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Modern contraceptive use in Ethiopia: a spatial and multilevel analysis

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Abstract

Objective: To assess spatial variations in modern contraceptive use and to identify factors associated with it among married women in Ethiopia.

Design: Cross-sectional analysis of population-based and health facility data.

Setting: Ethiopia Demographic and Health Survey data linked to Service Provision Assessment data.

Population: Eight thousand four hundred and seventy-three married women and 1020 facilities that reported providing family planning services.

Methods: A linked secondary data analysis of population and health facility data was carried out. Both multilevel and spatial analyses were conducted to identify key determinants of women's use of modern contraceptive and spatial clustering of modern contraceptive use.

Main outcome measure: Modern contraceptive use.

Results: About 24% of the variation in the use of modern contraception was accounted for by location. A one-unit increase in the mean score of health facilities' readiness to provide short-term modern contraceptives in a typical region was associated with a 20-fold increase in the odds of modern contraceptive use. In the spatial analysis, it was found that Addis Ababa and the Amhara region had high clusters of modern contraceptive use rates. On the other hand, low rates of contraceptive use were clustered in the Afar and Somali regions.

Conclusion: There were significant variations in the use of modern contraceptives across the different regions of Ethiopia. Therefore, regions with low contraceptive rates and high fertility rates should be targeted for scaling up and tailoring of services to the culture and lifestyles of the population of those regions.

Keywords: Modern contraceptives, spatial variations, family planning methods

Strengths and limitations of this study

- This study identified both the demand and supply-side determinants of modern contraceptive utilization using a linked population and health facility data.
- In addition to multilevel analysis, this study used spatial analyses to identify geographical variations of modern contraceptive utilization.
- This study excluded DHS clusters without geographic coordinates, and used sampled health facilities that might under or overestimate the study finding.
- This study did not consider sampling weights while running the multilevel analysis.
- DHS surveys provide an average weight (hv005 or v005); however, the GLIMMIX procedure in SAS requires weights at each level that did not enable to apply sampling weights in the multilevel analysis.

Background

Worldwide, modern contraceptives are believed to be important in fertility control (1). Especially for those in developing countries, contraceptives have a clear effect on the health of women, children, and families. For instance, contraceptives are estimated to prevent 2.7 million infant deaths and the loss of 60 million healthy lives a year worldwide (2). In countries with high fertility rates, promoting contraceptives averts 32% of all maternal deaths and approximately 10% of child mortality. Modern contraceptives also make a huge contribution to the achievement of universal primary schooling, female empowerment, and in reducing poverty and hunger (3). Family planning is also important in preventing unintended pregnancies and unsafe abortions (4, 5).

In spite of the above-mentioned importance, access and utilization of modern contraceptives vary worldwide. Women in developed countries have better access and use as compared to those from developing countries (4). In one study, from 2010 – 2014, it was reported that the global burden of unintended pregnancies was 44%. The rate of unintended pregnancies is substantially higher in developing countries as compared to developed regions (6). Higher levels of unmet need for contraception could contribute to higher rates of unintended pregnancies in developing regions. For instance, in sub-Saharan Africa, the prevalence of contraceptive use among reproductive-age women is only 17% (7).

Similarly, the utilization of modern contraceptives is a common healthcare challenge in Ethiopia. Even though there is an increase in women's use of modern contraceptives, still challenges remain (8). Discrepancies in the use of modern contraceptives are common within the different parts of the country. For instance, the Somali region accounts for the lowest rate of modern contraceptive use (1.4%) as compared to Addis Ababa (50.1%) (8).

The utilization of modern contraceptives could be influenced by both demand and supply-side factors. In previous studies, more emphasis was given on the importance of demand-side factors (7). Most of the investigated demand-side factors were women's education (7, 9) and age (9, 10), household wealth (7, 9, 11) and parity (12, 13). The importance of supply-side factors has been largely overlooked. In some studies, it was reported that the quality of family planning services (14), and living close to a family planning facility (15) were significantly associated with modern contraceptive utilization. In east Africa, it was observed that the

utilization of modern contraceptives was higher among facilities providing different contraceptive methods and with a higher family planning service environment scores (16).

Due to the increasing availability of geographically referenced health facility and population data, it is possible to do geographically linked analyses (17). This opportunity allows identification of the location of existing health facilities as well as mapping the eligible population without access to a particular health service, such as family planning. This further enables identification of both the demand and supply-side factors and helps the government determine where future investments should be targeted. Therefore, this study aimed to assess the spatial variations in the use of modern contraceptives among married women in Ethiopia. Furthermore, it aimed to identify the potential factors associated with the use of modern contraceptives among married women throughout the country, using the national population and health facility data.

Methods

Data sources

The main data sources of this study were the 2016 Ethiopia Demographic and Health Survey (EDHS) and the 2014 Ethiopian Service Provision Assessment Plus (ESPA+). The 2016 EDHS had information on population characteristics, such as contraception and obstetric care use. The survey details found elsewhere (8, 17). The latitude and longitude of each survey cluster were also collected (18). In this analysis, 8,473 married women were included.

The main source of the health facility data was the 2014 ESPA+ survey (19). The ESPA+ survey had information on service availability and readiness, including family planning services (19). Details of the survey found elsewhere (17, 19). In this analysis, 1,020 facilities that reported providing family planning services were included.

Data linking method

In this study, we used an administrative boundary link for linking health facility data with the population data (17). Details of this method found elsewhere (17). Ethiopia's administrative boundaries, used in this study, were obtained from Natural Earth (20).

Health service environment

Four health service environment variable scores were created. All service availability and readiness scores were computed for the nearest family planning providing facilities. Details of this computation found elsewhere (17). Average straight-line distance to the nearest family planning providing facility was calculated after linking each DHS cluster with SPA facility (17). First, the distance from each cluster to every family planning providing facility within the administrative boundaries was calculated. Second, the nearest family planning providing facility was identified and the average distance was computed per region.

With regard to the general service readiness score, eight general service readiness dimensions were obtained using principal component analysis (17). The average general service readiness score per region/city administration was computed using the SAS SCORE procedure. The first two principal components were used to compute two general service readiness scores (health facility management system and infrastructure). Furthermore, indices of family planning availability and readiness were computed. Two family planning availability scores (long-acting and short-term contraceptives methods) were created using seven variables (17). Similarly, two-family planning readiness scores (readiness to provide long-acting and short-term contraceptives) were created using seven variables (17).

A woman was considered to be using modern contraception if she used any of the modern contraceptive methods with the exception of male condoms (17). The male condom could be accessed from shops that the SPA survey did not capture.

Statistical analysis

Multilevel analysis

To account for the nested nature of DHS data, a two-level generalized linear mixed model was used. This study had binary outcomes: whether a married woman used modern contraception or not. We were interested in the probability of modern contraceptive utilization and the influence of individual and region-level characteristics. The equation used to estimate the two-level hierarchical model found elsewhere (17).

Binary distribution with the logit link function was used to model this binary outcome. To estimate this model, the GLIMMIX procedure in SAS was used (21). Four model building process was carried out. The Laplace estimation was used for estimating these models. The model building process was started with an empty model. The variance estimate from this

model was used to calculate the intra-class correlation coefficient (ICC) (21). Details of calculating ICC in hierarchical generalized linear models found elsewhere (17, 22). By checking improvements in model fit, complex models were built step by step. The negative two log-likelihood, Akaike Information Criteria (AIC) and Bayesian Information Criteria (BIC) were used to assess the best fitting model (21).

Spatial analysis

ArcGIS 10.6.1 was used to do spatial analyses. The Ethiopian Polyconic Projected Coordinate System (17) was used to flatten the Ethiopian map. Hot spot analysis was carried out to identify spatial clusters of modern contraceptive use. DHS clusters were the unit of spatial analyses.

We followed three analyses procedures while doing the hot spot analysis as discussed elsewhere (17). First, we run the Global Moran's I statistic; it is a global measure of spatial autocorrelation (23). Second, based on the Global Moran's I statistic, Incremental Spatial Autocorrelation was run to determine the critical distance at which clustering of modern contraception prevalence rate (mCPR) was peaked (165 kilometres) (17). Lastly, the Getis-Ord Gi* statistic was run to identify statistically significant spatial clusters of mCPR (17). The two statistical problems of local statistics of spatial association (multiple comparison and spatial dependence) were controlled using a False Discovery Rate (FDR) correction (17, 24).

Patient and public involvement

This study used secondary data sets: 2016 EDHS and 2014 ESPA+ that were previously collected with confidentiality information maintained (no personal identifier used). The data were collected under the collaboration of The Ethiopian Federal Ministry of Health, Ethiopian Central Statistical Agency, Ethiopian Public Health Institute and USAID. Hence, as we did not collect the data directly from participants, no recruitment and contact of participants were required. Thus, to access these data sets, ethical approval was obtained from the DHS program Institutional Review Board and Ethiopian Public Health Institute. Furthermore, this study was ethically approved by the Human Research Ethics Committee, The University of Newcastle on March 20, 2018 with a reference number H-2018-0066.

Results

Sociodemographic characteristics

The mean age of the study participants was 31.09 (standard deviation of ±8.22) years. Approximately 22% of respondents were within the age range of 25 – 29 years. Over 57% of the women had no education, while 27.58% had a primary level education. With regard to wealth, 29.26% of the women fell in the richest quintile and 27.86% were grouped in the poorest quintile. About 38% and 41% of the respondents were followers of the Orthodox Christian and Muslim faith, respectively. Seventy-three percent of the respondents were from rural areas (Table 1).

Table 1: Sociodemographic characteristics of married women in Ethiopia, 2016 (N = 8,473)

Variable		Frequency	Percentage
Age	15 – 19	534	6.30
	20 – 24	1436	16.95
	25 – 29	1876	22.14
	30 – 34	1591	18.78
	35 – 39	1412	16.66
	40 – 44	953	11.25
	45 – 49	671	7.92
Women's education	No education	4869	57.46
	Primary	2337	27.58
	Secondary	773	9.12
	Higher	494	5.83
Women's occupation	Have no work	6030	71.17
	Professional work	1310	15.46
	Agricultural work	749	8.84
	Others	384	4.53
Husbands'/partners' education	No education	3774	44.54
	Primary	2651	31.29
	Secondary	1060	12.51
	Higher	988	11.66
Husbands'/partners' occupation	Have no work	851	10.04
	Professional work	2592	30.59
	Agricultural work	4208	49.66
	Others	822	9.70
Head of household	Someone else	7147	84.35
	Herself	1326	15.65
Family size	1 – 4	3050	36.00
	5 – 8	4564	53.86
	>= 9	859	10.14
Wealth quintile	Lowest	2361	27.86
	Second	1291	15.24
	Middle	1184	13.97
	Fourth	1158	13.67
	Highest	2479	29.26
Religion	Orthodox	3243	38.27
	Protestant	1597	18.85
	Muslim	3474	41.00
	Other	159	1.88
Residence	Urban	2261	26.68
	Rural	6212	73.32

Women's obstetric characteristics

Amongst the 8,473 married women, 7,721 (91.12%) had given birth. The mean age at first childbirth was 18.98 (standard deviation of ±3.85) years. Over 37% of married women had five or more births; about 31% of the women had more than four living children. Amongst 5,708 women who were pregnant in the previous five years, 1,853 (32.46%) had no antenatal care visits for their most recent pregnancy. With regard to healthcare decisions, only 19.40% of the women had autonomy to decide on their own healthcare needs. Under a third (31.24%) of women had been exposed to family planning messages. More than half (52.79%) of married women had ever used contraceptive methods (Table 2).

Table 2: Obstetric characteristics of married women in Ethiopia, 2016 (N = 8,473)

Variable		Frequency	Percentage
Parity	0	752	8.88
	1 – 4	4577	54.02
	>= 5	3144	37.11
Number of living children	0	813	9.60
	1 – 4	5029	59.35
	>= 5	2631	31.05
Age at first childbirth (n = 7721)	<= 19 year	5618	66.30
	20 – 24 year	2224	26.25
	>= 25 year	631	7.45
Number of ANC visits (n = 5708)	0	1853	32.46
	1 – 3	1688	29.57
	>=4	2167	37.96
Autonomy in own personal healthcare decision making	Respondent alone	1644	19.40
	Joint decision	5298	62.53
	Husband/partner alone	1531	18.07
Autonomy in family planning decision making (n = 2954)	Mainly respondent	724	24.51
	Mainly husband/partner	149	5.04
	Joint decision	2081	70.45
Knowledge of modern contraceptive methods	No	324	3.82
	Yes	8149	96.18
Exposure to family planning messages	No	5826	68.76
	Yes	2647	31.24
Ever used any contraceptive method	No	4000	47.21
	Yes	4473	52.79

Health facility characteristics

Data were collected from 1,165 health facilities nationwide. Amongst these health facilities, 18.73% and 27.75% were hospitals and health centres, respectively. About 68% of the health facilities were managed by the government. With regard to family planning service provision, 1,020 (87.55%) of the health facilities provided family planning services. Three quarters (75.2%) had a contraceptive method mix; they provided three or more contraceptive methods. About 50% of the health facilities provided long-acting contraceptives, while, 99.31% of them provided short-term contraceptive methods. The national average distance from family planning health facilities to the 2016 EDHS clusters was 6.35 kilometres. The 2016 EDHS sampled clusters in the Somali region were the longest distance (18.58 km) from family planning facilities. Conversely, EDHS clusters in Addis Ababa were 0.55 km from family planning facilities (Table 3).

Table 3: The average distance from sampled family planning providing health facilities to demographic and health survey clusters in Ethiopia, 2016 (N = 1,020)

Region	Health facility type				Average distance (km)
	Hospitals n (%)	Health Centres n (%)	Health Posts n (%)	Private Clinics n (%)	
Tigray	30 (28.30)	30 (28.30)	25 (23.58)	21 (19.81)	5.53
Afar	6 (10.71)	25 (44.64)	16 (28.57)	9 (16.07)	9.69
Amhara	26 (16.77)	46 (29.68)	34 (21.94)	49 (31.61)	8.47
Oromia	49 (25.26)	50 (25.77)	43 (22.16)	52 (26.80)	8.99
Somali	10 (20.41)	21 (42.86)	12 (24.49)	6 (12.24)	18.58
Benishangul-Gumuz	2 (3.13)	16 (25.00)	29 (45.31)	17 (26.56)	5.28
SNNPR	24 (15.58)	40 (25.97)	38 (24.68)	52 (33.77)	7.08
Gambela	1 (1.79)	14 (25.00)	22 (39.29)	19 (33.93)	4.32
Harari	4 (9.30)	8 (18.60)	21 (48.84)	10 (23.26)	0.73
Addis Ababa	33 (42.31)	18 (23.08)	0	27 (34.62)	0.55
Dire Dawa	6 (9.23)	15 (23.08)	31 (47.69)	13 (20.00)	0.60
Total	191 (18.73)	283 (27.75)	271 (26.57)	275 (26.96)	6.35

The modern contraceptive prevalence rate

The prevalence of modern contraceptive use among married women was found to be 33.54% (urban 46.09%, 28.98% rural). Utilization of modern contraceptives varied across the different regions and city administrations; the highest modern contraceptive prevalence rate (mCPR) was reported in the Amhara region (51.65%), followed by Addis Ababa (50.08%) and the Southern Nations, Nationalities and Peoples Region (SNNPR) (45.48%). The map (Fig 1) shows the regional variations in modern contraceptive prevalence rates.

Spatial epidemiology of modern contraceptive use

There is strong evidence to support spatial clustering in utilization of modern contraceptives among married women in Ethiopia (Global Moran's I = 0.24, z-score = 8.09, P-value < 0.0001). Most of the hot spot areas (high contraceptive prevalence rates) were located in Addis Ababa and Amhara, followed by the Oromia region and the SNNPR. Conversely, the majority of the cold spot areas (low contraceptive prevalence rates) were located in Somali, Afar and Gambela regions followed by Tigray and Benishangul-Gumuz. This clustering was supported by the Getis-Ord Gi* statistic when conducting the spatial analysis (Fig 2).

Determinants of modern contraceptive use among married women

The calculated intra-class correlation coefficient (ICC) was 24.47%. This indicated that about 24% of the variability in using modern contraceptive methods was accounted for by location, leaving 76% of the variability to be accounted for by the differing characteristics of the women, or other unmeasured factors. The probability of using modern contraceptive methods in a typical region was estimated at 27.8%.

Women's age, husbands' / partners' education, household wealth, number of living children a woman had, and exposure to family planning messages were strong individual-level predictors of modern contraceptive use among married women. Women who were in the age groups of 35 – 39 (44%), 40 – 44 (55%) and 45 – 49 (82%) were less likely to use modern contraceptives compared to those in the 15 – 19 year age group. A woman whose husband attained a primary level of education was 54% more likely to use modern contraceptives as compared to those whose husband had no education. The odds ratio of modern contraceptive use increased with increasing wealth quintile. Therefore, women who were in the highest quintile were 5.26 times more likely to use the service as compared to those in the lowest quintile. Women who had been exposed to family planning messages were 68% more likely to use modern contraceptives relative to their counterparts with no exposure to family planning messages. Similarly, women

who had one to four children were 2.31 times more likely to use the service as compared to those having no child (Table 4).

At the regional level (level 2), only one variable was significantly associated with the use of modern contraceptives. A one-unit increase in the mean score of a health facility's readiness to provide short-term modern contraceptives in a typical region was associated with a 20 fold increase in the odds of modern contraceptive use (Table 4).

Finally, the majority of the between region variance was explained by this model: the between region variation in using a modern contraceptive decreased from 1.07 to 0.18, which is an 83.18% reduction in the unexplained variance between region modern contraceptive utilization. However, region level random effects are significant; the intra-class correlation is still 5%. This indicated that even after controlling for individual and regional level factors, there is still a considerable region level clustering of modern contraceptive use. The between region variance of slopes indicated that the following five variables varied significantly across regions: women's age, husbands' / partners' education, household wealth, number of living children and exposure to family planning messages (Table 4).

Table 4: Factors associated with utilization of modern contraceptive among married women in Ethiopia (N = 8,473)

Predictors		N	Adjusted odds ratio (95% CI)
Level-1 predictor variables			**Modern contraceptive use**
Age in years	15 – 19	534	1
	20 – 24	1436	1.26 (0.91, 1.76)
	25 – 29	1876	0.93 (0.67, 1.30)
	30 – 34	1591	0.74 (0.52, 1.04)
	35 – 39	1412	**0.56 (0.39, 0.80)**
	40 – 44	953	**0.45 (0.31, 0.65)**
	45 – 49	671	**0.18 (0.12, 0.27)**
Husbands' or partners' education	No education	3774	1
	Primary	2651	**1.54 (1.18, 2.02)**
	Secondary	1060	1.29 (0.96, 1.73)
	Higher	988	1.05 (0.77, 1.44)
Wealth quintile	Lowest	2361	1
	Second	1291	**1.95 (1.27, 2.99)**
	Middle	1184	**2.65 (1.72, 4.08)**
	Fourth	1158	**3.42 (2.21, 5.28)**
	Highest	2479	**5.26 (3.46, 7.99)**
Number of living children	0	813	1
	1 – 4	5029	**2.31 (1.64, 3.25)**
	>= 5	2631	**2.05 (1.40, 3.01)**
Exposure to family planning messages	No	5826	1
	Yes	2647	**1.68 (1.20, 2.36)**
Level-2 predictor variables			
General service readiness	Health facility management system		1.27 (0.05, 35.69)
	Health facility infrastructure		1.51 (0.18, 12.95)
Family planning service availability	Long-acting contraceptive methods		5.04 (0.19, 136.21)
	Short-term contraceptive methods		1.79 (0.03, 103.48)
Family planning service readiness	Long-acting contraceptives		0.43 (0.01, 17.12)
	Short-term contraceptives		**20.49 (1.44, 292.54)**
Average distance to the nearest health facility			1.02 (0.81, 1.28)
Random effects (Error variance)			
Var (Age)			**0.05 (0.02, 0.15)**
Var (Husbands' or partners' education)			**0.05 (0.02, 0.22)**
Var (Wealth quintile)			**0.14 (0.07, 0.32)**
Var (Number of living children)			**0.08 (0.04, 0.29)**
Var (Exposure to family planning messages)			**0.09 (0.03, 0.61)**
Var (constant) - level-2 variance			0.18 (0.05, 3.70)
Rho – Intra-class correlation			0.05
Fit statistics (-2 Log Likelihood)			8860.49

Discussion

In Ethiopia, the use of modern contraception varied by region. This is the first study to specifically identify hot spots and model the use of modern contraception using nationwide population and health facility data. Approximately 34% of married women use modern contraceptives; the highest mCPR was reported among urban married women (46.09% versus 28.98%). This is comparable with the findings of the 2011 EDHS data analysis where 27.3% of married women reported using modern contraceptive methods; the highest proportion of them was from urban areas (49.55% versus 22.5%) (9). There are also variations in modern contraceptive rate across different regions in the country. The highest contraceptive rate, more than 50% mCPR, was reported in the Amhara region and the Addis Ababa city administration. Conversely, the lowest, below 10% mCPR, was reported in the Somali and Afar regions. Even though there has been an increase in modern contraceptive use all over the country, it was found that there was significant regional variation in modern contraceptive use.

High mCPR spots (hot spots) were detected in the Amhara region and in Addis Ababa, followed by the Southern Nations, Nationalities and Peoples Region, and some parts of Oromia region. Conversely, the majority of low mCPR (cold spots) were detected in the Somali, Afar and Gambela regions followed by Tigray and Benishangul-Gumuz. In 2011, hot spots of modern contraceptive use were observed in Addis Ababa, followed by some parts of Amhara, Oromia and SNNPR. The lowest contraceptive rates (cold spots) were observed in the Afar, Somali, and Gambela regions, and some parts of Tigray region (9). This indicated that the government is doing a good job in some of the regions, but is less successful in most regions. Due to this reason, the unmet need for modern contraception will be much higher than expected in most of those regions. Thus, cold spots (low rates of modern contraception) will be much more concentrated in those areas.

In Ethiopia, the use of modern contraceptives varied across the different regions and city administrations. The highest modern contraceptive prevalence rate was reported in the Amhara region, followed by Addis Ababa and SNNPR. This variation is demonstrated by the national demographic and health surveys conducted every five years since 2000. Over 16 years, between 2000 and 2016, Ethiopia showed a 28.7% (6.3 - 35.0%) increase in the utilization of modern contraceptives. Amongst the nine regions and two city administrations, the Amhara region showed a 40.4% (6.6 - 47%) increase in modern contraceptive use. This is the highest consistent increase in modern contraceptive use across the four EDHS surveys. Similarly, the Amhara

region showed a consistent decrease in the total fertility rate (5.9 – 3.7) over these years (8, 25-27). This consistent increase in the use of modern contraceptives and a consistent decrease in total fertility rate in the Amhara region might be attributable to the absence of 2.4 million Amharas in the 2007 Population Census (28, 29).

Furthermore, the SNNPR is the second top region with a 35% increase in the use of modern contraceptives (5 - 40%) and a 1.5 decrease in total fertility rate (5.9 – 4.4). Even though Addis Ababa has the highest modern contraceptive prevalence rate, it did not show a consistent increase in the use of modern contraceptives across the four EDHS surveys (8, 25-27). In Addis Ababa, between 2000 and 2011, there was a 22% increase in modern contraceptive use (34.3% - 56.3%); however, this figure decreased to 50% in 2016. Conversely, the Afar and Somali regions had the lowest use of modern contraceptives in the 2000 to 2016 time period (8, 25-27). The large increase in the use of modern contraceptives in the Amhara region, as well as SNNPR, might be related to the high number of family planning organizations and the government's focus on these regions.

Different individual and regional level factors were significantly associated with the use of modern contraceptives. Health facilities' readiness to provide short-term modern contraceptives was the only regional level (level-2) variable that was significantly associated with the use of modern contraceptives. It was found that a one-unit increase in the mean score of health facilities' readiness to provide short-term modern contraceptives was significantly associated with utilization of modern contraceptives. In a study which used DHS and SPA data from several East African countries (Kenya, Uganda, Rwanda and Tanzania), it was found that modern contraceptive utilization was strongly associated with health facilities offering a wide range of contraceptives, and with a higher score of family planning service environment (16). Even though it is not directly related, in a study carried out in rural Ethiopia researchers found that women who live close to a health facility providing a wide range of contraceptives were more likely to use modern contraceptives (11). This indicated that the potential impact of family planning services should not be underestimated. Therefore, family planning health facilities should be fully equipped to provide a wide range of modern contraception.

Amongst the individual-level factors, an increase in the age of women was significantly associated with a decrease in the use of modern contraceptives. This is similar to the results of other studies carried out in Ethiopia where the utilization of modern contraceptives was negatively influenced by an increase in the age of women (9, 11, 12). This could be related to

the knowledge gap, beliefs and/or attitudes that each woman had; as the age of woman increases the probability of changing women's attitudes or beliefs towards contraception might sometimes be difficult.

In Ethiopia, among the individual-level variables, husbands'/partners' level of educational attainment was a significant predictor of the increase in modern contraceptive use. In a study conducted in the North Gondar, Amhara region of Ethiopia, it was found that the level of the husband's education was a significant predictor of contraceptive use (30). This might be due to the involvement of husbands in contraception decision making. This is supported by other studies demonstrating the influence of discussing modern contraceptives with the husband and the husband's approval of using modern contraceptives (31, 32). It was found that the utilization of modern contraceptives was significantly higher among those women whose husbands had approved of using modern contraceptives. Similarly, the odds of using modern contraceptives was higher among those women who had discussed modern contraceptives with their husbands (31, 32). This indicated that husband's education, as well as male involvement, has an important role in the use of modern contraceptives. Thus, educational opportunities for men and increasing male involvement in every family planning service should be emphasized for higher engagement in the use of modern contraception.

The increase in household wealth was a significant predictor of an increase in modern contraceptive utilization. In two studies conducted in Ethiopia, including a study done among rural women (11), it was found that women who were in the fourth and highest quintile were more likely to use modern contraceptives (9, 11). Furthermore, family monthly income was significantly associated with the use of modern contraceptives (31). In Ethiopia, despite family planning services being free of charge in public health facilities, the cost of transport might be attributable to the use of modern contraception. Moreover, the costs of family planning services in private health facilities might also be related to the use of modern contraceptives. Thus, issues of the cost of transport and family planning service fees in private health facilities might not be important for wealthy families.

In this current study, it was found that, as compared to those who have no children, having one or more living children increases women's likelihood of using modern contraceptives. In the 2011 EDHS data analysis (9) and a study done in the SNNPR (12), researchers also found that an increase in the number of living children was significantly associated with an increase in modern contraceptive utilization. Furthermore, among rural women in Ethiopia, an increase in

parity was positively associated with an increase in modern contraceptive use (11). This finding is similar to other studies done in Bangladesh, Pakistan and Tanzania where it was reported that an increase in the number of living children was significantly associated with an increase in the use of modern contraceptives (13, 33, 34). This indicated that women's fertility desires might influence their contraceptive use behaviour. Thus, women with a high number of living children might satisfy their fertility desire and continue using contraception.

Exposure to family planning messages, the last individual-level variable in the multilevel model, showed an increase in the likelihood of using modern contraception. In a study done among reproductive-age women in SNNPR region, it was found that the odds of modern contraceptive utilization were significantly associated with women's overall knowledge of family planning methods. It was observed that women with good family planning knowledge were more likely to use modern contraceptives (12). Thus, exposure to family planning messages through different public and private media outlets is an important recommendation to arise from this study.

In this study, it was found that the utilization of modern contraceptives varied across regions. The individual-level variables (age, husbands'/partners' education, wealth, number of living children and exposure to family planning messages) varied significantly across the regions. In a study carried out in rural Ethiopia, it was found that the use of modern contraceptives was significantly higher in the Amhara and SNNPR regions (11). This might be related to variations in the availability and accessibility of different family planning services across administrative regions of the country. In addition to the multilevel analysis, this study has identified the hot spot and cold spot areas to help the government in improving the provision of modern contraceptives, especially those areas with the low rates of modern contraception.

This study identified both the demand and supply-side determinants of modern contraceptive utilization using a linked population and health facility data. This was overlooked in previous studies where they mainly studied these factors separately. In addition to multilevel analysis, this study used spatial analyses to identify geographical variations of modern contraceptive utilization. Geographically looking family planning use is very important for effective resource allocation and intervention, informed decision making, and monitoring and evaluation purposes.

This study had several methodological limitations. However, most of these limitations were minimized (17). The exclusion of DHS clusters without latitudes and longitudes, and using sampled health facilities might under or overestimate our study finding. This study did not consider sampling weights while running the multilevel analysis. DHS surveys provide an average weight (hv005 or v005); however, the GLIMMIX procedure in SAS requires weights at each level. Due to this issue, we could not able to apply sampling weights in the multilevel analysis.

Conclusion

In this study, it was found that more than a third of married women in Ethiopia use modern contraceptives. It was also found that different individual-level variables, as well as regional level variables, were predictors of modern contraceptive use. Furthermore, there is evidence of a wide geographical variation in the use of modern contraceptives across the country. The findings of this study have several implications: first, regions with low contraceptive rates and high fertility rates should be targeted for scaling up and tailoring of services to the lifestyles of the population of those regions. Second, the available and newly constructed health facilities should be equipped to provide modern contraceptive methods. Third, increasing educational opportunities for men and increasing male involvement, and exposure to family planning messages are also important recommendations to arise from this research. The importance of awareness and the potential impact of services cannot be underestimated.

Abbreviations

CRS	Coordinate Reference System
DHS	Demographic and Health Survey
EAs	Enumeration Areas
EDHS	Ethiopia Demographic and Health Survey
ESPA+	Ethiopia Service Provision Assessment Plus
FDR	False Discovery Rate
GIS	Geographic Information Systems
HGLM	Hierarchical Generalized Linear Model
ICC	Intra-class Correlation Coefficient
IUD	Intrauterine Device
mCPR	modern Contraceptive Prevalence Rate
SNNPR	Southern Nations, Nationalities and Peoples Region
SPA	Service Provision Assessment
WGS84	World Geodetic System 84

Ethics approval

Ethical approval was obtained from the Human Research Ethics Committee, The University of Newcastle on March 20, 2018 with a reference number H-2018-0066. We also got the Ethiopian Public Health Institute (EPHI) and the Measure DHS program approval to access the datasets.

Consent for publication

Not applicable.

Availability of data and material

Not applicable.

Competing interests

The authors declared that they have no competing interests.

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Authors' contributions

TKT, CC, RS, DL conceptualized the design of the analysis. TKT developed and drafted the manuscript. CC, PF, TG, RS and DL participated in critically revising the intellectual contents of the manuscript. All authors read, provided feedback and approved the final manuscript.

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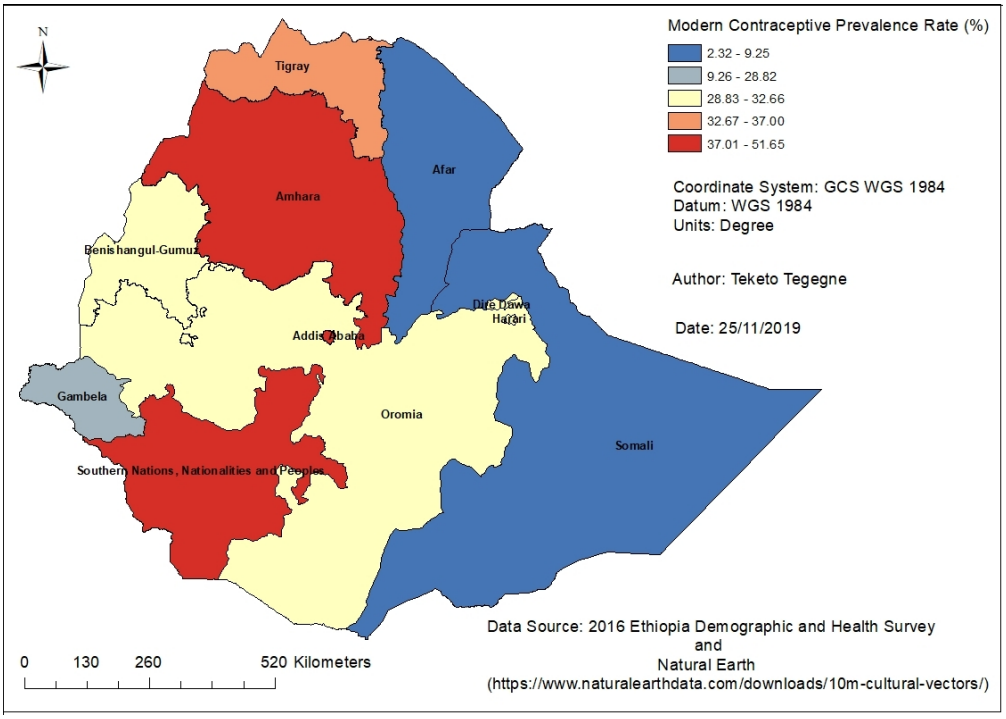
Figure Legends

Figure 1: Modern contraceptive use among married women in Ethiopia, 2016

Figure 2: Clusters of high and low modern contraceptive prevalence rates in Ethiopia, 2016



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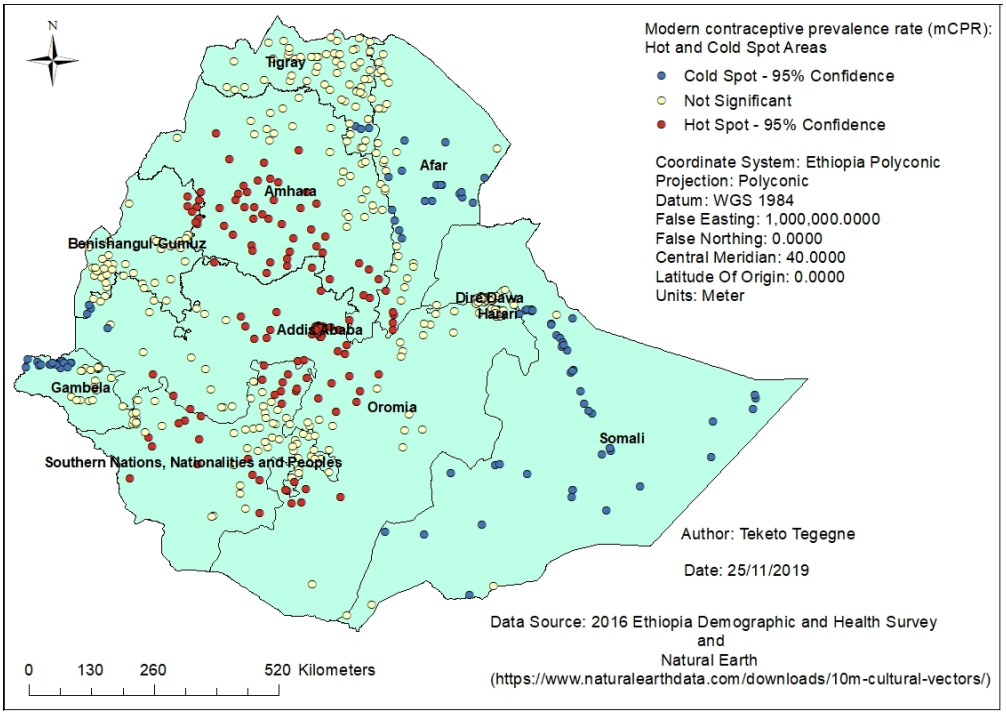

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STROBE Statement—Checklist of items that should be included in reports of ***cross-sectional studies***

	Item No	Recommendation	Page No
Title and abstract	1	(*a*) Indicate the study's design with a commonly used term in the title or the abstract	1
		(*b*) Provide in the abstract an informative and balanced summary of what was done and what was found	2
Introduction			
Background/rationale	2	Explain the scientific background and rationale for the investigation being reported	4 - 5
Objectives	3	State specific objectives, including any prespecified hypotheses	5
Methods			
Study design	4	Present key elements of study design early in the paper	5
Setting	5	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection	5
Participants	6	(*a*) Give the eligibility criteria, and the sources and methods of selection of participants	5
Variables	7	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable	6
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	*5 - 6*
Bias	9	Describe any efforts to address potential sources of bias	6
Study size	10	Explain how the study size was arrived at	5
Quantitative variables	11	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why	6
Statistical methods	12	(*a*) Describe all statistical methods, including those used to control for confounding	7
		(*b*) Describe any methods used to examine subgroups and interactions	7
		(*c*) Explain how missing data were addressed	7
		(*d*) 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	8 - 13
		(b) Give reasons for non-participation at each stage	8 - 13
		(c) Consider use of a flow diagram	8 - 13
Descriptive data	14*	(a) Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders	8 - 13
		(b) Indicate number of participants with missing data for each variable of interest	8 - 13
Outcome data	15*	Report numbers of outcome events or summary measures	14
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	14 - 16

		(*b*) Report category boundaries when continuous variables were categorized	16
		(*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	14
Discussion			
Key results	18	Summarise key results with reference to study objectives	17
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	3, 21
Interpretation	20	Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence	17 – 20
Generalisability	21	Discuss the generalisability (external validity) of the study results	21
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	22

*Give information separately for exposed and unexposed groups.

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.

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Modern contraception in Ethiopia: a spatial and multilevel analyses to determine service readiness and factors associated with modern contraceptive use

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Abstract

Objective: To assess spatial variations in modern contraceptive use and to identify factors associated with it among married women in Ethiopia.

Design: Cross-sectional analysis of population-based and health facility data.

Setting: Ethiopia Demographic and Health Survey data linked to Service Provision Assessment data.

Population: Eight thousand four hundred and seventy-three married women and 1020 facilities that reported providing family planning services.

Methods: A linked secondary data analysis of population and health facility data was carried out. Both multilevel and spatial analyses were conducted to identify key determinants of women's use of modern contraceptive and spatial clustering of modern contraceptive use.

Main outcome measure: Modern contraceptive use.

Results: About 24% of the variation in the use of modern contraception was accounted for by location. A one-unit increase in the mean score of health facilities' readiness to provide short-term modern contraceptives in a typical region was associated with a 20-fold increase in the odds of modern contraceptive use (Adjusted Odds Ratio [AOR] = 20.49, 95% CI 1.44 - 29.54). In the spatial analysis, it was found that Addis Ababa and the Amhara region had high clusters of modern contraceptive use rates. On the other hand, low rates of contraceptive use were clustered in the Afar and Somali regions.

Conclusion: There were significant variations in the use of modern contraceptives across the different regions of Ethiopia. Therefore, regions with low contraceptive rates and high fertility rates should be targeted for scaling up and tailoring of services to the culture and lifestyles of the population of those regions.

Keywords: Modern contraceptives, spatial variations, family planning methods

Strengths and limitations of this study

- This study identified both the demand and supply-side determinants of modern contraceptive utilization using a linked population and health facility data.
- In addition to multilevel analysis, this study used spatial analyses to identify geographic variations of modern contraceptive utilization.
- This study excluded DHS clusters without geographic coordinates and used sampled health facilities that might under or overestimate the study finding.
- This study did not consider sampling weights while running the multilevel analysis.
- DHS surveys provide an average weight (hv005 or v005); however, the GLIMMIX procedure in SAS requires weights at each level that did not enable to apply sampling weights in the multilevel analysis.

Introduction

Worldwide, modern contraceptives are important in fertility control (1). In developing countries, contraceptives have a clear effect on the health of women, children and families. For instance, contraceptives are estimated to prevent 2.7 million infant deaths and the loss of 60 million healthy lives a year worldwide (2). In countries with high fertility rates, promoting contraceptives averts 32% of all maternal deaths and approximately 10% of child mortality. Modern contraceptives also make a huge contribution to the achievement of universal primary schooling, female empowerment, and in reducing poverty and hunger (3). Family planning is also important in preventing unintended pregnancies and unsafe abortions (4, 5).

Despite its importance, access to and utilisation of modern contraceptives vary worldwide. Women in developed countries have better access to and use of contraceptives compared to women in developing countries (4). In a study from 2010–2014, it was reported that the global burden of unintended pregnancies was 44%; the rate of unintended pregnancies is substantially higher in developing countries compared to developed regions (6). Higher levels of unmet need for contraception could contribute to higher rates of unintended pregnancies in developing regions. For instance, in sub-Saharan Africa, the prevalence of contraceptive use among women of reproductive age is only 17% (7).

Similarly, the utilisation of modern contraceptives is a common healthcare challenge in Ethiopia. Even though there is an increase in women's use of modern contraceptives, challenges remain (8). Discrepancies in the use of modern contraceptives are common within the different parts of the country. For instance, the Somali region accounts for the lowest rate of modern contraceptive use (1.4%), compared to Addis Ababa (50.1%) (8).

The utilisation of modern contraceptives can be influenced by both demand- and supply-side factors. In previous studies, more emphasis has been given to the importance of demand-side factors (7). Most of the investigated demand-side factors were women's education (7, 9), age (9, 10), household wealth (7, 9, 11) and parity (12, 13). The importance of supply-side factors has been largely overlooked. In some studies, it was reported that the quality of family planning services (14) and living close to a family planning facility (15) were significantly associated with modern contraceptive utilisation. In East Africa, it was observed that the utilisation of

modern contraceptives was higher among facilities providing different contraceptive methods and with higher family planning service environment scores (16).

Due to the increasing availability of geographically referenced health facility and population data, it is possible to do geographically linked analyses (17). This opportunity allows identification of the location of existing health facilities as well as mapping the eligible population without access to a particular health service, such as family planning. This further enables identification of both the demand- and supply-side factors and helps the government determine where future investments should be targeted.

This study aimed to assess spatial variations in the use of modern contraceptives among married women in Ethiopia and identify the potential factors associated with the use of modern contraceptives among married women throughout the country, using the national population and health facility data. Contraception is more critical for women of reproductive age. However, married women or women in union are more likely to be sexually active as opposed to single, divorced or widowed women, particularly in Ethiopia where sex outside of a union is uncommon. Therefore, this study focused on only married women's modern contraceptive use.

Methods

Data Sources

The main data sources of this study were the 2016 Ethiopia Demographic and Health Survey (EDHS) and the 2014 Ethiopian Service Provision Assessment Plus (ESPA+). Ethical approval was obtained from the DHS program Institutional Review Board and the Ethiopian Public Health Institute. Furthermore, this study was ethically approved by the Human Research Ethics Committee, The University of Newcastle on March 20, 2018 (approval number H-2018-0066).

The 2016 EDHS collected information on population characteristics, such as contraception and obstetric care use. The survey details can be found elsewhere (8, 17). The geographic coordinates of each survey cluster were also collected (18). In the population survey, all women aged 15–49 years were eligible for individual interviews. The survey identified 16583 eligible women. Of these women, from 645 DHS clusters, 15683 were interviewed. In this analysis, 8473 married women who were not pregnant at the time of the interview were included from

622 DHS clusters. A total of 261 married, non-pregnant women from 23 clusters were excluded from the analysis since they had missing geographic coordinates.

The main source of the health facility data was the 2014 ESPA+ survey (19). The ESPA+ survey had information on service availability and readiness, including family planning services (19). Details of the survey can be found elsewhere (17, 19). The ESPA+ survey collected data from 1165 facilities. The survey used a combination of a census of hospitals and a sample of other health facilities (health centres, health posts and clinics). Of the 1165 facilities, 1020 facilities reported providing family planning services. In this analysis, 1020 facilities that reported providing family planning services were included.

Data Linking Method

In this study, we used an administrative boundary link for linking health facility data with the population data (17). Details of this method can be found elsewhere (17). Ethiopia's administrative boundaries, used in this study, were obtained from Natural Earth (20).

Health Service Environment

Four health service environment variable scores were created (average distance to the nearest family planning facility, family planning service availability, readiness to provide family planning services and general health facility readiness). All service availability and readiness scores were computed for the nearest family planning providing facilities. Details of this computation can be found elsewhere (17). Average straight-line distance to the nearest family planning providing facility was calculated after linking each DHS cluster with an ESPA+ survey facility (17). First, the distance from each cluster to every family planning providing facility within the administrative boundaries was calculated. Second, the nearest family planning providing facility was identified, and the average distance was computed per region.

In terms of the general service readiness score, eight general service readiness dimensions were obtained using principal component analysis (17). The average general service readiness score per region/city administration was computed using the SAS SCORE procedure. The first two principal components were used to compute two general service readiness scores (health facility management system and infrastructure). Further, indices of family planning availability and readiness were computed. Two family planning availability scores (long-acting and short-term contraceptive methods) were created using seven variables (17). Two family planning

readiness scores (readiness to provide long-acting and short-term contraceptives) were created using seven variables (17).

Outcome and Explanatory Variables

Explanatory Variables

The explanatory variables of this study were sociodemographic and obstetric characteristics and health facility variables. The sociodemographic characteristics include age, education, occupation, husband/partner education and occupation, wealth, place of residence, and average distance to the nearest family planning facility. The obstetric characteristics were parity, the number of living children, ever use of modern contraception, and exposure to family planning messages. Further, the health facility variables were general service readiness, family planning service availability and family planning service readiness.

The occupational status of respondents was grouped into four categories: have no work, agricultural work, professional/technical/managerial work, and others. This was done based on the DHS occupation grouping. Respondents who responded not working at the time of the interview or did not work in the last 12 months before the survey were grouped as have no work. Professional/technical/managerial category constitutes teaching professionals, health professionals, business and administration professionals, legal and social workers, managers, etc. Agricultural categories also include fishermen, foresters and hunters. Other categories include daily laborers, street and related sales and service workers.

Exposure to family planning messages was measured based on three DHS questions. The DHS collected data on woman's exposure to family planning messages whether the respondent has heard about family planning in the last few months (preceding the survey) from any of the following sources: a) heard family planning on the radio last months, b) heard family planning on TV last months and c) heard family planning from the newspaper last months. In this paper, exposure to the contraceptive message was measured if the respondent had exposure to one or more information sources.

Outcome Variable

The outcome variable of this study was modern contraceptive use. A woman was considered to be using modern contraception if she used any of the modern contraceptive methods other

than male condoms (17). The male condom could be accessed from shops that the ESPA+ survey did not capture.

Statistical Analysis

Multilevel Analysis

To account for the nested nature of DHS data, a two-level generalised linear mixed model was used. This study had binary outcomes: whether a married woman used modern contraception or not. We were interested in the probability of modern contraceptive utilisation and the influence of individual and regional characteristics. The equation used to estimate the two-level hierarchical model can be found elsewhere (17).

Binary distribution with the logit link function was used to model this binary outcome. To estimate this model, the GLIMMIX procedure in SAS was used (21). Four model building processes were undertaken. The Laplace estimation was used for estimating these models. The model building process began with an empty model. The variance estimate from this model was used to calculate the intra-class correlation coefficient (ICC) (21). Details of calculating ICC in hierarchical generalised linear models can be found elsewhere (17, 22). By checking improvements in model fit, complex models were built step by step. The negative two log-likelihood (–2LL), Akaike Information Criteria (AIC) and Bayesian Information Criteria (BIC) were used to assess the best-fitting model (21).

Spatial Analysis

ArcGIS 10.6.1 was used to do spatial analyses. The Ethiopian Polyconic Projected Coordinate System (17) was used to flatten the Ethiopian map. Hot spot analysis was carried out to identify spatial clusters of modern contraceptive use. DHS clusters were the unit of spatial analyses.

We followed three analyses procedures while doing the hot spot analysis, as discussed elsewhere (17). First, we ran the Global Moran's I statistic, which is a global measure of spatial autocorrelation (23). Second, based on the Global Moran's I statistic, incremental spatial autocorrelation was run to determine the critical distance at which clustering of modern contraception prevalence rate (mCPR) peaked (165 km) (17). Last, the *Getis-Ord Gi** statistic was run to identify statistically significant spatial clusters of mCPR (17). The two statistical problems of local statistics of spatial association (multiple comparison and spatial dependence) were controlled using an FDR correction (17, 24).

Patient and Public Involvement

This study used secondary data sets: 2016 EDHS and 2014 ESPA+ that were previously collected with confidentiality information maintained (no personal identifier used). The data were collected under the collaboration of The Ethiopian Federal Ministry of Health, Ethiopian Central Statistical Agency, Ethiopian Public Health Institute and USAID. Hence, as we did not collect the data directly from participants, no recruitment and contact of participants were required for this analysis.

Results

Sociodemographic Characteristics

The mean age of the study participants was 31.09 (standard deviation of ±8.22) years. Regarding education, 57.46% of the women had no formal education, while 27.58% had primary level education. In terms of wealth, 29.26% of the women fell in the richest quintile and 27.86% were grouped in the poorest quintile. Regarding religion, 38.27% of respondents identified as Orthodox Christian and 41% as Muslim. Seventy-three percent of the respondents were from rural areas (see Table 1).

Table 1: Sociodemographic characteristics of married women in Ethiopia, 2016 (N = 8473)

Variable		Frequency	Percentage
Age	15–19	534	6.30
	20–24	1436	16.95
	25–29	1876	22.14
	30–34	1591	18.78
	35–39	1412	16.66
	40–44	953	11.25
	45–49	671	7.92
Level of education	No education	4869	57.46
	Primary	2337	27.58
	Secondary	773	9.12
	Higher	494	5.83
Occupation	Have no work	6030	71.17
	Professional/technical/managerial work	1310	15.46
	Agricultural work	749	8.84
	Other	384	4.53
Husband/partner's level of education	No education	3774	44.54
	Primary	2651	31.29
	Secondary	1060	12.51
	Higher	988	11.66
Husband/partner's occupation	Have no work	851	10.04
	Professional/technical/managerial work	2592	30.59
	Agricultural work	4208	49.66
	Other	822	9.70
Head of household	Someone else	7147	84.35
	Herself	1326	15.65
Family size	1–4	3050	36.00
	5–8	4564	53.86
	≥ 9	859	10.14
Wealth quintile	Lowest	2361	27.86
	Second	1291	15.24
	Middle	1184	13.97
	Fourth	1158	13.67
	Highest	2479	29.26
Religion	Orthodox	3243	38.27
	Protestant	1597	18.85
	Muslim	3474	41.00
	Other	159	1.88
Residence	Urban	2261	26.68
	Rural	6212	73.32

Women's Obstetric Characteristics

Of the 8473 married women, 7721 (91.12%) had ever given birth. The mean age at first childbirth was 18.98 (standard deviation of ±3.85) years. In terms of parity, 37.11% of married women had five or more births; 31.05% of the women had more than four living children. Among the 5708 women who were pregnant in the previous five years, 1853 (32.46%) had no ANC visits for their most recent pregnancy. There were 19.40% of women who reported they had the autonomy to decide on their own healthcare needs. Under one-third (31.24%) of women had been exposed to family planning messages. More than half (52.79%) of married women had ever used contraceptive methods. Of the 8473 married women, 5519 (65.14%) were not using any contraceptive methods at the time of the survey. Among these women, 1957 (35.46%) had a future intention to use contraception (see Table 2).

Table 2: Obstetric characteristics of married women in Ethiopia, 2016 (N = 8473)

Variable		Frequency	Percentage
Parity	0	752	8.88
	1–4	4577	54.02
	≥ 5	3144	37.11
Number of living children	0	813	9.60
	1–4	5029	59.35
	≥ 5	2631	31.05
Age at first childbirth (n = 7721)	≤ 19 years	5618	66.30
	20–24 years	2224	26.25
	≥ 25 years	631	7.45
Number of ANC visits (n = 5708)	0	1853	32.46
	1–3	1688	29.57
	≥ 4	2167	37.96
Autonomy in personal healthcare decision-making	Respondent alone	1644	19.40
	Joint decision	5298	62.53
	Husband/partner alone	1531	18.07
Autonomy in family planning decision-making (n = 2954)	Mainly respondent	724	24.51
	Mainly husband/partner	149	5.04
	Joint decision	2081	70.45
Knowledge of modern contraceptive methods	No	324	3.82
	Yes	8149	96.18
Exposure to family planning messages	No	5826	68.76
	Yes	2647	31.24
Ever used any contraceptive method	No	4000	47.21
	Yes	4473	52.79
Non-users' future intention to use a contraceptive method (n = 5519)	Intends to use later	1957	35.46
	Unsure about future use	90	1.63
	Does not intend to use	3472	62.91

Health Facility Characteristics

Data were collected from 1165 health facilities nationwide. Among them, 18.73% were hospitals and 27.75% were health centres. Regarding health facility managing body, 68.43% of the health facilities were managed by the government. Of the facilities, 1020 (87.55%) provided family planning services. Three-quarters (75.2%) had a contraceptive method mix; they provided three or more contraceptive methods. In terms of modern contraceptive method types, 53.73% of the health facilities provided long-acting contraceptives, while 99.31% provided short-term contraceptive methods. The national average distance from family planning health facilities to the 2016 EDHS clusters was 6.35 kilometres. The 2016 EDHS-sampled clusters in the Somali region were the longest distance (18.58 km) from family planning facilities. Conversely, EDHS clusters in Addis Ababa were 0.55 kilometres from family planning facilities (see Table 3).

Table 3: The average distance from sampled family planning providing health facilities to demographic and health survey clusters in Ethiopia, 2016 ($N = 1020$)

Region	Population projection for 2016 (in thousands) *	Health facility type				Average distance (km)
		Hospitals *n* (%)	Health centres *n* (%)	Health posts *n* (%)	Private clinics *n* (%)	
Tigray	5,151	30 (28.30)	30 (28.30)	25 (23.58)	21 (19.81)	5.53
Afar	1,768	6 (10.71)	25 (44.64)	16 (28.57)	9 (16.07)	9.69
Amhara	20,771	26 (16.77)	46 (29.68)	34 (21.94)	49 (31.61)	8.47
Oromia	34,575	49 (25.26)	50 (25.77)	43 (22.16)	52 (26.80)	8.99
Somali	5,599	10 (20.41)	21 (42.86)	12 (24.49)	6 (12.24)	18.58
Benishangul-Gumuz	1,035	2 (3.13)	16 (25.00)	29 (45.31)	17 (26.56)	5.28
SNNPR	18,720	24 (15.58)	40 (25.97)	38 (24.68)	52 (33.77)	7.08
Gambela	422	1 (1.79)	14 (25.00)	22 (39.29)	19 (33.93)	4.32
Harari	238	4 (9.30)	8 (18.60)	21 (48.84)	10 (23.26)	0.73
Addis Ababa	3,353	33 (42.31)	18 (23.08)	0	27 (34.62)	0.55
Dire Dawa	453	6 (9.23)	15 (23.08)	31 (47.69)	13 (20.00)	0.60
Total	92,085	191 (18.73)	283 (27.75)	271 (26.57)	275 (26.96)	6.35

Note: SNNPR =Southern Nations, Nationalities and Peoples Region.

*Central Statistical Agency – Population Projections for Ethiopia: 2007 - 2037

Modern Contraceptive Prevalence Rate

The prevalence of modern contraceptive use among married women was found to be 33.54% (urban 46.09%, 28.98% rural). The utilisation of modern contraceptives varied across the different regions and city administrations; the highest mCPR was reported in the Amhara region (51.65%), followed by Addis Ababa (50.08%) and the SNNPR (45.48%). Figure 1 shows the regional variations in mCPRs.

Spatial Epidemiology of Modern Contraceptive Use

There is strong evidence to support spatial clustering in the utilisation of modern contraceptives among married women in Ethiopia (Global Moran's I = 0.24; Z-score = 8.09; $P < 0.0001$). Most of the hot spot areas, those with high contraceptive prevalence rates, were located in Addis Ababa and Amhara, followed by the Oromia region and the SNNPR. Conversely, the majority of the cold spot areas, those with low contraceptive prevalence rates, were located in the Somali, Afar and Gambela regions followed by Tigray and Benishangul-Gumuz. This clustering was supported by the *Gi** statistic when conducting the spatial analysis (see Figure 2).

Determinants of Modern Contraceptive Use Among Married Women

The calculated ICC was 24.47%. This indicated that about 24% of the variability in using modern contraceptive methods was accounted for by location, leaving 76% of the variability to be accounted for by the differing characteristics of the women, or other unmeasured factors. The probability of using modern contraceptive methods in a typical region was estimated at 27.8%.

The strong individual-level predictors of modern contraceptive use among married women were their age, their husband/partner's education, household wealth, number of living children and exposure to family planning messages. Women who were in the age groups 35–39 years (44%), 40–44 years (55%) and 45–49 years (82%) were less likely to use modern contraceptives compared to those aged 15–19 years. A woman whose husband attained a primary level of education was 54% more likely to use modern contraceptives compared to those whose husband had no education. The odds ratio of modern contraceptive use increased with increasing wealth quintile. Women who were in the highest quintile were 5.26 times more likely to use the service compared to those in the lowest quintile. Women who had been exposed to family planning messages were 68% more likely to use modern contraceptives

relative to their counterparts with no exposure to family planning messages. Similarly, women who had one to four children were 2.31 times more likely to use the service compared to those having no child (see Table 4).

At the regional level (level 2), only one variable was significantly associated with the use of modern contraceptives. A one-unit increase in the mean score of a health facility's readiness to provide short-term modern contraceptives in a typical region was associated with a 20-fold increase in the odds of modern contraceptive use (Table 4).

Finally, the majority of the variance between regions was explained by this model. The proportional change in variance indicated that the addition of predictors to the empty model explained an increased proportion of variation in modern contraceptive use. The variance estimates between regions decreased from 1.07 in the empty model to 0.18 in the final random intercept and random slope model. The proportion of variance explained by the final model was 83.18%. Similarly, the empty model showed that 24.47% of the variability in the odds of modern contraceptive use was explained by region-level characteristics (ICC = 24.47%). The between-region variability declined over successive models, from 24.47% in the empty model to 5.2% in the final model (see Table 4).

Table 4: Factors Associated with Utilisation of Modern Contraceptives Among Married Women in Ethiopia ($N = 8473$)

Predictors		Frequency	Adjusted odds ratio (95% confidence interval)
			Modern contraceptive use
Level 1 predictor variables			
Age	15–19	534	1.00
	20–24	1436	1.26 (0.91, 1.76)
	25–29	1876	0.93 (0.67, 1.30)
	30–34	1591	0.74 (0.52, 1.04)
	35–39	1412	**0.56 (0.39, 0.80)**
	40–44	953	**0.45 (0.31, 0.65)**
	45–49	671	**0.18 (0.12, 0.27)**
Husband/partner's level of education	No education	3774	1.00
	Primary	2651	**1.54 (1.18, 2.02)**
	Secondary	1060	1.29 (0.96, 1.73)
	Higher	988	1.05 (0.77, 1.44)
Wealth quintile	Lowest	2361	1.00
	Second	1291	**1.95 (1.27, 2.99)**
	Middle	1184	**2.65 (1.72, 4.08)**
	Fourth	1158	**3.42 (2.21, 5.28)**
	Highest	2479	**5.26 (3.46, 7.99)**
Number of living children	0	813	1.00
	1–4	5029	**2.31 (1.64, 3.25)**
	>= 5	2631	**2.05 (1.40, 3.01)**
Exposure to family planning messages	No	5826	1.00
	Yes	2647	**1.68 (1.20, 2.36)**
Level-2 predictor variables			
General service readiness	Health facility management system		1.27 (0.05, 35.69)
	Health facility infrastructure		1.51 (0.18, 12.95)
Family planning service availability	Long-acting contraceptive methods		5.04 (0.19, 136.21)
	Short-term contraceptive methods		1.79 (0.03, 103.48)
Family planning service readiness	Long-acting contraceptives		0.43 (0.01, 17.12)
	Short-term contraceptives		**20.49 (1.44, 29.54)**
Average distance to the nearest health facility			1.02 (0.81, 1.28)
Random effects (Error variance)			
Var (Age)			0.05 (0.02, 0.15)
Var (Husband/partner's level of education)			0.05 (0.02, 0.22)
Var (Wealth quintile)			0.14 (0.07, 0.32)
Var (Number of living children)			0.08 (0.04, 0.29)
Var (Exposure to family planning messages)			0.09 (0.03, 0.61)
Var (constant)—level-2 variance			0.18 (0.05, 3.70)
ρ—Intra-class correlation			0.05
Fit statistics (-2 log-likelihood)			8860.49

Discussion

In Ethiopia, the use of modern contraception varied by region. This is the first study to specifically identify hot spots and model the use of modern contraception using nationwide population and health facility data. Approximately 34% of married women use modern contraceptives; the highest mCPR was reported among urban married women (46.09% versus 28.98%). This is comparable with the findings of the 2011 EDHS data analysis where 27.3% of married women reported using modern contraceptive methods; the highest proportion was from urban areas (49.55% versus 22.5%) (9). There are also variations in modern contraceptive rate across different regions in the country. The highest contraceptive rate, more than 50% mCPR, was reported in the Amhara region and the Addis Ababa city administration. Conversely, the lowest, below 10% mCPR, was reported in the Somali and Afar regions. Even though there has been an increase in modern contraceptive use all over the country, it was found that there was significant regional variation in modern contraceptive use.

High mCPR spots (hot spots) were detected in the Amhara region and Addis Ababa, followed by the SNNPR and some parts of Oromia region. Conversely, the majority of low mCPR (cold spots) were detected in the Somali, Afar and Gambela regions followed by Tigray and Benishangul-Gumuz. In 2011, hot spots of modern contraceptive use were observed in Addis Ababa, followed by some parts of Amhara, Oromia and SNNPR. The lowest contraceptive rates (cold spots) were observed in the Afar, Somali and Gambela regions, and some parts of Tigray region (9). This indicated that the government is doing a good job in some of the regions, but is less successful in most regions. Due to this reason, the unmet need for modern contraception will be much higher than expected in most of those regions. Thus, cold spots (low rates of modern contraception) will be much more concentrated in those areas.

In Ethiopia, the use of modern contraceptives varied across the different regions and city administrations. The highest modern contraceptive prevalence rate was reported in the Amhara region, followed by Addis Ababa and SNNPR. This variation is demonstrated by the national DHSs conducted every five years since 2000. Over 16 years, between 2000 and 2016, the Amhara region and SNNPR showed an increase in the utilisation of modern contraceptives (8, 25-27). The large increase in the use of modern contraceptives in the Amhara region, as well as SNNPR, might be related to the high number of family planning organisations and the government's focus on these regions.

Different individual and regional factors were significantly associated with the use of modern contraceptives. The readiness of health facilities to provide short-term modern contraceptives was the only regional (level-2) variable that was significantly associated with the use of modern contraceptives. It was found that a one-unit increase in the mean score of the readiness of health facilities to provide short-term modern contraceptives was significantly associated with the utilisation of modern contraceptives. In a study that used DHS and SPA survey data from several East African countries (Kenya, Uganda, Rwanda and Tanzania), it was found that modern contraceptive utilisation was strongly associated with health facilities offering a wide range of contraceptives, and with a higher score of family planning service environment (16). Even though it is not directly related, in a study carried out in rural Ethiopia, researchers found that women who lived close to a health facility providing a wide range of contraceptives were more likely to use modern contraceptives (11). This indicated that the potential impact of family planning services should not be underestimated. Therefore, family planning health facilities should be fully equipped to provide a wide range of modern contraception.

Among the individual factors, an increase in the age of women was significantly associated with a decrease in the use of modern contraceptives. This is similar to results of other studies carried out in Ethiopia, where the utilisation of modern contraceptives was negatively influenced by an increase in the age of women (9, 11, 12). This could be related to the knowledge gap, beliefs and/or attitudes that each woman has; as the age of a woman increases, the probability of changing her attitudes or beliefs towards contraception may reduce.

In Ethiopia, among the individual-level variables, the educational attainment of husband/partners was a significant predictor of the increase in modern contraceptive use. In a study conducted in the North Gondar, Amhara region of Ethiopia, it was found that the educational attainment of husbands was a significant predictor of women's contraceptive use (28). This might be due to the involvement of husbands in contraception decision-making. This is supported by other studies demonstrating the influence of discussing modern contraceptives with the husband and the husband's approval of using modern contraceptives (29, 30). It was found that the utilisation of modern contraceptives was significantly higher among women whose husbands had approved of using modern contraceptives. Similarly, the odds of using modern contraceptives was higher among those women who had discussed modern contraceptives with their husbands (29, 30). This indicated that a woman's husband's

education, as well as male involvement, has an important role in the use of modern contraceptives. Thus, educational opportunities for men and increasing male involvement in every family planning service should be emphasised for higher engagement in the use of modern contraception.

The increase in household wealth was a significant predictor of an increase in modern contraceptive utilisation. In two studies conducted in Ethiopia, including a study performed among rural women (11), it was found that women who were in the fourth and highest quintile were more likely to use modern contraceptives (9, 11). Family monthly income was significantly associated with the use of modern contraceptives (29). Wealth might directly or indirectly affect modern contraceptive use. Women might know about the importance of contraception. However, knowledge alone will not be important in some cases. They should have money for transport and service. The trade-off associated with the time they spent on traveling to and from health facilities is also important. They may use that particular time for household activities, farming, or other business-generating activities. For instance, in Ethiopia, despite family planning services being free of charge in public health facilities, the cost of transport might be attributable to the use of modern contraception. Moreover, the costs of family planning services in private health facilities might also be related to the use of modern contraceptives. Thus, the cost of transport and family planning service fees in private health facilities might not be important for wealthy families.

In this current study, it was found that, compared to having no children, having one or more living children increases the likelihood a woman will use modern contraceptives. In the 2011 EDHS data analysis (9) and a study done in the SNNPR (12), researchers also found that an increase in the number of living children was significantly associated with an increase in modern contraceptive use. Among rural women in Ethiopia, an increase in parity was positively associated with an increase in modern contraceptive use (11). This finding is similar to studies done in Bangladesh, Pakistan and Tanzania, where it was reported that an increase in the number of living children was significantly associated with an increase in the use of modern contraceptives (13, 31, 32). This indicated that women's desire to have children might influence their contraceptive use behaviours: women with a high number of living children may be more likely to use contraception.

Exposure to family planning messages, the last individual-level variable in the multilevel model, showed an increase in the likelihood of using modern contraception. In a study done among women of reproductive age in the SNNPR region, it was found that the odds of modern contraceptive utilisation were significantly associated with women's overall knowledge of family planning methods. It was observed that women with good family planning knowledge were more likely to use modern contraceptives (12). Thus, exposure to family planning messages through different public and private media outlets is an important recommendation arising from this study.

In this study, it was found that the utilisation of modern contraceptives varied across regions. The individual-level variables (age, husband/partner's education, wealth, number of living children and exposure to family planning messages) varied significantly across the regions. In a study in rural Ethiopia, it was found that the use of modern contraceptives was significantly higher in the Amhara and SNNPR regions (11). This might be related to variations in the availability and accessibility of different family planning services across administrative regions of the country. In addition to the multilevel analysis, this study has identified the hot spot and cold spot areas to help the government in improving the provision of modern contraceptives, especially those areas with the low rates of modern contraception.

This study identified both the demand- and supply-side determinants of modern contraceptive utilisation using a linked population and health facility data. This was overlooked in previous studies, which generally studied these factors separately. In addition to multilevel analysis, this study used spatial analyses to identify geographic variations in modern contraceptive utilisation. Taking a geographic perspective on family planning is very important for effective resource allocation and intervention, informed decision-making, and monitoring and evaluation purposes.

This study had several methodological limitations, most of which were minimised (17). The exclusion of DHS clusters without information relating to geographic coordinates, and using sampled health facilities, may underestimate or overestimate our study findings. This study did not consider sampling weights while running the multilevel analysis. DHSs provide an average weight (hv005 or v005); however, the GLIMMIX procedure in SAS requires weights at each level. Due to this issue, we could not able to apply sampling weights in the multilevel analysis.

Conclusion

In this study, it was found that more than one-third of married women in Ethiopia use modern contraceptives. It was also found that different individual-level variables, as well as regional-level variables, were predictors of modern contraceptive use. There is evidence of wide geographic variations in the use of modern contraceptives across the country. The findings of this study have several implications: first, regions with low contraceptive rates and high fertility rates should be targeted for scaling up and tailoring of services to the lifestyles of their populations. Second, available health facilities should be equipped to provide modern contraceptive methods. Strong emphasis should also be given to the contraceptive method mix/choice available at each health facility to increase contraceptive uptake. Third, increasing educational opportunities for men and increasing male involvement, and exposure to family planning messages are also important recommendations to arise from this research. The importance of awareness and the potential impact of services cannot be underestimated.

Abbreviations

CRS	Coordinate Reference System
DHS	Demographic and Health Survey
EAs	Enumeration Areas
EDHS	Ethiopia Demographic and Health Survey
ESPA+	Ethiopia Service Provision Assessment Plus
FDR	False Discovery Rate
GIS	Geographic Information Systems
HGLM	Hierarchical Generalized Linear Model
ICC	Intra-class Correlation Coefficient
IUD	Intrauterine Device
mCPR	modern Contraceptive Prevalence Rate
SNNPR	Southern Nations, Nationalities and Peoples Region
SPA	Service Provision Assessment
WGS84	World Geodetic System 84

Ethics approval

Ethical approval was obtained from the Human Research Ethics Committee, The University of Newcastle on March 20, 2018 with a reference number H-2018-0066. We also got the Ethiopian Public Health Institute (EPHI) and the Measure DHS program approval to access the datasets.

Consent for publication

Not applicable.

Availability of data and material

All data relevant to the study are included in the article.

Competing interests

The authors declared that they have no competing interests.

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Authors' contributions

TKT, CC, RS, DL conceptualized the design of the analysis. TKT developed and drafted the manuscript. CC, PF, TG, RS and DL participated in critically revising the intellectual contents of the manuscript. All authors read, provided feedback and approved the final manuscript.

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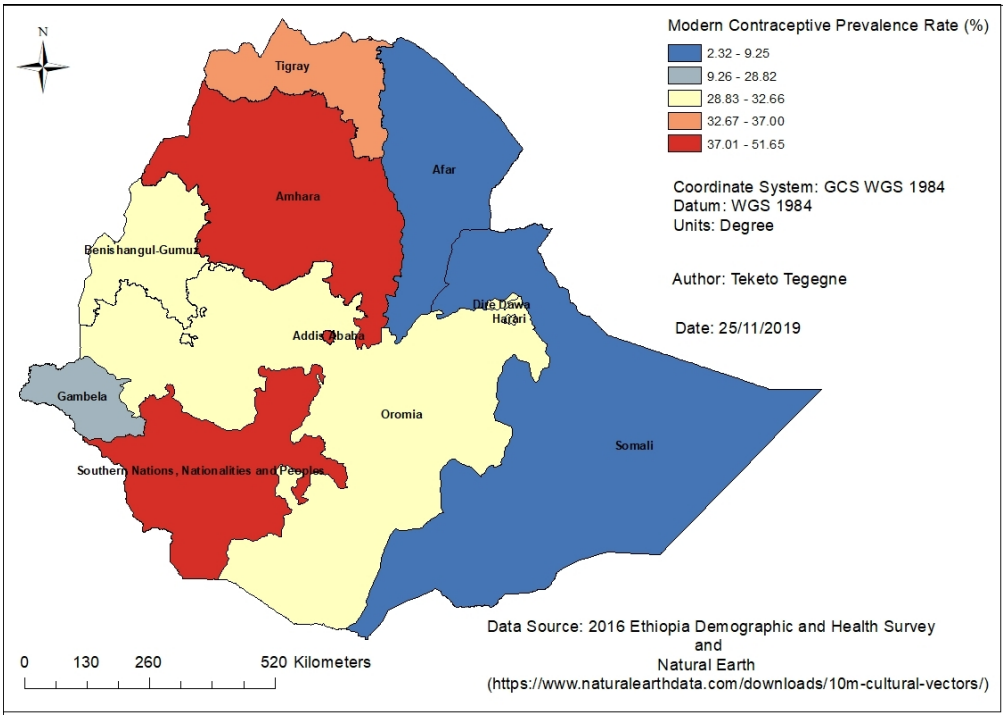
Figure Legends

Figure 1: Modern contraceptive use among married women in Ethiopia, 2016

Figure 2: Clusters of high and low modern contraceptive prevalence rates in Ethiopia, 2016



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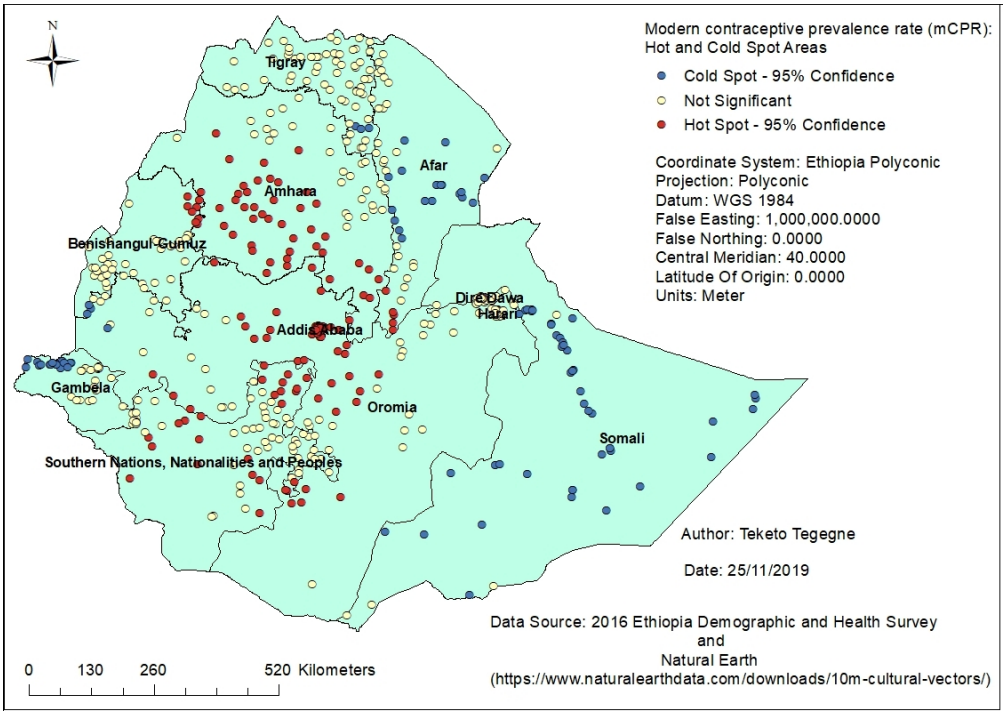

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STROBE Statement—Checklist of items that should be included in reports of ***cross-sectional studies***

	Item No	Recommendation	Page No
Title and abstract	1	(*a*) Indicate the study's design with a commonly used term in the title or the abstract	1
		(*b*) Provide in the abstract an informative and balanced summary of what was done and what was found	2
Introduction			
Background/rationale	2	Explain the scientific background and rationale for the investigation being reported	4 - 5
Objectives	3	State specific objectives, including any prespecified hypotheses	5
Methods			
Study design	4	Present key elements of study design early in the paper	5 - 6
Setting	5	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection	5 - 6
Participants	6	(*a*) Give the eligibility criteria, and the sources and methods of selection of participants	5 - 6
Variables	7	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable	6 - 7
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	*5 - 7*
Bias	9	Describe any efforts to address potential sources of bias	5 - 6
Study size	10	Explain how the study size was arrived at	5 - 6
Quantitative variables	11	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why	7 - 8
Statistical methods	12	(*a*) Describe all statistical methods, including those used to control for confounding	8
		(*b*) Describe any methods used to examine subgroups and interactions	8
		(*c*) Explain how missing data were addressed	8
		(*d*) 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	9 - 16
		(b) Give reasons for non-participation at each stage	9 - 16
		(c) Consider use of a flow diagram	9 - 16
Descriptive data	14*	(a) Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders	9 - 16
		(b) Indicate number of participants with missing data for each variable of interest	9 - 16
Outcome data	15*	Report numbers of outcome events or summary measures	14 - 15
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	14 - 16

		(*b*) Report category boundaries when continuous variables were categorized	16
		(*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	15
Discussion			
Key results	18	Summarise key results with reference to study objectives	17
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	3, 20
Interpretation	20	Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence	17 – 20
Generalisability	21	Discuss the generalisability (external validity) of the study results	21
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	22

*Give information separately for exposed and unexposed groups.

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.

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Spatial variations and associated factors of modern contraceptive use in Ethiopia: a spatial and multilevel analysis

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Abstract

Objective: To assess spatial variations in modern contraceptive use and to identify factors associated with it among married women in Ethiopia.

Design: Cross-sectional analysis of population-based and health facility data.

Setting: Ethiopia Demographic and Health Survey data linked to Service Provision Assessment data.

Population: Eight thousand four hundred and seventy-three married women and 1020 facilities that reported providing family planning services.

Methods: A linked secondary data analysis of population and health facility data was carried out. Both multilevel and spatial analyses were conducted to identify key determinants of women's use of modern contraceptive and spatial clustering of modern contraceptive use.

Main outcome measure: Modern contraceptive use.

Results: About 24% of the variation in the use of modern contraception was accounted for by location. A one-unit increase in the mean score of health facilities' readiness to provide short-term modern contraceptives in a typical region was associated with a 20-fold increase in the odds of modern contraceptive use (Adjusted Odds Ratio [AOR] = 20.49, 95% CI 1.44 - 29.54). In the spatial analysis, it was found that Addis Ababa and the Amhara region had high clusters of modern contraceptive use rates. On the other hand, low rates of contraceptive use were clustered in the Afar and Somali regions.

Conclusion: There were significant variations in the use of modern contraceptives across the different regions of Ethiopia. Therefore, regions with low contraceptive rates and high fertility rates should be targeted for scaling up and tailoring of services to the culture and lifestyles of the population of those regions.

Keywords: Modern contraceptives, spatial variations, family planning methods

Strengths and limitations of this study

- This study identified both the demand and supply-side determinants of modern contraceptive utilization using a linked population and health facility data.
- In addition to multilevel analysis, this study used spatial analyses to identify geographic variations of modern contraceptive utilization.
- This study excluded DHS clusters without geographic coordinates and used sampled health facilities that might under or overestimate the study finding.
- This study did not consider sampling weights while running the multilevel analysis.
- DHS surveys provide an average weight (hv005 or v005); however, the GLIMMIX procedure in SAS requires weights at each level that did not enable to apply sampling weights in the multilevel analysis.

Introduction

Worldwide, modern contraceptives are important in fertility control (1). In developing countries, contraceptives have a clear effect on the health of women, children and families. For instance, contraceptives are estimated to prevent 2.7 million infant deaths and the loss of 60 million healthy lives a year worldwide (2). In countries with high fertility rates, promoting contraceptives averts 32% of all maternal deaths and approximately 10% of child mortality. Modern contraceptives also make a huge contribution to the achievement of universal primary schooling, female empowerment, and in reducing poverty and hunger (3). Family planning is also important in preventing unintended pregnancies and unsafe abortions (4, 5).

Despite its importance, access to and utilisation of modern contraceptives vary worldwide. Women in developed countries have better access to and use of contraceptives compared to women in developing countries (4). In a study from 2010–2014, it was reported that the global burden of unintended pregnancies was 44%; the rate of unintended pregnancies is substantially higher in developing countries compared to developed regions (6). Higher levels of unmet need for contraception could contribute to higher rates of unintended pregnancies in developing regions. For instance, in sub-Saharan Africa, the prevalence of contraceptive use among women of reproductive age is only 17% (7).

Similarly, the utilisation of modern contraceptives is a common healthcare challenge in Ethiopia. Even though there is an increase in women's use of modern contraceptives, challenges remain (8). Discrepancies in the use of modern contraceptives are common within the different parts of the country. For instance, the Somali region accounts for the lowest rate of modern contraceptive use (1.4%), compared to Addis Ababa (50.1%) (8).

The utilisation of modern contraceptives can be influenced by both demand- and supply-side factors. In previous studies, more emphasis has been given to the importance of demand-side factors (7). Most of the investigated demand-side factors were women's education (7, 9), age (9, 10), household wealth (7, 9, 11) and parity (12, 13). The importance of supply-side factors has been largely overlooked. In some studies, it was reported that the supply-side factors have influence on contraceptive use. For instance, the quality of family planning services (14) and living close to a family planning facility (15) were significantly associated with modern contraceptive utilisation. In East Africa, it was observed that the utilisation of modern

contraceptives was higher among facilities providing different contraceptive methods and with higher family planning service environment scores (16).

Due to the increasing availability of geographically referenced health facility and population data, it is possible to do geographically linked analyses (17). This opportunity allows identification of the location of existing health facilities as well as mapping the eligible population without access to a particular health service, such as family planning. This further enables identification of both the demand- and supply-side factors and helps the government determine where future investments should be targeted.

This study aimed to assess spatial variations in the use of modern contraceptives among married women in Ethiopia and identify the potential factors associated with the use of modern contraceptives among married women throughout the country, using the national population and health facility data. Contraception is more critical for women of reproductive age. However, married women or women in union are more likely to be sexually active as opposed to single, divorced or widowed women, particularly in Ethiopia where sex outside of a union is uncommon. Therefore, this study focused on only married women's modern contraceptive use.

Methods

Data Sources

The main data sources of this study were the 2016 Ethiopia Demographic and Health Survey (EDHS) and the 2014 Ethiopian Service Provision Assessment Plus (ESPA+). Ethical approval was obtained from the DHS program Institutional Review Board and the Ethiopian Public Health Institute. Furthermore, this study was ethically approved by the Human Research Ethics Committee, The University of Newcastle on March 20, 2018 (approval number H-2018-0066).

The 2016 EDHS collected information on population characteristics, such as contraception and obstetric care use. The survey details can be found elsewhere (8, 17). The geographic coordinates of each survey cluster were also collected (18). In the population survey, all women aged 15–49 years were eligible for individual interviews. The survey identified 16583 eligible women. Of these women, from 645 DHS clusters, 15683 were interviewed.

Contraception is more critical for women of reproductive age. However, married women or women in union are more likely to be sexually active as opposed to single, divorced or widowed women, particularly in Ethiopia where sex outside of a union is uncommon. Therefore, this study focused on only married women's modern contraceptive use. In this analysis, 8473 married women who were not pregnant at the time of the interview were included from 622 DHS clusters. A total of 261 married, non-pregnant women from 23 clusters were excluded from the analysis since they had missing geographic coordinates.

The main source of the health facility data was the 2014 ESPA+ survey (19). The ESPA+ survey had information on service availability and readiness, including family planning services (19). Details of the survey can be found elsewhere (17, 19). The ESPA+ survey collected data from 1165 facilities. The survey used a combination of a census of hospitals and a sample of other health facilities (health centres, health posts and clinics). Of the 1165 facilities, 1020 facilities reported providing family planning services. In this analysis, 1020 facilities that reported providing family planning services were included.

Data Linking Method

In this study, we used an administrative boundary link for linking health facility data with the population data (17). Details of this method can be found elsewhere (17). Ethiopia's administrative boundaries, used in this study, were obtained from Natural Earth (20).

Health Service Environment

Four health service environment variable scores were created (average distance to the nearest family planning facility, family planning service availability, readiness to provide family planning services and general health facility readiness). All service availability and readiness scores were computed for the nearest family planning providing facilities. Details of this computation can be found elsewhere (17). Average straight-line distance to the nearest family planning providing facility was calculated after linking each DHS cluster with an ESPA+ survey facility (17). First, the distance from each cluster to every family planning providing facility within the administrative boundaries was calculated. Second, the nearest family planning providing facility was identified, and the average distance was computed per region.

In terms of the general service readiness score, eight general service readiness dimensions were obtained using principal component analysis (17). The average general service readiness score per region/city administration was computed using the SAS SCORE procedure. The first two principal components were used to compute two general service readiness scores (health facility management system and infrastructure). Further, indices of family planning availability and readiness were computed. Two family planning availability scores (long-acting and short-term contraceptive methods) were created using seven variables (17). Two family planning readiness scores (readiness to provide long-acting and short-term contraceptives) were created using seven variables (17).

Outcome and Explanatory Variables

Explanatory Variables

The explanatory variables of this study were sociodemographic (7, 9-11) and obstetric characteristics (11-13) and health facility variables (11, 14-16). The sociodemographic characteristics include age, education, occupation, husband/partner education and occupation, wealth, place of residence, and average distance to the nearest family planning facility. The obstetric characteristics were parity, the number of living children, ever use of modern contraception, and exposure to family planning messages. Further, the health facility variables were general service readiness, family planning service availability and family planning service readiness.

The occupational status of respondents was grouped into four categories: have no work, agricultural work, professional/technical/managerial work, and others. This was done based on the DHS occupation grouping. Respondents who responded not working at the time of the interview or did not work in the last 12 months before the survey were grouped as have no work. Professional/technical/managerial category constitutes teaching professionals, health professionals, business and administration professionals, legal and social workers, managers, etc. Agricultural categories also include fishermen, foresters and hunters. Other categories include daily laborers, street and related sales and service workers.

Exposure to family planning messages was measured based on three DHS questions. The DHS collected data on woman's exposure to family planning messages whether the respondent has heard about family planning in the last few months (preceding the survey) from any of the following sources: a) heard family planning on the radio last months, b) heard family planning on TV last months and c) heard family planning from the newspaper last months. In this paper, exposure to the contraceptive message was measured if the respondent had exposure to one or more information sources.

Outcome Variable

The outcome variable of this study was modern contraceptive use. A woman was considered to be using modern contraception if she used any of the modern contraceptive methods other than male condoms (17). The male condom could be accessed from shops that the ESPA+ survey did not capture.

Statistical Analysis

Multilevel Analysis

To account for the nested nature of DHS data, a two-level generalised linear mixed model was used. This study had binary outcomes: whether a married woman used modern contraception or not. We were interested in the probability of modern contraceptive utilisation and the influence of individual and regional characteristics. The equation used to estimate the two-level hierarchical model can be found elsewhere (17).

Binary distribution with the logit link function was used to model this binary outcome. To estimate this model, the GLIMMIX procedure in SAS was used (21). Four model building processes were undertaken. The Laplace estimation was used for estimating these models. The model building process began with an empty model. By checking improvements in model fit, complex models were built step by step. The random effects were measured by the intra-class correlation coefficient (ICC) and proportional change in variance (PCV). The variance estimate from each successive model was used to calculate the intra-class correlation coefficient (ICC) (21). Details of calculating ICC in hierarchical generalised linear models can be found elsewhere (17, 22). The PCV was used to measure the change in the area level variance between the empty model and the individual level model, and between successive models (23, 24). It was calculated using this mathematical equation: $PCV = \frac{V_{n-1} - V_{n-2}}{V_{n-1}}$; where V_{n-1} is the

neighbourhood variance in the empty model and V_{n-2} is the neighbourhood variance in the subsequent model.

Model Fit Statistics

The Akaike Information Criteria (AIC) and Schwarz's Bayesian Information Criteria (BIC) were used to assess the best-fitting model (21). The AIC and BIC values of each successive model were compared, and the model with the lowest value was considered as the best-fitting model (25, 26). During model building process, it is possible to increase the likelihood of fitting models by adding parameters. However, increasing model parameters can result in overfitting. Unlike statistical methods that employ hypothesis testing approaches like log-likelihood ratio test, AIC and BIC penalise the deviance for a larger number of parameters (26-28). Thus, they prevent overfitting by introducing a penalty term for the number of parameters in the model.

Spatial Analysis

ArcGIS 10.6.1 was used to do spatial analyses. The Ethiopian Polyconic Projected Coordinate System (17) was used to flatten the Ethiopian map. Hot spot analysis was carried out to identify spatial clusters of modern contraceptive use. DHS clusters were the unit of spatial analyses.

We followed three analyses procedures while doing the hot spot analysis, as discussed elsewhere (17). First, we ran the Global Moran's I statistic, which is a global measure of spatial autocorrelation (29). Second, based on the Global Moran's I statistic, incremental spatial autocorrelation was run to determine the critical distance at which clustering of modern contraception prevalence rate (mCPR) peaked (165 km) (17). Last, the *Getis-Ord Gi** statistic was run to identify statistically significant spatial clusters of mCPR (17). The two statistical problems of local statistics of spatial association (multiple comparison and spatial dependence) were controlled using an FDR correction (17, 30).

Patient and Public Involvement

This study used secondary data sets: 2016 EDHS and 2014 ESPA+ that were previously collected with confidentiality information maintained (no personal identifier used). The data were collected under the collaboration of The Ethiopian Federal Ministry of Health, Ethiopian Central Statistical Agency, Ethiopian Public Health Institute and USAID. Hence, as we did not collect the data directly from participants, no recruitment and contact of participants were required for this analysis.

Results

Sociodemographic Characteristics

The mean age of the study participants was 31.09 (standard deviation of ±8.22) years. Regarding education, 57.46% of the women had no formal education, while 27.58% had primary level education. In terms of wealth, 29.26% of the women fell in the richest quintile and 27.86% were grouped in the poorest quintile. Regarding religion, 38.27% of respondents identified as Orthodox Christian and 41% as Muslim. Seventy-three percent of the respondents were from rural areas (see Table 1).

Table 1: Sociodemographic characteristics of married women in Ethiopia, 2016 (N = 8473)

Variable		Frequency	Percentage
Age	15–19	534	6.30
	20–24	1436	16.95
	25–29	1876	22.14
	30–34	1591	18.78
	35–39	1412	16.66
	40–44	953	11.25
	45–49	671	7.92
Level of education	No education	4869	57.46
	Primary	2337	27.58
	Secondary	773	9.12
	Higher	494	5.83
Occupation	Have no work	6030	71.17
	Professional/technical/managerial work	1310	15.46
	Agricultural work	749	8.84
	Other	384	4.53
Husband/partner's level of education	No education	3774	44.54
	Primary	2651	31.29
	Secondary	1060	12.51
	Higher	988	11.66
Husband/partner's occupation	Have no work	851	10.04
	Professional/technical/managerial work	2592	30.59
	Agricultural work	4208	49.66
	Other	822	9.70
Head of household*	Someone else	7147	84.35
	Woman - herself	1326	15.65
Family size	1–4	3050	36.00
	5–8	4564	53.86
	≥ 9	859	10.14
Wealth quintile	Lowest	2361	27.86
	Second	1291	15.24
	Middle	1184	13.97
	Fourth	1158	13.67
	Highest	2479	29.26
Religion	Orthodox	3243	38.27
	Protestant	1597	18.85
	Muslim	3474	41.00
	Other	159	1.88
Residence	Urban	2261	26.68
	Rural	6212	73.32

* *The head of household was dichotomised as the woman herself or someone else (this include her husband and other family members, such father-in law and mother-in law).*

Women's Obstetric Characteristics

Of the 8473 married women, 7721 (91.12%) had ever given birth. The mean age at first childbirth was 18.98 (standard deviation of ±3.85) years. In terms of parity, 37.11% of married women had five or more births; 31.05% of the women had more than four living children. Among the 5708 women who were pregnant in the previous five years, 1853 (32.46%) had no ANC visits for their most recent pregnancy. There were 19.40% of women who reported they had the autonomy to decide on their own healthcare needs. Under one-third (31.24%) of women had been exposed to family planning messages. More than half (52.79%) of married women had ever used contraceptive methods. Of the 8473 married women, 5519 (65.14%) were not using any contraceptive methods at the time of the survey. Among these women, 1957 (35.46%) had a future intention to use contraception (see Table 2).

Table 2: Obstetric characteristics of married women in Ethiopia, 2016 (N = 8473)

Variable		Frequency	Percentage
Parity	0	752	8.88
	1–4	4577	54.02
	≥ 5	3144	37.11
Number of living children	0	813	9.60
	1–4	5029	59.35
	≥ 5	2631	31.05
Age at first childbirth (n = 7721)	≤ 19 years	5618	66.30
	20–24 years	2224	26.25
	≥ 25 years	631	7.45
Number of ANC visits (n = 5708)	0	1853	32.46
	1–3	1688	29.57
	≥ 4	2167	37.96
Autonomy in personal healthcare decision-making	Respondent alone	1644	19.40
	Joint decision	5298	62.53
	Husband/partner alone	1531	18.07
Autonomy in family planning decision-making (n = 2954)	Mainly respondent	724	24.51
	Mainly husband/partner	149	5.04
	Joint decision	2081	70.45
Knowledge of modern contraceptive methods	No	324	3.82
	Yes	8149	96.18
Exposure to family planning messages	No	5826	68.76
	Yes	2647	31.24
Ever used any contraceptive method	No	4000	47.21
	Yes	4473	52.79
Non-users' future intention to use a contraceptive method (n = 5519)	Intends to use later	1957	35.46
	Unsure about future use	90	1.63
	Does not intend to use	3472	62.91

Health Facility Characteristics

Data were collected from 1165 health facilities nationwide. Among them, 18.73% were hospitals and 27.75% were health centres. Regarding health facility managing body, 68.43% of the health facilities were managed by the government. Of the facilities, 1020 (87.55%) provided family planning services. Three-quarters (75.2%) had a contraceptive method mix; they provided three or more contraceptive methods. In terms of modern contraceptive method types, 53.73% of the health facilities provided long-acting contraceptives, while 99.31% provided short-term contraceptive methods. The national average distance from family planning health facilities to the 2016 EDHS clusters was 6.35 kilometres. The 2016 EDHS-sampled clusters in the Somali region were the longest distance (18.58 km) from family planning facilities. Conversely, EDHS clusters in Addis Ababa were 0.55 kilometres from family planning facilities (see Table 3).

Table 3: The average distance from sampled family planning providing health facilities to demographic and health survey clusters in Ethiopia, 2016 ($N = 1020$)

Region	Population projection for 2016 (in thousands) *	Health facility type				Average distance (km)
		Hospitals *n* (%)	Health centres *n* (%)	Health posts *n* (%)	Private clinics *n* (%)	
Tigray	5,151	30 (28.30)	30 (28.30)	25 (23.58)	21 (19.81)	5.53
Afar	1,768	6 (10.71)	25 (44.64)	16 (28.57)	9 (16.07)	9.69
Amhara	20,771	26 (16.77)	46 (29.68)	34 (21.94)	49 (31.61)	8.47
Oromia	34,575	49 (25.26)	50 (25.77)	43 (22.16)	52 (26.80)	8.99
Somali	5,599	10 (20.41)	21 (42.86)	12 (24.49)	6 (12.24)	18.58
Benishangul-Gumuz	1,035	2 (3.13)	16 (25.00)	29 (45.31)	17 (26.56)	5.28
SNNPR	18,720	24 (15.58)	40 (25.97)	38 (24.68)	52 (33.77)	7.08
Gambela	422	1 (1.79)	14 (25.00)	22 (39.29)	19 (33.93)	4.32
Harari	238	4 (9.30)	8 (18.60)	21 (48.84)	10 (23.26)	0.73
Addis Ababa	3,353	33 (42.31)	18 (23.08)	0	27 (34.62)	0.55
Dire Dawa	453	6 (9.23)	15 (23.08)	31 (47.69)	13 (20.00)	0.60
Total	92,085	191 (18.73)	283 (27.75)	271 (26.57)	275 (26.96)	6.35

Note: SNNPR =Southern Nations, Nationalities and Peoples Region.

*Central Statistical Agency – Population Projections for Ethiopia: 2007 - 2037

Modern Contraceptive Prevalence Rate

The prevalence of modern contraceptive use among married women was found to be 33.54% (urban 46.09%, 28.98% rural). The utilisation of modern contraceptives varied across the different regions and city administrations; the highest mCPR was reported in the Amhara region (51.65%), followed by Addis Ababa (50.08%) and the SNNPR (45.48%). Figure 1 shows the regional variations in mCPRs.

Spatial Epidemiology of Modern Contraceptive Use

There is strong evidence to support spatial clustering in the utilisation of modern contraceptives among married women in Ethiopia (Global Moran's I = 0.24; Z-score = 8.09; $P < 0.0001$). Most of the hot spot areas, those with high contraceptive prevalence rates, were located in Addis Ababa and Amhara, followed by the Oromia region and the SNNPR. Conversely, the majority of the cold spot areas, those with low contraceptive prevalence rates, were located in the Somali, Afar and Gambela regions followed by Tigray and Benishangul-Gumuz. This clustering was supported by the *Gi** statistic when conducting the spatial analysis (see Figure 2).

Determinants of Modern Contraceptive Use Among Married Women

The calculated ICC was 24.47%. This indicated that about 24% of the variability in using modern contraceptive methods was accounted for by location, leaving 76% of the variability to be accounted for by the differing characteristics of the women, or other unmeasured factors. The probability of using modern contraceptive methods in a typical region was estimated at 27.8%.

The strong individual-level predictors of modern contraceptive use among married women were their age, their husband/partner's education, household wealth, number of living children and exposure to family planning messages. Women who were in the age groups 35–39 years (44%), 40–44 years (55%) and 45–49 years (82%) were less likely to use modern contraceptives compared to those aged 15–19 years. A woman whose husband attained a primary level of education was 54% more likely to use modern contraceptives compared to those whose husband had no education. The odds ratio of modern contraceptive use increased with increasing wealth quintile. Women who were in the highest quintile were 5.26 times more likely to use the service compared to those in the lowest quintile. Women who had been exposed to family planning messages were 68% more likely to use modern contraceptives

relative to their counterparts with no exposure to family planning messages. Similarly, women who had one to four children were 2.31 times more likely to use the service compared to those having no child (see Table 4).

At the regional level (level 2), only one variable was significantly associated with the use of modern contraceptives. A one-unit increase in the mean score of a health facility's readiness to provide short-term modern contraceptives in a typical region was associated with a 20-fold increase in the odds of modern contraceptive use (Table 4).

Finally, the majority of the variance between regions was explained by this model. The proportional change in variance indicated that the addition of predictors to the empty model explained an increased proportion of variation in modern contraceptive use. The variance estimates between regions decreased from 1.07 in the empty model to 0.18 in the final random intercept and random slope model. The proportion of variance explained by the final model was 83.51%. Similarly, the empty model showed that 24.47% of the variability in the odds of modern contraceptive use was explained by region-level characteristics (ICC = 24.47%). The between-region variability declined over successive models, from 24.47% in the empty model to 5.07% in the final model (see Table 5).

Table 4: Factors Associated with Utilisation of Modern Contraceptives Among Married Women in Ethiopia ($N = 8473$)

Predictors		Model 2[a] AOR (95% CI)	Model 3[b] AOR (95% CI)	Model 4[c] AOR (95% CI)
Level 1 predictor variables				
Age	15–19	1.00	1.00	1.00
	20–24	1.21(0.94, 1.55)	1.27(0.91, 1.76)	1.26 (0.91, 1.76)
	25–29	0.92(0.71, 1.18)	0.94(0.67, 1.31)	0.93 (0.67, 1.30)
	30–34	**0.74(0.57, 0.97)**	0.74(0.52, 1.04)	0.74 (0.52, 1.04)
	35–39	**0.60(0.45, 0.79)**	**0.56(0.40, 0.80)**	**0.56 (0.39, 0.80)**
	40–44	**0.50(0.37, 0.67)**	**0.45(0.31, 0.65)**	**0.45 (0.31, 0.65)**
	45–49	**0.20(0.14, 0.28)**	**0.18(0.12, 0.27)**	**0.18 (0.12, 0.27)**
Husband/partner's level of education	No education	1.00	1.00	1.00
	Primary	**1.38(1.21, 1.57)**	**1.55(1.18, 2.04)**	**1.54 (1.18, 2.02)**
	Secondary	1.18(0.98, 1.42)	1.29(0.96, 1.74)	1.29 (0.96, 1.73)
	Higher	0.88(0.72, 1.08)	1.06(0.77, 1.45)	1.05 (0.77, 1.44)
Wealth quintile	Lowest	1.00	1.00	1.00
	Second	**1.96(1.62, 2.38)**	**1.96(1.27, 3.02)**	**1.95 (1.27, 2.99)**
	Middle	**2.53(2.09, 3.07)**	**2.66(1.72, 4.13)**	**2.65 (1.72, 4.08)**
	Fourth	**3.14(2.58, 3.82)**	**3.46(2.23, 5.37)**	**3.42 (2.21, 5.28)**
	Highest	**5.09(4.17, 6.22)**	**5.45(3.56, 8.33)**	**5.26 (3.46, 7.99)**
Number of living children	0	1.00	1.00	1.00
	1–4	**2.04(1.66, 2.50)**	**2.31(1.65, 3.23)**	**2.31 (1.64, 3.25)**
	>= 5	**1.96(1.52, 2.52)**	**2.05(1.40, 3.00)**	**2.05 (1.40, 3.01)**
Exposure to family planning messages	No	1.00	1.00	1.00
	Yes	**1.49(1.28, 1.72)**	**1.68(1.20, 2.34)**	**1.68 (1.20, 2.36)**
Level-2 predictor variables				
General service readiness	Health facility management system			1.27 (0.05, 35.69)
	Health facility infrastructure			1.51 (0.18, 12.95)
Family planning service availability	Long-acting contraceptive methods			5.04 (0.19, 136.21)
	Short-term contraceptive methods			1.79 (0.03, 103.48)
Family planning service readiness	Long-acting contraceptives			0.43 (0.01, 17.12)
	Short-term contraceptives			**20.49 (1.44, 29.54)**
Average distance to the nearest health facility				1.02 (0.81, 1.28)

AOR = Adjusted Odds Ratio; CI = Confidence Interval; Model 2[a] is adjusted for individual-level factors; Model 3[b] is random slope and random intercept model adjusted for individual-level factors; Model 4[c] is the final model adjusted for individual- and region-level factors

N.B. Model 1 (Empty model) is not included in this table (but is in Table 5).

Table 5: Variations in modern contraceptive use in Ethiopia: random slope and random intercept model

Random effects (Measure of variation for modern contraceptive use)	**Model 1[a]**	**Model 2[b]**	**Model 3[c]**	**Model 4[d]**
Region-level variance (SE)	1.07 (0.47)	0.90 (0.47)	0.84 (0.38)	0.18 (0.16)
P value	<0.05	<0.05	<0.05	<0.05
Variance in age (SE)			0.04 (0.02)	0.05 (0.02)
P value			<0.05	<0.05
Variance in husband/partner's level of education variance (SE)			0.06 (0.03)	0.05 (0.03)
P value			<0.05	<0.05
Variance in wealth quintile (SE)			0.14 (0.05)	0.14 (0.05)
P value			<0.01	<0.01
Variance in number of living children (SE)			0.08 (0.04)	0.08 (0.04)
P value			<0.05	<0.05
Variance in exposure to family planning messages) (SE)			0.08 (0.05)	0.09 (0.06)
P value			<0.05	>0.05
ICC (%)	24.47	21.47	20.43	5.07
Explained variance (PCV) (%)	Reference	15.61	20.74	83.51
Model fit statistics				
AIC	9959.57	9073.71	8920.49	8918.61
BIC	9960.36	9080.87	8932.43	8927.76

SE = Standard Error; ICC = Intra-Class Correlation; PCV = Percentage Change in Variance; CI = Confidence Interval; AIC = Akaike's Information Criterion; BIC = Schwarz's Bayesian Information Criteria; Model 1[a] is the null model, a baseline model without any determinant variable; Model 2[b] is adjusted for individual-level factors; Model 3[c] is random slope and random intercept model adjusted for individual-level factors; Model 4[d] is the final model adjusted for individual- and region-level factors

Discussion

In Ethiopia, the use of modern contraception varied by region. This is the first study to specifically identify hot spots and model the use of modern contraception using nationwide population and health facility data. Approximately 34% of married women use modern contraceptives; the highest mCPR was reported among urban married women (46.09% versus 28.98%). This is comparable with the findings of the 2011 EDHS data analysis where 27.3% of married women reported using modern contraceptive methods; the highest proportion was from urban areas (49.55% versus 22.5%) (9). There are also variations in modern contraceptive rate across different regions in the country. The highest contraceptive rate, more than 50% mCPR, was reported in the Amhara region and the Addis Ababa city administration. Conversely, the lowest, below 10% mCPR, was reported in the Somali and Afar regions. Even though there has been an increase in modern contraceptive use all over the country, it was found that there was significant regional variation in modern contraceptive use.

High mCPR spots (hot spots) were detected in the Amhara region and Addis Ababa, followed by the SNNPR and some parts of Oromia region. Conversely, the majority of low mCPR (cold spots) were detected in the Somali, Afar and Gambela regions followed by Tigray and Benishangul-Gumuz. In 2011, hot spots of modern contraceptive use were observed in Addis Ababa, followed by some parts of Amhara, Oromia and SNNPR. The lowest contraceptive rates (cold spots) were observed in the Afar, Somali and Gambela regions, and some parts of Tigray region (9). This indicated that the government is doing a good job in some of the regions, but is less successful in most regions. Due to this reason, the unmet need for modern contraception will be much higher than expected in most of those regions. Thus, cold spots (low rates of modern contraception) will be much more concentrated in those areas.

In Ethiopia, the use of modern contraceptives varied across the different regions and city administrations. The highest modern contraceptive prevalence rate was reported in the Amhara region, followed by Addis Ababa and SNNPR. This variation is demonstrated by the national DHSs conducted every five years since 2000. Over 16 years, between 2000 and 2016, the Amhara region and SNNPR showed an increase in the utilisation of modern contraceptives (8, 31-33). The large increase in the use of modern contraceptives in the Amhara region, as well as SNNPR, might be related to the high number of family planning organisations and the government's focus on these regions.

Different individual and regional factors were significantly associated with the use of modern contraceptives. The readiness of health facilities to provide short-term modern contraceptives was the only regional (level-2) variable that was significantly associated with the use of modern contraceptives. It was found that a one-unit increase in the mean score of the readiness of health facilities to provide short-term modern contraceptives was significantly associated with the utilisation of modern contraceptives. In a study that used DHS and SPA survey data from several East African countries (Kenya, Uganda, Rwanda and Tanzania), it was found that modern contraceptive utilisation was strongly associated with health facilities offering a wide range of contraceptives, and with a higher score of family planning service environment (16). Even though it is not directly related, in a study carried out in rural Ethiopia, researchers found that women who lived close to a health facility providing a wide range of contraceptives were more likely to use modern contraceptives (11). This indicated that the potential impact of family planning services should not be underestimated. Therefore, family planning health facilities should be fully equipped to provide a wide range of modern contraception.

Among the individual factors, an increase in the age of women was significantly associated with a decrease in the use of modern contraceptives. This is similar to results of other studies carried out in Ethiopia, where the utilisation of modern contraceptives was negatively influenced by an increase in the age of women (9, 11, 12). This could be related to the knowledge gap, beliefs and/or attitudes that each woman has; as the age of a woman increases, the probability of changing her attitudes or beliefs towards contraception may reduce.

In Ethiopia, among the individual-level variables, the educational attainment of husband/partners was a significant predictor of the increase in modern contraceptive use. In a study conducted in the North Gondar, Amhara region of Ethiopia, it was found that the educational attainment of husbands was a significant predictor of women's contraceptive use (34). This might be due to the involvement of husbands in contraception decision-making. This is supported by other studies demonstrating the influence of discussing modern contraceptives with the husband and the husband's approval of using modern contraceptives (35, 36). It was found that the utilisation of modern contraceptives was significantly higher among women whose husbands had approved of using modern contraceptives. Similarly, the odds of using modern contraceptives was higher among those women who had discussed modern contraceptives with their husbands (35, 36). This indicated that a woman's husband's

education, as well as male involvement, has an important role in the use of modern contraceptives. Thus, educational opportunities for men and increasing male involvement in every family planning service should be emphasised for higher engagement in the use of modern contraception.

The increase in household wealth was a significant predictor of an increase in modern contraceptive utilisation. In two studies conducted in Ethiopia, including a study performed among rural women (11), it was found that women who were in the fourth and highest quintile were more likely to use modern contraceptives (9, 11). Family monthly income was significantly associated with the use of modern contraceptives (35). Wealth might directly or indirectly affect modern contraceptive use. Women might know about the importance of contraception. However, knowledge alone will not be important in some cases. They should have money for transport and service. The trade-off associated with the time they spent on traveling to and from health facilities is also important. They may use that particular time for household activities, farming, or other business-generating activities. For instance, in Ethiopia, despite family planning services being free of charge in public health facilities, the cost of transport might be attributable to the use of modern contraception. Moreover, the costs of family planning services in private health facilities might also be related to the use of modern contraceptives. Thus, the cost of transport and family planning service fees in private health facilities might not be important for wealthy families.

In this current study, it was found that, compared to having no children, having one or more living children increases the likelihood a woman will use modern contraceptives. In the 2011 EDHS data analysis (9) and a study done in the SNNPR (12), researchers also found that an increase in the number of living children was significantly associated with an increase in modern contraceptive use. Among rural women in Ethiopia, an increase in parity was positively associated with an increase in modern contraceptive use (11). This finding is similar to studies done in Bangladesh, Pakistan and Tanzania, where it was reported that an increase in the number of living children was significantly associated with an increase in the use of modern contraceptives (13, 37, 38). This indicated that women's desire to have children might influence their contraceptive use behaviours: women with a high number of living children may be more likely to use contraception.

Exposure to family planning messages, the last individual-level variable in the multilevel model, showed an increase in the likelihood of using modern contraception. In a study done among women of reproductive age in the SNNPR region, it was found that the odds of modern contraceptive utilisation were significantly associated with women's overall knowledge of family planning methods. It was observed that women with good family planning knowledge were more likely to use modern contraceptives (12). Thus, exposure to family planning messages through different public and private media outlets is an important recommendation arising from this study.

In this study, it was found that the utilisation of modern contraceptives varied across regions. The individual-level variables (age, husband/partner's education, wealth, number of living children and exposure to family planning messages) varied significantly across the regions. In a study in rural Ethiopia, it was found that the use of modern contraceptives was significantly higher in the Amhara and SNNPR regions (11). This might be related to variations in the availability and accessibility of different family planning services across administrative regions of the country. In addition to the multilevel analysis, this study has identified the hot spot and cold spot areas to help the government in improving the provision of modern contraceptives, especially those areas with the low rates of modern contraception.

This study identified both the demand- and supply-side determinants of modern contraceptive utilisation using a linked population and health facility data. This was overlooked in previous studies, which generally studied these factors separately. In addition to multilevel analysis, this study used spatial analyses to identify geographic variations in modern contraceptive utilisation. Taking a geographic perspective on family planning is very important for effective resource allocation and intervention, informed decision-making, and monitoring and evaluation purposes.

This study had several methodological limitations, most of which were minimised (17). The exclusion of DHS clusters without information relating to geographic coordinates, and using sampled health facilities, may underestimate or overestimate our study findings. This study did not consider sampling weights while running the multilevel analysis. DHSs provide an average weight (hv005 or v005); however, the GLIMMIX procedure in SAS requires weights at each level. Due to this issue, we could not able to apply sampling weights in the multilevel analysis.

Conclusion

In this study, it was found that more than one-third of married women in Ethiopia use modern contraceptives. It was also found that different individual-level variables, as well as regional-level variables, were predictors of modern contraceptive use. There is evidence of wide geographic variations in the use of modern contraceptives across the country. The findings of this study have several implications: first, regions with low contraceptive rates and high fertility rates should be targeted for scaling up and tailoring of services to the lifestyles of their populations. Second, available health facilities should be equipped to provide modern contraceptive methods. Strong emphasis should also be given to the contraceptive method mix/choice available at each health facility to increase contraceptive uptake. Third, increasing educational opportunities for men and increasing male involvement, and exposure to family planning messages are also important recommendations to arise from this research. The importance of awareness and the potential impact of services cannot be underestimated.

Abbreviations

CRS	Coordinate Reference System
DHS	Demographic and Health Survey
EAs	Enumeration Areas
EDHS	Ethiopia Demographic and Health Survey
ESPA+	Ethiopia Service Provision Assessment Plus
FDR	False Discovery Rate
GIS	Geographic Information Systems
HGLM	Hierarchical Generalized Linear Model
ICC	Intra-class Correlation Coefficient
IUD	Intrauterine Device
mCPR	modern Contraceptive Prevalence Rate
SNNPR	Southern Nations, Nationalities and Peoples Region
SPA	Service Provision Assessment
WGS84	World Geodetic System 84

Ethics approval

Ethical approval was obtained from the Human Research Ethics Committee, The University of Newcastle on March 20, 2018 with a reference number H-2018-0066. We also got the Ethiopian Public Health Institute (EPHI) and the Measure DHS program approval to access the datasets.

Consent for publication

Not applicable.

Availability of data and material

All data relevant to the study are included in the article.

Competing interests

The authors declared that they have no competing interests.

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Authors' contributions

TKT, CC, RS, DL conceptualized the design of the analysis. TKT developed and drafted the manuscript. CC, PF, TG, RS and DL participated in critically revising the intellectual contents of the manuscript. All authors read, provided feedback and approved the final manuscript.

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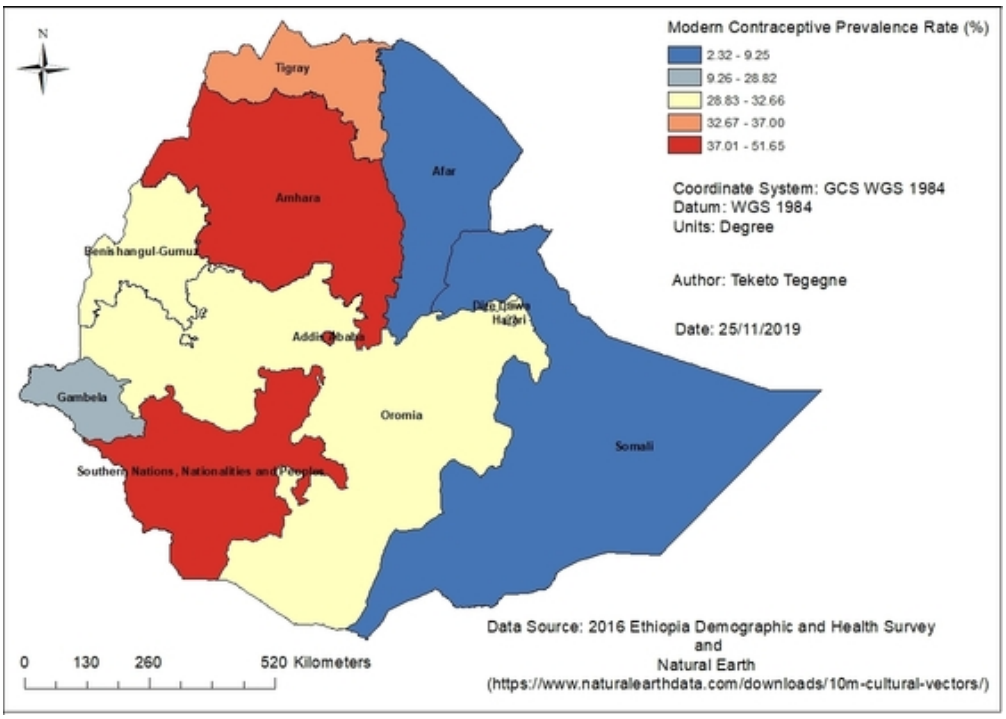
Figure Legends

Figure 1: Modern contraceptive use among married women in Ethiopia, 2016

Figure 2: Clusters of high and low modern contraceptive prevalence rates in Ethiopia, 2016



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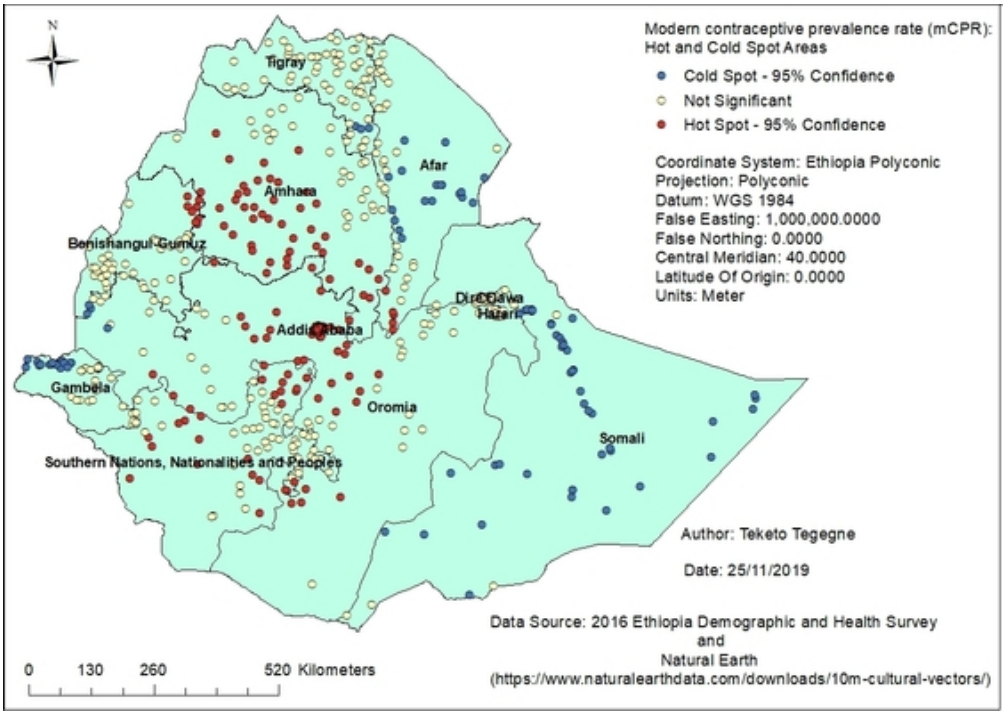

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STROBE Statement—Checklist of items that should be included in reports of ***cross-sectional studies***

	Item No	Recommendation	Page No
Title and abstract	1	(*a*) Indicate the study's design with a commonly used term in the title or the abstract	1
		(*b*) Provide in the abstract an informative and balanced summary of what was done and what was found	2
Introduction			
Background/rationale	2	Explain the scientific background and rationale for the investigation being reported	4 - 5
Objectives	3	State specific objectives, including any prespecified hypotheses	5
Methods			
Study design	4	Present key elements of study design early in the paper	5 - 6
Setting	5	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection	5 - 6
Participants	6	(*a*) Give the eligibility criteria, and the sources and methods of selection of participants	5 - 6
Variables	7	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable	6 - 7
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	*5 - 7*
Bias	9	Describe any efforts to address potential sources of bias	5 - 6
Study size	10	Explain how the study size was arrived at	5 - 6
Quantitative variables	11	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why	7 - 8
Statistical methods	12	(*a*) Describe all statistical methods, including those used to control for confounding	8
		(*b*) Describe any methods used to examine subgroups and interactions	8
		(*c*) Explain how missing data were addressed	8
		(*d*) 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	9 - 16
		(b) Give reasons for non-participation at each stage	9 - 16
		(c) Consider use of a flow diagram	9 - 16
Descriptive data	14*	(a) Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders	9 - 16
		(b) Indicate number of participants with missing data for each variable of interest	9 - 16
Outcome data	15*	Report numbers of outcome events or summary measures	14 - 15
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	14 - 16

		(*b*) Report category boundaries when continuous variables were categorized	16
		(*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	15
Discussion			
Key results	18	Summarise key results with reference to study objectives	17
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	3, 20
Interpretation	20	Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence	17 – 20
Generalisability	21	Discuss the generalisability (external validity) of the study results	21
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	22

*Give information separately for exposed and unexposed groups.

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.