clusters were included in
26
27 33 the analysis. The households were selected using a stratified two-stage cluster sampling technique.
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29 34 Multilevel binary logistic regression analyses were performed to identify factors associated with
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31 35 access to an improved drinking water source and toilet facilities. Adjusted odds ratio with a 95%
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33 36 CI was reported with p-value < 0.05 was used to declare a significant association between the
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35 37 covariates and the outcome variables.
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39 38 **Results:** The proportions of households' access to improved sources of drinking water and toilet
40
41 39 facilities were 69.94%, [95% CI: (69.23, 70.63)], and 25.36%, [95% CI: (24.69, 26.03)],
42
43 40 respectively. Households headed by females and households with a better wealth index were
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45 41 positively associated with access to improved drinking water sources. Whereas rural households,
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47 42 ≥ 30 minutes round trip to obtain drinking water and region were factors negatively associated
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49 43 with households access to improved drinking water sources. A higher probability of having access
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51 44 to improved toilet facilities: households with heads who had attained higher education, households
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3 45 having better access to improved sources of drinking water, and households with better wealth
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5 46 index. While the following households were less likely to have access to improved toilet facilities:
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8 47 households with heads were widowed, households with four to six members, rural households, and
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10 48 region

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13 49 **Conclusion:** The study found that the proportions of households' access to improved drinking
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15 50 water sources and toilet facilities in Ethiopia were relatively low, which demands the need to tailor
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17 51 strategies to increase the coverage of access to improved drinking water sources and toilet
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19 52 facilities.

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23 53 **Keywords:** Improved toilet facilities, improved water sources, multilevel analysis, Ethiopia
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27 28 29 55 **Strength and limitations of the study**

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32 56 ☞ The use of nationally representative data that can enhance the generalizability of the
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34 57 findings is one of the strengths of this study.
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36 58 ☞ This study used data from a cross-sectional survey; as a result, the results from analyzing the data
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38 59 cannot establish causal relationships.
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40 60 ☞ Moreover, important variables such as culture, traditions, and social norms were not
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42 61 available in EDHS data which could influence the use of toilet facility type.

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63 INTRODUCTION

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

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

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

81 Regarding factors associated with improved drinking water sources and toilet facilities: Sex of
82 household heads, region, residence, family size, and time to get to drinking water source, age of
83 household head, educational level, and marital status of the household heads were predictors linked
84 to access to improved drinking water sources and toilet facilities reported by previous studies. ^{(2,}

85 [12-16\)](#)

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3 86 In Sub-Saharan Africa, particularly in Ethiopia, access to improved sources of drinking water and
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5 87 toilet facilities is still lacking and people are practicing open defecation. (17, 18) There is no study in
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8 88 Ethiopia using nationally representative data (2016 Ethiopian Demographic and Health Survey
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10 89 (EDHS) data), which accounts for the hierarchical nature of the data. However, national studies
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12 90 conducted in Sub-Saharan African countries in 2014 indicated the spatial variation in the coverage
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14 91 of households' use of improved drinking water supply and sanitation. (19) Therefore, the current
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16 92 study aimed to assess access to improved drinking water sources and toilet facilities and their
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18 93 associated factors in Ethiopia using EDHS 2016 data.
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94 **METHODS**

95 **Patient and public involvement**

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

98 **Study design and area**

99 The 2016 main EDHS was a cross-sectional survey conducted from 18 January 2016 to 27 June
100 2016 in Ethiopia by the Ethiopian Central Statistical Agency (ECSA). For our case, we used an
101 in-depth secondary data analysis of the survey. It was the fourth survey conducted in each of the
102 11 regions of Ethiopia (9 regional states and 2 administrative cities). Administratively, each region
103 in Ethiopia is divided into Zones, each Zone, in turn, is divided into Woredas, and each Woreda
104 into Kebeles (the lowest administrative units in the country). ⁽²⁰⁾

105 **Data sources**

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

110 **Sample size and sampling procedure**

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

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3 115 were successfully interviewed, yielding a response rate of 98%. (20) The current study included
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5 116 individual-level data for 16650 household heads as well as community characteristics of 645
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8 117 clusters.
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10 118 **Variables of the study**

11 119 **Outcome variables**

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16 120 Access to improved drinking water sources and improved toilet facilities.
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19 121 **Explanatory variables**

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22 122 The explanatory variables for this study were classified as individual and community level factors
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24 123 for both outcome variables. . The individual-level factors for the outcome variables were; Sex, age,
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26 124 educational level, and marital status of the household head. Whereas, the community-level factors
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28 125 for the first outcome variable (access to improved drinking water sources) were; household wealth
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30 126 index, time to get to drinking water sources, family size, place of residence, and region. While, for
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32 127 the second outcome variable (access to improved toilet facilities) the community-level factors were
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34 128 household wealth index, household size, sources of drinking water, place of residence, and region.
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36 129 The variables were selected based on the literature review for factors affecting access to improved
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38 130 drinking water sources and improved toilet facilities. The basis of the classification of explanatory
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40 131 variables into the individual level, household level, and community level variables were based on
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42 132 previous studies (2, 21, 22) and our professional judgments.
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136 **Operational definitions**

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

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

144 **Data processing and analysis**

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

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

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3 158 and toilet facilities. **Model II** was used to assess the impact of community-level factors on the
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5 159 likelihood of having access to improved sources of drinking water and toilet facilities. **Model III**
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8 160 was employed to assess the impact of individual and community-level factors altogether on access
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10 161 to improved sources of drinking water and toilet facilities.

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13 162 The random effects (variation of effects) were measured by ICC, percentage change in variance
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15 163 (PCV), Median Odds Ratio (MOR), and deviance (-2log likelihood), which measure the variability
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17 164 between clusters in the multilevel models. The ICC explains the cluster variability, while MOR is
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19 165 used to quantify unexplained cluster variability (heterogeneity). The MOR was used to translate
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21 166 cluster variance into OR scale. (24-26) In the multilevel model, deviance can measure the total
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23 167 variation due to factors at the community and individual levels. (25, 27)

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27 168 Adjusted odds ratio with a 95% confidence interval was reported with p-value < 0.05 was used to
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29 169 declare a significant association among covariates and outcome variables. A multicollinearity test
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31 170 was performed to rule out if there was a significant correlation between explanatory variables. If
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33 171 the values of variance inflation factor (VIF) was lower than 10, then the collinearity problem was
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35 172 considered less likely. (28)

36 37 38 39 173 **RESULTS**

40 41 42 174 **Socio-demographic characteristics of the study participants**

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45 175 A total of 16650 study participants were included in the study. The median (\pm SD) age of the
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47 176 household heads was 40 years (\pm 16.22 years, range 15 - 95). Approximately, seven out of ten
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49 177 (69.94%) of the households had access to improved sources of drinking water and only one-fourth
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51 178 (25.36%) of households had access to improved sources of toilet facilities. Majority (98.37%) of
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53 179 respondents had no formal education. About 68.55% of households were male-headed. [Table 1].
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180 Table 1: Socio-demographic characteristics of the study participants in Ethiopia, EDHS 2016 (n=
181 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	

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

184 Among Ethiopian regions, nearly all households in Addis Abeba (99.40%) had access to improved
 185 sources of drinking water. On the contrary, Somali (56.52%) and Afar regions (51.39%) had the
 186 least access to improved sources of drinking water. Households in Benishangul-Gumuz and
 187 Amhara regions were lowest in access to toilet facilities with 4.30% and 6.31%, respectively while
 188 households in Dire Dawa and Addis Ababa had the highest access to improved toilet facilities with
 189 65.20% and 79.31%, respectively [S1 Table 1].

190 **Factors associated with access to improved drinking water sources**

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

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

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

199 Compared to poorest households, poorer [AOR = 1.48, CI: (1.26, 1.74)], middle-income [AOR =
200 2.42, CI: (2.03, 2.90)], richer [AOR = 3.26, CI: (2.68, 3.97)] and richest [AOR = 6.97, CI: (5.17,
201 9.41)] households were 1.48, 2.42, 3.26, and 6.97 times higher probability to have access to
202 improved drinking water sources, respectively.

203 In contrast to households who got drinking water in \leq 30 minutes, households who got drinking
204 water $>$ 30 minutes were 35% less likely to access to improved drinking water sources [AOR =
205 0.65, CI: (0.58, 0.73)].

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

208 The likelihood of access to improved sources of drinking water was 95.00% [AOR = 0.05, (0.01,
209 0.21)] in Afar, 94.00% [AOR = 0.06, (0.01, 0.27)] in Amhara, 92.00% [AOR = 0.08, (0.02, 0.35)]
210 in Oromia, 98.00% [AOR = 0.02, (0.01, 0.10)] in Somalia, 93.00% [AOR = 0.07, (0.02, 0.30)] in
211 SNNPR, and 82.00% [AOR = 0.18 (0.04, 0.89)] in Harari compared to access to improved water
212 sources in Addis Ababa city [Table 2].

213 **Table 2:** Multivariable multilevel logistic regression model of the effects of individual- and
214 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

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	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

23 Note:

24 ^{a, b} significant at ^a P < 0.05; ^b P < 0.001;25 **AOR:** Adjusted Odds Ratio,26 **CI:** Confidence Interval,27 **Model 0-** Empty (null) model28 **Model I-** Only individual-level explanatory variables included in the model;29 **Model II-** Only community-level explanatory variables included in the model;30 **Model III-** Combined model; both individual-level and community-level explanatory variables31 **PCV:** Proportional Change in Variance,32 **MOR:** Median Odds Ratio

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

217 The proportion of households with access to an improved sources of toilet facility was 25.36% at
 218 [95% CI: (24.69%, 26.03%)]. Individual-level factors such as educational level and marital status
 219 of the household head, and community level factors such as wealth index, sources of drinking
 220 water, number of household members, residence, and region were factors significantly impacting
 221 households' access to improved toilet facilities.

222 Compared to household heads that had no formal education, households with heads who attained
223 higher education were 2.21 times more likely to have access to improved toilet facilities at [AOR
224 = 2.21 CI: (1.12, 4.36)]. The likelihood of access to improved toilet facilities was 25% [AOR =
225 0.75, CI: (0.57, 0.98)] lower in households with heads who were widowed compared to those who never
226 married.

227 Compared to poorest households' access to improved toilet facilities, households with the
228 following wealth indices have the following positive associations: poor households had [AOR =
229 3.97 CI: (2.99, 5.29) higher probability, middle households had a [AOR = 5.82 CI: (4.35, 7.80)]
230 higher probability, richer households had a [AOR = 8.58 CI: (6.40, 11.50)] higher probability, and
231 richest households had an [AOR = 23.94 CI: (17.45, 32.83) higher probability.

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

235 Households with more members were less likely to have access to improved toilet facilities.

236 Compared to households with one to three members, households with four to six members had a
237 24% [AOR = 0.86 (0.75, 0.98)] lower probability to have access to improved toilet facilities.

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

240 About 72.00% in Tigray [AOR = 0.28, CI: (0.17, 0.46)], 63.00% in Afar [AOR = 0.37, CI: (0.21,
241 0.67)], 96.00% in Amhara [AOR = 0.04, (0.02, 0.06)], 90.00% in Oromia [AOR = 0.10, CI: (0.06,
242 0.17)], 95.00% in Benishangul Gumuz [AOR = 0.05 CI: (0.03, 0.10)], 80.00% in SNNPR [AOR
243 = 0.20 CI: (0.12, 0.33)], 85% in Gambella [AOR = 0.15 CI:(0.09, 0.26)], and 60.00% in Harari
244 [AOR = 0.40 CI: (0.24, 0.66)] households had a higher probability to have access to improved
245 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

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	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

28 Note:

29 ^a, ^b, ^c significant at ^a P < 0.05; ^b p < 0.01, ^c P < 0.001;30 ^aAOR: Adjusted Odds Ratio,31 ^bCI: Confidence Interval,32 ^cModel 0- Empty (null) model33 ^dModel I- Only individual-level explanatory variables included in the model;34 ^eModel II- Only community-level explanatory variables included in the model;35 ^fModel III- Combined model; both individual-level and community-level explanatory variables36 ^gPCV: Proportional Change in Variance,37 ^hMOR: Median Odds Ratio

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249 Random-effects analysis

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

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3 254 variability declined over successive models, from 78.81% in the null model to 78.55% in the only
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5 255 individual-level, 59.08% in the only community-level, and 58.97% in the final (combined) models.
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8 256 The proportional change in variance indicated that the addition of predictors to the empty model
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10 257 explained an increased proportion of variation in access to improved drinking water sources. The
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12 258 combined model showed that a higher PCV, i.e., 61.36% of the variance in access to improved
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14 259 drinking water sources could be explained by the combined factors at the individual- and
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17 260 community-level factors.

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20 261 In [Table 3] the final model (Model III), ICC value of 0.2708 displayed that 27.08% of the total
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22 262 variation in access to improved toilet facilities is accounted for the community-level factors. The
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24 263 remaining 72.92% variation is therefore triggered by the individual- level and other unknown
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27 264 factors. The proportional change in variance indicated that the addition of predictors to the empty
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29 265 model explained an increased proportion of variation in access to improved toilet facilities. The
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31 266 combined model showed a higher PCV, i.e., 85.91% of the variance in access to improved toilet
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33 267 facilities could be explained by the combined factors at the individual- and community-level
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36 268 factors.

37 38 39 269 **Model fit statistics**

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41 270 As shown in [Tables 2 & 3] (model fit statistics), the values of log-likelihood and Deviance
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43 271 showed a subsequent reduction which demonstrated that each model represents a significant
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45 272 improvement over the previous model and it points to the goodness of fit for the final model built
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48 273 in the analysis.

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276 **DISCUSSION**

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

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

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

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3 298 quality health outcomes, and educated people usually are more aware of the condition that
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5 299 guarantees their well beings. This implies that educated household heads in this study may have
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8 300 utilized their resources to provide their households with improved toilet facilities.
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11 301 In addition to individual-level factors, community-level factors were also a significant factor in
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13 302 determining access to improved drinking water sources and toilet facilities. Compared to
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15 303 households within the poorest category, households within the poor, middle, richer, and richest
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17 304 wealth index category were 1.48, 2.42, 3.26, and 6.97 times more likely to have access to improved
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19 305 sources of drinking water and 3.97, 5.82, 8.58, and 23.94 times higher odds to access to improved
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21 306 toilet facilities, respectively. This result is consistent with results from previous studies. (13, 14, 32)

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24 307 People who have better incomes would intend to fulfill the necessities of life. Economically, the
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26 308 rich can afford the initial high cost of both water and sanitation facilities and the poor may be
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28 309 disproportionately underserved in the distribution of public utility, and hence consume poor quality
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30 310 water and use unimproved toilet facilities.

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33 311 Compared to households that got drinking water < 30 minutes, households which obtained
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35 312 drinking water \geq 30 minutes were 35% less likely to access improved drinking water sources.
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37 313 Hence, the length of time to get drinking (proximity of a house to a drinking water sources) water
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39 314 might make difference in access to improved sources of drinking water and coverage (%) with
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41 315 improved water supply (HH connection, public standpipes, protected underground water sources,
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43 316 rainwater collection). This is not surprising as physical distance is one of the reasons of WASH
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45 317 service inaccessibility.
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51 318 The adjusted odds of access to improved drinking water sources and toilet facilities were 94.00%
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53 319 and 72.00% less likely among rural households as compared to urban households, respectively.
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55 320 The rural-urban disparity in access to improved sources of drinking water and toilet facilities have
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3 321 been reported by several other previous studies, too. (12, 33, 34). The disparity might be, in Sub-
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5 322 Saharan Africa, most of the people live in rural areas and their economic status is poor. Therefore,
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7 323 they do not have adequate financial resources to acquire improved drinking water sources and
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9 324 toilet facilities.

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13 325 Furthermore, households who had improved sources of drinking water were 1.37 times more likely
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15 326 to access an improved toilet facilities. This study finding is consistent with an earlier study. (29)
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17 327 The possible explanation could be a lack of access to adequate sanitation is also linked to the
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19 328 limited access to water supply and households who had improved water sources may be practicing
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21 329 more in hygiene and sanitation.

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25 330 Lastly, those households with four to six members were 24% less likely to have access to improved
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27 331 toilet facilities compared to households with one to three members. This is contrary to that of an
28
29 332 earlier study. (2) The possible explanation could be the highest number of household members, the
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31 333 fewer resources they could have to build improved toilet facilities.

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35 334 The results of our study should be interpreted with the following limitations. Since the information
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37 335 is recorded retrospectively, it might be prone to recall bias, and the analyses were conducted using
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39 336 data collected in a cross-sectional survey, which prevents causal inferences.

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3 338 **CONCLUSIONS**
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6 339 The proportion of households' access to an improved sources of drinking water and toilet facilities
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8 340 was low in Ethiopia. Sex of the household head, household wealth index, time to get drinking
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10 341 water, place of household/ urban/ rural residence, and region were factors impacting access to
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12 342 improved drinking water sources. Educational level of the household head, household wealth
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14 343 index, marital status of the household head (widowed), sources of drinking water, number of
15
16 344 household members, household or rural/urban residence, and region were factors associated with
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18 345 access to improved toilet facilities. Thus, we authors recommend governmental and non-
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20 346 governmental organizations working on water, hygiene, and sanitation should consider a multi-
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22 347 faceted policy approach that accounts for the regions and residence variations and other identified
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24 348 factors to ease up the problem.
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3 350 **Acknowledgments**
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5 351 We would like to thank the Demographic and Health Survey (DHS) programme for allowing the
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7
8 352 use of Ethiopian Demographic and Health Survey (EDHS) data for this study.
9

10 353 **Competing interests:** None declared.
11

12 354 **Patient consent for publication:** Not required.
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14
15 355 **Ethics approval:** The EDHS 2016 was approved by the National Research Ethics Review
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17 356 Committee of Ethiopia and ICF Macro International. The approval letter was obtained from the
18
19 357 measure DHS for the use of this data, and the dataset was downloaded from www.measuredhs.com.
20

21 358 This analysis was approved by the Department of Environmental and occupational health and
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23
24 359 safety, University of Gondar.
25

26 360 **Funding**
27

28 361 The author(s) received no specific funding for this work.
29

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31 362 **Availability of data and materials**
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33 363 The dataset analyzed during the current study available from the corresponding author upon
34
35 364 reasonable request.
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37
38 365 **Authors' contributions**
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40 366 ZA wrote the analyzed data, drafted the manuscript, and prepared the manuscript. HD, ZNA, AAT,
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42 367 BD, RF, AGM, and YY involved in drafting, writing – review & editing, and commenting the
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45 368 manuscript. All authors read and approved the final manuscript.
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370 **REFERENCES**

- 371 1. Prüss-Ustün A, Wolf J, Bartram J, Clasen T, Cumming O, Freeman MC, et al. Burden of
372 disease from inadequate water, sanitation and hygiene for selected adverse health outcomes: An
373 updated analysis with a focus on low-and middle-income countries. *International journal of*
374 *hygiene and environmental health.* 2019;222(5):765-77.
- 375 2. Agbadi P, Darkwah E, Kenney PL. A Multilevel Analysis of Regressors of Access to
376 Improved Drinking Water and Sanitation Facilities in Ghana. *Journal of environmental and*
377 *public health.* 2019;2019.
- 378 3. Assembly UG. Resolution on Human Right to Water and Sanitation. New York: United
379 Nations. 2010.
- 380 4. Brookes JD, Carey CC. Ensure availability and sustainable management of water and
381 sanitation for all. *UN Chronicle.* 2015;51(4):15-6.
- 382 5. Mills JE, Cumming O. The impact of water, sanitation and hygiene on key health and
383 social outcomes. URL: [https://www.lshtm.ac.uk/sites/default/files/2017-](https://www.lshtm.ac.uk/sites/default/files/2017-07/WASHEvidencePaper_HighRes_01)
384 [07/WASHEvidencePaper_HighRes_01.](https://www.lshtm.ac.uk/sites/default/files/2017-07/WASHEvidencePaper_HighRes_01) 2016;23.
- 385 6. Saxena SK, Kumar S, Haikerwal A, Bhatt ML. Introductory chapter: Neglected tropical
386 waterborne infectious diseases-strategies for mitigation. *Water Challenges of an Urbanizing*
387 *World.* 2018:1.
- 388 7. Organization WH. Water, sanitation, hygiene, and waste management for the COVID-19
389 virus: interim guidance, 23 April 2020. World Health Organization, 2020.
- 390 8. Organization WH. Progress on drinking water, sanitation and hygiene: 2017 update and
391 SDG baselines. 2017.
- 392 9. Organization WH. Water, sanitation, hygiene and health: a primer for health
393 professionals. World Health Organization, 2019.
- 394 10. Organization WH. Safer water, better health. 2019.
- 395 11. UNICEF. Water, sanitation and hygiene (WASH) 2020 [cited 2020 April, 14]. Available
396 from: [https://www.unicef.org/ethiopia/water-sanitation-and-hygiene-wash.](https://www.unicef.org/ethiopia/water-sanitation-and-hygiene-wash)
- 397 12. Mulenga JN, Bwalya BB, Kaliba-Chishimba K. Determinants and inequalities in access
398 to improved water sources and sanitation among the Zambian households. *International Journal*
399 *of Development and Sustainability.* 2017;6(8):746-62.

- 1
2
3 400 13. Morakinyo OM, Adebowale SA, Oloruntoba EO. Wealth status and sex differential of
4 401 household head: implication for source of drinking water in Nigeria. *Archives of Public Health*.
5 402 2015;73(1):58.
6
7
8 403 14. Simelane MS, Shongwe MC, Vermaak K, Zwane E. Determinants of Households'
9 404 Access to Improved Drinking Water Sources: A Secondary Analysis of Eswatini 2010 and 2014
10 405 Multiple Indicator Cluster Surveys. *Advances in Public Health*. 2020;2020.
11
12 406 15. Wang C, Pan J, Yaya S, Yadav RB, Yao D. Geographic Inequalities in Accessing
13 407 Improved Water and Sanitation Facilities in Nepal. *International journal of environmental*
14 408 *research and public health*. 2019;16(7):1269.
15
16 409 16. Tuyet-Hanh TT, Long TK, Van Minh H, Huong LTT. Longitudinal household trends in
17 410 access to improved water sources and sanitation in Chi Linh town, Hai Duong province, Viet
18 411 Nam and associated factors. *AIMS public health*. 2016;3(4):880.
19
20 412 17. Organization WH, UNICEF. Progress on drinking water and sanitation: special focus on
21 413 sanitation. *Progress on drinking water and sanitation: special focus on sanitation*2008.
22
23 414 18. Beyene A, Hailu T, Faris K, Kloos H. Current state and trends of access to sanitation in
24 415 Ethiopia and the need to revise indicators to monitor progress in the Post-2015 era. *BMC Public*
25 416 *Health*. 2015;15:451-.
26
27 417 19. Pullan RL, Freeman MC, Gething PW, Brooker SJ. Geographical inequalities in use of
28 418 improved drinking water supply and sanitation across sub-Saharan Africa: mapping and spatial
29 419 analysis of cross-sectional survey data. *PLoS Med*. 2014;11(4):e1001626.
30
31 420 20. Central Statistical Agency (CSA). Central Statistical Agency (CSA) [Ethiopia] and ICF
32 421 Ethiopia demographic and health Survey 2016. Addis Ababa, Ethiopia, and Rockville, Maryland,
33 422 USA: CSA and ICF,2017.
34
35 423 21. Simelane M, Shongwe M, Vermaak K, Zwane E. Determinants of Households' Access to
36 424 Improved Drinking Water Sources: A Secondary Analysis of Eswatini 2010 and 2014 Multiple
37 425 Indicator Cluster Surveys. 2020;2020.
38
39 426 22. Ribeiro Sarmiento MPH D. An Analysis of Access to Improved Drinking Water and
40 427 Sanitation and Distance to the Water Source in a Newly Independent Country, Timor-Leste:
41 428 Assessing Geographical and Socioeconomic Disparities. 2015.
42
43 429 23. Supply WUJW, Programme SM, Organization WH, Supply WUJMPfW, Sanitation,
44 430 UNICEF. *Water for life: making it happen: World health organization*; 2005.
45
46
47
48
49
50
51
52
53
54
55
56
57
58
59
60

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2
3 431 24. Merlo J, Chaix B, Ohlsson H, Beckman A, Johnell K, Hjerpe P, et al. A brief conceptual
4 432 tutorial of multilevel analysis in social epidemiology: using measures of clustering in multilevel
5 433 logistic regression to investigate contextual phenomena. *Journal of Epidemiology & Community*
6 434 *Health*. 2006;60(4):290-7.
- 7
8 435 25. Merlo J, Yang M, Chaix B, Lynch J, Råstam L. A brief conceptual tutorial on multilevel
9 436 analysis in social epidemiology: investigating contextual phenomena in different groups of
10 437 people. *Journal of Epidemiology & Community Health*. 2005;59(9):729-36.
- 11
12 438 26. Larsen K, Merlo J. Appropriate assessment of neighborhood effects on individual health:
13 439 integrating random and fixed effects in multilevel logistic regression. *American journal of*
14 440 *epidemiology*. 2005;161(1):81-8.
- 15
16 441 27. Spiegelhalter DJ, Best NG, Carlin BP, Van Der Linde A. Bayesian measures of model
17 442 complexity and fit. *Journal of the royal statistical society: Series b (statistical methodology)*.
18 443 2002;64(4):583-639.
- 19
20 444 28. Joseph F. Hair, Jr. William, Black Barry J., Babin Rolph, E. Anderson. *Multivariate Data*
21 445 *Analysis Edition S, editor*2018.
- 22
23 446 29. Abubakar IR. Access to sanitation facilities among Nigerian households: determinants
24 447 and sustainability implications. *Sustainability*. 2017;9(4):547.
- 25
26 448 30. Morakinyo OM, Adebowale SA, Oloruntoba EO. Wealth status and sex differential of
27 449 household head: implication for source of drinking water in Nigeria. *Archives of public health =*
28 450 *Archives belges de sante publique*. 2015;73:58.
- 29
30 451 31. Akpakli DE, Manyeh AK, Akpakli JK, Kukula V, Gyapong M. Determinants of access to
31 452 improved sanitation facilities in rural districts of southern Ghana: evidence from Dodowa Health
32 453 and Demographic Surveillance Site. *BMC Res Notes*. 2018;11(1):473-.
- 33
34 454 32. Njuguna J. Progress in sanitation among poor households in Kenya: evidence from
35 455 demographic and health surveys. *BMC Public Health*. 2019;19(1):135.
- 36
37 456 33. Irianti S, Prasetyoputra P, Sasimartoyo TP. Determinants of household drinking-water
38 457 source in Indonesia: An analysis of the 2007 Indonesian family life survey. *Cogent Medicine*.
39 458 2016;3(1).
- 40
41 459 34. Prasetyoputra P, Irianti S. Access to improved sanitation facilities in indonesia: An
42 460 econometric analysis of geographical and socioeconomic disparities. *Journal of Applied Sciences*
43 461 *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) <i>Cohort study</i> —Give the eligibility criteria, and the sources and methods of selection of participants. Describe methods of follow-up <i>Case-control study</i> —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 <i>Cross-sectional study</i> —Give the eligibility criteria, and the sources and methods of selection of participants	
		(b) <i>Cohort study</i> —For matched studies, give matching criteria and number of exposed and unexposed <i>Case-control study</i> —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) <i>Cohort study</i> —If applicable, explain how loss to follow-up was addressed <i>Case-control study</i> —If applicable, explain how matching of cases and controls was addressed <i>Cross-sectional study</i> —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) <i>Cohort study</i> —Summarise follow-up time (eg, average and total amount)	
Outcome Data	15*	<i>Cohort study</i> —Report numbers of outcome events or summary measures over time	
		<i>Case-control study</i> —Report numbers in each exposure category, or summary measures of exposure	
		<i>Cross-sectional study</i> —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.

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