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# BMJ Open

**Exploring spatial distribution and associated factors of stillbirth among births from reproductive-age women in Ethiopia based on the Ethiopian demographic health survey 2016: Spatial and Multilevel Analysis**

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3 **1 Exploring spatial distribution and associated factors of stillbirth among births**  
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6 **2 from reproductive-age women in Ethiopia based on the Ethiopian**  
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9 **3 demographic health survey 2016: Spatial and Multilevel Analysis**  
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12 4 Getayeneh Antehunegn<sup>1\*</sup>, Lemma Dersseh<sup>1</sup>, Solomon Gedlu<sup>1</sup>  
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## 17 Abstract

18 **Objective:** Although the stillbirth rate has been reduced globally, the rate is still very high in  
19 developing countries. So far, only ten countries carry the burden of over 65% of stillbirth in the  
20 world including Ethiopia in the seventh position. Exploring the spatial variation is important to  
21 monitor and design effective intervention programs but there is no available study on spatial  
22 distribution and factors associated with a stillbirth at the national level. Therefore, this study  
23 aimed to explore the spatial distribution and associated factors of stillbirth.

24 **Methods:** secondary data analysis was conducted using the 2016 Ethiopian Demographic and  
25 Health Survey data. Weighted samples of 11,375 women were included for analysis. The  
26 Bernoulli model was fitted using spatial scan statistics version 9.6 to identify hotspot areas and  
27 ArcGIS version 10.6 to explore the spatial distribution of stillbirth. For associated factors, a  
28 multilevel logistic regression model that accounts for the hierarchical structure of the data was  
29 fitted using STATA 14.

30 **Result:** the study showed geographic variability of stillbirth across the country (Global Moran's  
31  $I = 0.017$ ,  $p < 0.05$ ). The SaTScan spatial analysis identified primary cluster in Northeast Somali  
32 region (LLR=13.4,  $p < 0.001$ ) while the secondary cluster was detected in the border area between  
33 Oromia and Amhara region (LLR=8.8,  $p < 0.05$ ). Rural residence (AOR=4.83, 95%CI:1.44-  
34 16.19), primary education (AOR=0.39, 95%CI:0.20-0.74), not having ANC visit(AOR=2.77,  
35 95%CI:1.70-4.51), caesarean delivery (AOR=5.07, 95%CI: 1.65-15.58), birth interval <24  
36 month (AOR=1.95, 95%CI: 1.20,3.10), and height<150 cm(AOR=2.73, 95%CI:1.45-4.97) were  
37 significant predictors of stillbirth.

38 **Conclusion and recommendation:** In Ethiopia, stillbirth had spatial variation across the  
39 country. Residence, maternal stature, preceding birth interval, caesarean delivery, education, and

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3 40 ANC visit were significant predictors of stillbirth. This has public health implications to target  
4  
5 41 interventions to identified hotspot areas of stillbirth and the government should scale up maternal  
6  
7 42 health programs in rural areas  
8  
9

10 43 **Keywords:** stillbirth, Ethiopia, multilevel logistic regression, spatial analysis  
11  
12 44

### 16 45 **Strength and limitation of the study**

- 19 46 • The study used national survey by weighted the data since some regions were oversampled  
20  
21 47 and some under sampled to make it nationally representative, the study has the potential to  
22  
23 48 inform policy-makers, planners and programmers to design appropriate intervention at  
24  
25 49 national and regional levels
- 28 50 • As a study was a cross—sectional study, the study are unable to show temporal relationship.  
29  
30 51 However, our method used multilevel modeling which took into account the effect of  
31  
32 52 clustering to get reliable estimate and standard error.
- 35 53 • The EDHS survey did not incorporate clinically confirmed data rather it relied on mothers or  
36  
37 54 caregivers report
- 40 55 • The study was based on self-reports of respondents. There may have the possibility of social  
41  
42 56 desirability and recall bias since stillbirth is not culturally acceptable though CSA claim that  
43  
44 57 strong effort was made to minimize it mainly through extensive training of data collectors,  
45  
46 58 recruiting experienced data collectors and supervisors this might underestimate our finding
- 49 59 • The SaTScan detect only circular clusters, irregular shaped clusters were not detected

## 60 **BACKGROUND**

61 For international comparison, the World Health Organization (WHO) defines stillbirth as fetal  
62 death (death before the complete expulsion or extraction of a product of conception from its  
63 mother) in the third trimester ( $\geq 28$  completed weeks of gestation) or birth weight  $\geq 1000$  gram or  
64 length  $\geq 35$  centimeter(1, 2). Globally, stillbirth is a huge public health concern, especially in  
65 Sub-Saharan Africa (SSA) and South Asia (SA) including Ethiopia (3). Around 2.6 million  
66 stillbirths occur annually, 98% of which occur in developing countries (4). An overwhelming  
67 majority (67%) of the world's stillbirth occurred in Sub-Saharan Africa and South Asia, and most  
68 of the stillbirth occurs during the intrapartum period which is preventable by improving  
69 obstetrics services (5).

70 More than half of the 2.6 million stillbirths occur during labor and delivery, indicating poor  
71 quality of healthcare services in many of the developing countries with a high burden of stillbirth  
72 (6). It is considered to be an important indicator of access to and quality of obstetric care,  
73 including the utilization of services in a geographic location (7). According to the most recent  
74 global estimate of the World Health Organization (WHO), the average global stillbirth rates was  
75 18.4 per 1000 births (8), while developing countries have the stillbirth rates ten-fold higher than  
76 developed countries (9). Sub-Saharan Africa is particularly affected by the highest stillbirth rate  
77 globally 28.3 per 1000 births (10).

78 The rate of stillbirth varies across countries and remains a huge challenge to achieve Every  
79 Newborn Action Plan (ENAP) of the target of 12 or fewer stillbirths per 1000 births in every  
80 country by 2030 (1). Even though many high-income countries and upper-middle-income  
81 countries have already met this target, developing countries particularly Africa will have to more  
82 than double present progress to reach this target (1).

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2  
3 83 Despite the various international and national commitments and interventions on improving  
4  
5 84 newborn and maternal health (11), stillbirth has been grossly under-reported and invisible in  
6  
7  
8 85 policies and programs worldwide, with little recognition of potential strategies for intervention  
9  
10 86 (12). Like many countries in SSA, stillbirth is not routinely recorded and monitored in Ethiopia.  
11  
12 87 Stillbirth has been reduced more slowly than maternal mortality or under 5 mortality, which  
13  
14 88 remains invisible in global policies with an Annual Average Rate of Reduction (ARR) of 2.0% in  
15  
16 89 comparison to ARR of 3.0% for maternal death or 3.1% for neonatal death (13). The death of a  
17  
18 90 fetus in utero or at birth is a devastating experience for the affected mothers and families (14). It  
19  
20 91 has been associated with extensive psychosocial consequences for parents and family and has  
21  
22 92 been linked to a post-traumatic stress disorder, anxiety, depression, suicide, fear of the next  
23  
24 93 pregnancy and reduced relation with their partner (15, 16).

25  
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28  
29 94 In Ethiopia, a study conducted based on Ethiopian Demographic and Health Survey (EDHS)  
30  
31 95 2011 revealed a stillbirth rate of 25.5 per 1000 births with significant variability across regions  
32  
33 96 and they recommend researchers to conduct spatial analysis to investigate the spatial variability  
34  
35 97 of experiencing stillbirth (17). A study done at the Amhara region based on Ethiopian Mini  
36  
37 98 Demographic and Health Survey 2014 reported that a stillbirth rate of 85 per 1000 births(18).  
38  
39 99 Different studies done on experiencing stillbirth showed that rural residence, parity, educational  
40  
41 100 status, mode of delivery, ANC utilization, and place of delivery, maternal nutritional status, and  
42  
43 101 maternal obstetric factors were the significant predictors of experiencing stillbirth (14, 19-21).

44  
45  
46  
47 102 There is a wide gap in the stillbirth rate not only among different countries but also within the  
48  
49 103 country (17, 22). A high rate of stillbirth has been reported among rural, poor and marginalized  
50  
51 104 societies that are the least beneficial of maternal health promotion activities and services (12).  
52  
53  
54 105 Thus, the identification of geographic areas with a high rate of stillbirth using Geographic  
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3 106 Information System (GIS) and Spatial Scan statistical analysis (SaTScan) has become  
4  
5 107 fundamental to guide targeted public health interventions. However, previous studies in Ethiopia  
6  
7 108 have focused on the prevalence and associated factors of stillbirth (18, 23, 24), by using standard  
8  
9  
10 109 logistic regression models despite the hierarchical structure of DHS data this could result in  
11  
12 110 biased estimate since the data is nested within-cluster and violates the independent assumption  
13  
14 111 unless we take into account by using multilevel models (17). The findings of these studies are  
15  
16 112 insufficient and limited to capture the spatial distribution of stillbirth and community-level  
17  
18 113 factors contributing to stillbirth. Therefore, the current study was done to explore the spatial  
19  
20 114 distribution and associated factors of stillbirth among births from reproductive-age women in  
21  
22 115 Ethiopia using Spatial and multilevel Analysis. Thus, understanding the spatial epidemiology of  
23  
24 116 stillbirth is crucial for evidence-based decision making to improve pregnancy outcomes by  
25  
26 117 designing effective maternal health programs.

## 31 118 **Method and materials**

### 34 119 **Study design, setting and period**

37 120 A community-based cross-sectional study was conducted from January 18 to June 27, 2016. The  
38  
39 121 study was conducted in Ethiopia, which is situated in the Horn of Africa. It has 9 Regional states  
40  
41 122 (Afar, Amhara, Benishangul-Gumuz, Gambela, Harari, Oromia, Somali, Southern Nations,  
42  
43 123 Nationalities, and People's Region (SNNP) and Tigray) and two Administrative Cities (Addis  
44  
45 124 Ababa and Dire-Dawa) (Figure 1).

48  
49 125 Ethiopia is an agrarian country and agriculture accounts for 43 percent of the gross domestic  
50  
51 126 product (GDP) and 84% of the population lives in rural areas. More than 80 percent of the  
52  
53 127 country's total population lives in the regional states of Amhara, Oromia, and SNNP(25).

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2  
3 128 In 2016, the population was 102 million of which 43.47% the population ages less than 14 years  
4  
5 129 with birth rate of 36.5 births per 1000 population and fertility rate of 4.46, Ethiopia is the 13th in  
6  
7 130 the world and 2nd in Africa most populous country Ethiopia has 3 tiers health systems, Primary  
8  
9 131 health care unit (Primary hospital, health center, health post, primary clinic, and medium clinic);  
10  
11 132 Secondary health care (General hospital, specialty clinics and specialty centers); and Tertiary  
12  
13 133 health care (Specialized hospital). The number of hospitals varies from region to region in  
14  
15 134 response to differences in population size. The most populous region, Oromia has 30 hospitals.  
16  
17 135 The other two predominant regions Amhara and SNNPR have 19 and 20 respectively with  
18  
19 136 Tigray in fourth place with 16 hospitals, Gambela has only one hospital and Benishangul-Gumuz  
20  
21 137 two had two hospitals (26).  
22  
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### 27 **Sample and population**

28  
29 139 The source population was all births from reproductive age women within five years before the  
30  
31 140 survey in Ethiopia and all births from reproductive-age women in the selected enumeration areas  
32  
33 141 within five years before the survey were the study population. The EDHS used a stratified two-  
34  
35 142 stage cluster sampling technique selected in two stages using 2007 the Population and Housing  
36  
37 143 Census as a sampling frame. Stratification was achieved by separating each region into urban  
38  
39 144 and rural areas. In total, 21 sampling strata have been created because the Addis Ababa region is  
40  
41 145 entirely urban. In the first stage, 645 EAs (202 in the urban area) were selected with probability  
42  
43 146 proportional to the EA size and with independent selection in each sampling stratum. In the  
44  
45 147 second stage, because the time has passed since the PHC, a complete household listing operation  
46  
47 148 was carried out in all selected EAs before the start of fieldwork and on average 28 households  
48  
49 149 were systematically selected. Of these, 18,008 households and 16,583 eligible women included.  
50  
51  
52  
53 150 The detailed sampling procedure was presented in the full EDHS 2016 report (27).  
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## 151 **Study variables**

### 152 *Outcome variables*

153 The 2016 EDHS asked women to report any pregnancy loss that occurred in the five years  
154 preceding the survey. For each pregnancy that did not end in a live birth, the duration of the  
155 pregnancy was recorded. Pregnancy losses occurring after seven completed months of gestation  
156 are defined as stillbirths. The response variable of this study is the occurrence of stillbirth among  
157 mothers of childbearing age.

158 The response variable for the  $i^{\text{th}}$  mother is represented by a random variable  $Y_i$  with two possible  
159 values coded as 1 and 0. So, the response variable of the  $i^{\text{th}}$  mother  $Y_i$  was measured as a  
160 dichotomous variable with possible values  $Y_i = 1$ , if  $i^{\text{th}}$  mother had experienced stillbirth and  $Y_i =$   
161 0 if mother had a live birth.

### 162 *Independent variables*

163 Consistent with the objective of the study and given the hierarchical structure of EDHS data  
164 where women were nested within the cluster/community, two levels of independent variables  
165 were considered. Level 1 contained individual socio-demographic and economic factors (Age,  
166 marital status, religion, maternal education, paternal education, wealth index, maternal  
167 occupation, maternal working Status), pregnancy and pregnancy-related factors (Mother's  
168 height, BMI, ANC visit, Parity, Preceding birth interval, contraceptive use, Place of delivery,  
169 Birth order, Mode of delivery, wanted pregnancy, Maternal anemia), and behavioral factors  
170 (Smoking, media exposure) and that of community-level factors (region, residence, community  
171 women education, community poverty, community media exposure, and community ANC  
172 utilization) at level 2, which included the characteristics of the community in which each woman  
173 resided. In EDHS data no variable describes the cluster except region and place of residence.

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2  
3 174 Therefore, Individual-level variables were aggregated at the cluster level to generate community-  
4  
5 175 level variables to see whether cluster-level variables had an effect on stillbirth and which were  
6  
7 176 categorized by their proportion as higher or lower based on national median value since it was  
8  
9  
10 177 not normally distributed. Community-level variables used in the analysis were from two sources;  
11  
12 178 direct community-level variables that were used without any manipulation and aggregated  
13  
14 179 community-level variables that were generated by aggregating individual-level variables at the  
15  
16  
17 180 cluster level.

### 181 **Data collection procedure**

182 The study was conducted based on EDHS data by accessing from the DHS program official  
183 database [www.measuredhs.com](http://www.measuredhs.com) after permission was granted through an online request by  
184 explaining the objective of our study. The raw data was collected from all parts of the country  
185 on childbearing aged women using a structured and pre-tested questionnaire. We used the EDHS  
186 2016 birth data set and extracted the outcome and independent variables. Geographic coordinate  
187 data (longitude and latitude coordinates) was taken at the cluster level/ enumeration area level.

### 188 **Data management and analysis**

189 Before the actual data collection, the Pre-test was conducted which consisted of in-class training,  
190 biomarker training, and field practice days. The questionnaires were pretested in all three local  
191 languages (Amharic, Oromia, and Tigrigna) to make sure that the questions were clear and could  
192 be understood by the respondents. The data were weighted using sampling weight, primary  
193 sampling unit, and strata before any statistical analysis to restore the representativeness of the  
194 survey and to tell the STATA to take into account the sampling design when calculating standard  
195 errors to get reliable statistical estimates. Cross tabulations and summary statistics were

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2  
3 196 conducted to describe the study population. Descriptive and summary statistics were conducted  
4  
5 197 using STATA version 14 software.  
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7

8 198 In EDHS data, women are nested within a cluster and we expect that women within the same  
9  
10 199 cluster may be more similar to each other than women in the rest of the country. This violates the  
11  
12 200 assumption of the traditional regression model which is the independence of observations and  
13  
14 201 equal variance across clusters. This implies that the need to take into account the between cluster  
15  
16 202 variability by using an advanced model. Therefore, a multilevel logistic regression model (both  
17  
18 203 fixed and random effect) was fitted, since the outcome variable was binary. Model comparison  
19  
20 204 was done based on Deviance since the models were nested. Likelihood ratio test, ICC (Intra-class  
21  
22 205 correlation), MOR (median odds ratio) and PCV (proportional change in variance) were  
23  
24 206 computed to measure the variation between clusters. The intra-class correlation coefficient  
25  
26 207 (ICC) quantifies the degree of heterogeneity of stillbirth between clusters (the proportion of the  
27  
28 208 total observed individual variation in stillbirth that is attributable to between cluster variations).  
29  
30  
31  
32  
33

34 209  $ICC = \frac{\sigma^2}{(\sigma^2 + \pi^2/3)}$  (28), but MOR is quantifying the variation or heterogeneity in outcomes  
35  
36 210 between clusters and is defined as the median value of the odds ratio between the cluster at high  
37  
38 211 risk of stillbirth and cluster at lower risk when randomly picking out two clusters (EAs).  
39  
40

41 212  $MOR = \exp(\sqrt{2 * \partial^2 * 0.6745}) \sim MOR = \exp(0.95 * \partial)$  (29)  
42  
43

44 213  $\partial^2$  indicates that cluster variance  
45  
46

47 214 PCV measures the total variation attributed to individual-level factors and community-level  
48  
49 215 factors in the multilevel model as compared to the null model.  
50  
51

52 216  $PCV = \frac{\text{var}(\text{null model}) - \text{var}(\text{full model})}{\text{var}(\text{null model})}$   
53  
54

55 217  $\text{Var}(\text{null model})$   
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3 218 Two-level multilevel multivariable logistic regression was used to analyze factors associated  
4  
5 219 with a stillbirth at two levels, at individual and community (cluster) levels. Four models were  
6  
7 220 constructed for the multilevel logistic regression analysis. The first model was an empty model  
8  
9 221 without any explanatory variables, to determine the extent of cluster variation on stillbirth. The  
10  
11 222 second model was adjusted with individual-level variables; the third model was adjusted for  
12  
13 223 community-level variables while the fourth was fitted with both individual and community level  
14  
15 224 variables simultaneously. A model with the lowest deviance was chosen.

16  
17 225 Variables with p-value  $\leq 0.2$  in the bi-variable analysis for both individual and community-level  
18  
19 226 factors were fitted in the multivariable model. Adjusted Odds Ratio (AOR) with a 95%  
20  
21 227 Confidence Interval (CI) and p-value  $< 0.05$  in the multivariable model were used to declare  
22  
23 228 significant association with experiencing stillbirth. Multi-collinearity was also checked using the  
24  
25 229 variance inflation factor (VIF) which indicates that there is no multi-collinearity since all  
26  
27 230 variables have  $VIF < 5$  and tolerance greater than 0.1.

### 231 *Spatial analysis*

232 For the spatial analysis ArcGIS version 10.6 software and SaTScan version 9.6 software.

### 233 *Incremental spatial autocorrelation*

234 It measures spatial autocorrelation for a series of distances and creates a line graph of those  
235 distances and their corresponding Z-score. Z-scores reflect the intensity of spatial clustering and  
236 statistically significant peak Z-scores. Z-scores indicate where the spatial clustering of stillbirth  
237 is more pronounced. The maximum peak distance was used as a distance band for hotspot  
238 analysis.

### 239 *Spatial autocorrelation analysis*

1  
2  
3 240 The spatial autocorrelation (Global Moran's I) statistic measures whether stillbirth patterns were  
4  
5 241 dispersed, clustered or randomly distributed in the study area(30). Moran's I is a spatial statistics  
6  
7  
8 242 used to measure spatial autocorrelation by taking the entire data set and produce a single output  
9  
10 243 value which ranges from -1 to +1. Moran's I Values close to -1 indicate disease dispersed,  
11  
12 244 whereas Moran's I close to +1 indicate disease clustered and disease distributed randomly if I  
13  
14  
15 245 value is zero. A statistically significant Moran's I ( $p < 0.05$ ) leads to rejection of the null  
16  
17 246 hypothesis (stillbirth is randomly distributed) and indicates the presence of spatial  
18  
19 247 autocorrelation.

20  
21  
22 248 Anselin Local Moran's I used to investigate the local level cluster locations of stillbirth in terms  
23  
24 249 of positively correlated (high-high and low-low) clusters or negatively correlated (high-low and  
25  
26 250 low-high). A positive value for 'I' indicated that a case had neighboring cases with similar  
27  
28  
29 251 values, part of a cluster. A negative value for 'I' indicated that a case was surrounded by cases  
30  
31 252 with dissimilar values an outlier.

### 32 33 34 253 ***Hot spot analysis (Getis-OrdGi\* statistic)***

35  
36  
37 254 Getis-OrdGi\* statistics were computed to measure how spatial autocorrelation varies over the  
38  
39 255 study location by calculating GI\* statistic for each area. Z-score is computed to determine the  
40  
41 256 statistical significance of clustering, and the p-value computed for the significance. Statistical  
42  
43  
44 257 output with high GI\* indicates "hotspot" whereas low GI\* means a "cold spot"(31).

### 45 46 47 258 ***Spatial interpolation***

48  
49  
50 259 It is very expensive and laborious to collect reliable data in all areas of the country to know the  
51  
52 260 burden of a certain event. Therefore, part of a certain area can be predicted by using observed  
53  
54  
55 261 data using a method called interpolation. Spatial interpolation technique is used to predict

1  
2  
3 262 stillbirth on the un-sampled areas in the country based on sampled EAs. There are various  
4  
5 263 deterministic and geostatistical interpolation methods. Among all of the methods, ordinary  
6  
7 264 Kriging and empirical Bayesian Kriging are considered the best method since it incorporates the  
8  
9 265 spatial autocorrelation and it statistically optimizes the weight(32). Ordinary Kriging spatial  
10  
11 266 interpolation method was used for this study for predictions of stillbirth in unobserved areas of  
12  
13  
14  
15 267 Ethiopia.

### 16 17 268 ***Spatial scan statistical analysis***

18  
19  
20  
21 269 Spatial scan statistical analysis Bernoulli based model was employed to test for the presence of  
22  
23 270 statistically significant spatial clusters of stillbirth using Kuldorff's SaTScan version 9.6 software.  
24  
25 271 The spatial scan statistic uses a circular scanning window that moves across the study area.  
26  
27 272 Women with stillbirth were taken as cases and those who have live birth as controls to fit the  
28  
29 273 Bernoulli model. The numbers of cases in each location had Bernoulli distribution and the model  
30  
31 274 required data for cases, controls, and geographic coordinate. The default maximum spatial  
32  
33 275 cluster size of <50% of the population was used, as an upper limit, which allowed both small and  
34  
35 276 large clusters to be detected and ignored clusters that contained more than the maximum limit.  
36  
37  
38  
39 277 For each potential cluster, a likelihood ratio test statistic and the p-value was used to determine if  
40  
41 278 the number of observed stillbirth within the potential cluster was significantly higher than  
42  
43 279 expected or not. The scanning window with maximum likelihood was the most likely performing  
44  
45 280 cluster, and the p-value was assigned to each cluster using Monte Carlo hypothesis testing by  
46  
47 281 comparing the rank of the maximum likelihood from the real data with the maximum likelihood  
48  
49 282 from the random datasets. The primary and secondary clusters were identified and assigned p-  
50  
51 283 values and ranked based on their likelihood ratio test, based on 999 Monte Carlo replications(33)  
52  
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3 285 **Patient and public involvement statement**  
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6  
7 287 Patients and public involvement were not involved in this study since we have conducted a  
8  
9 288 secondary data analysis based on already available DHS data which was collected to provide  
10  
11 289 estimates of common health and health related indicators. For the original project from which  
12  
13  
14 290 data were obtained, patient and public involvement statement was essential since biomarker  
15  
16 291 data's such as anemia, HIV testing and anthropometric measurements were collected (34).  
17  
18

19 292 **Ethical consideration**  
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21

22 293 Ethical clearance was obtained from the Institutional Review Board of Institute of Public Health,  
23  
24 294 CMHS, and the University of Gondar. Permission for data access was obtained from major  
25  
26  
27 295 demographic and health survey through an online request from <http://www.dhsprogram.com>.  
28  
29 296 The data used for this study were publicly available with no personal identifier.  
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## 298 **Result**

### 299 **Socio-demographic and economic characteristics of respondents**

300 A total of 11,375 women who gave birth within five years preceding the survey were included  
301 for the analysis. Of 11,375 of women, 10,149 (89.2%) were rural residents and half of the  
302 respondent were in the age group 20-29 years. Regarding maternal education status, 7,606  
303 (66.9%) had no formal education (Table 1).

### 304 **Pregnancy and maternal health service-related characteristics of respondents**

305 Among 11375 respondents who gave birth within five years, two-third 7,468 (65.7%) of the  
306 respondents delivered at home and 194 (1.7%) gave birth through cesarean section. With regard  
307 to ANC utilization, 2,602 (22.9 %) had no ANC visit during pregnancy (Table 2).

308 The overall rate of stillbirth among births from childbearing age women within five years  
309 preceding the survey in Ethiopia was 9.2 [95% CI; 7.9, 11.1] per 1000 birth. Stillbirth rate was  
310 highest in the Amhara region (19.7) and lowest in Diredawa (3.0) (Figure 2).

### 311 **Spatial distribution of stillbirth**

312 A total of 622 clusters were considered for the spatial analysis of stillbirth. Each point on the  
313 map represents one enumeration area with the proportion of stillbirth cases in each cluster. The  
314 red color indicates areas with a high proportion of stillbirth whereas blue color indicates EAs  
315 with a lower proportion of stillbirth. A higher proportion of stillbirth has occurred in the south  
316 and east Amhara, east Benishangul-Gumuz, East Gambella, central Oromia, north Tigray,  
317 southwest and northeast Somali, and northeast SNNPR whereas, a low proportion of stillbirth  
318 were aggregated in Afar, southwest Benishangul, west Gambella and SNNPR (Figure 3).

### 319 **Incremental spatial autocorrelation**

320 Totally 10 distance bands were detected by a beginning distance of 121,803 meters, the first peak  
321 of 136,586.06 meters and the maximum peak (clustering) was observed at 166152.17 meters.  
322 The maximum peak was used as the distance band for hotspot analysis (Figure 4).

### 323 **Spatial autocorrelation**

324 This study revealed that the spatial distribution of stillbirth was found to be non-random in  
325 Ethiopia with Global Moran's I 0.017 ( $p < 0.05$ ) (Figure 5). The clustered patterns (on the right  
326 sides) show high rates of stillbirth occurred over the study area. The outputs have automatically  
327 generated keys on the right and left sides of each panel. Given the z-score of 2.4 indicated that  
328 there is less than 1.5% likelihood that this clustered pattern could be the result of chance. The  
329 bright red and blue colors to the end tails indicate an increased significance level (Figure 5).

### 330 **Cluster and outlier analysis of stillbirth**

331 The significant cluster was detected in Tigray, Amhara, Oromia, Addis Ababa, SNNPR,  
332 Benishangul-Gumuz, Somali and Gambella regions. Hot spot areas for stillbirth were found in  
333 southwest Somali, southern Amhara, and west SNNPR, While the cold spot regions were found  
334 in south and west Benishangul-Gumuz, Addis Ababa, southwest of Oromia region, west  
335 Gambella and Northeast SNNPR. Outliers were found in the central and southern parts of  
336 Amhara, north Tigray, southeast Gambella and Somali regions (Figure 6).

### 337 **Hot spot analysis of stillbirth**

338 The red color indicates that significant hotspot areas (high rate of stillbirth). Which was found in  
339 the central and southern part of Amhara, west SNNPRs, south and north Tigray, and south West  
340 Somali region ( $p\text{-value} < 0.05$ ), whereas, the blue and yellow color indicates significant more

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3 341 non-risky areas (cold spot areas). This was found in Addis Ababa, central Oromia, and east  
4  
5 342 SNNPRs when the level of confidence increases in both directions its significant level also  
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8 343 increases (Figure 7).  
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### 10 344 **Interpolation of stillbirth**

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12  
13 345 North West Tigray, northern and North West Oromia, east and south Amhara, east Benishangul,  
14  
15 346 East Gambella, Harari, and Northwest SNNPR were detected as predicted more risky areas of  
16  
17  
18 347 stillbirth compared to other regions. Predicted low-risk areas were found in Oromia, Afar, and  
19  
20 348 Gambella regions. Continuous images produced by interpolating (Kriging interpolation method)  
21  
22  
23 349 stillbirth among birth from reproductive-age women (Figure 8).  
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### 25 350 **Spatial scan statistical analysis**

26  
27  
28 351 A total of 56 significant clusters were identified of which 22 clusters were primary (most likely  
29  
30 352 clusters) and 34 secondary clusters of stillbirth were identified. The primary cluster spatial  
31  
32  
33 353 window was located in the northeast Somali region, which was centered 7.829198 N, 43.706264  
34  
35 354 E of geographic location with 166.48 km radius, a relative risk of 22.5 and Log-Likelihood ratio  
36  
37  
38 355 (LLR) of 13.4, at  $p < 0.001$ . It showed that women within the spatial window had 22.5 times  
39  
40 356 higher risk for stillbirth than women outside the window. The secondary clusters scanning  
41  
42  
43 357 window was located between the border area of the south Amhara region and the north Oromia  
44  
45 358 region, and the southern Afar region (Table 3). The red circular ring indicates that the most  
46  
47 359 statistically significant spatial window contains the primary cluster of stillbirth. There was a  
48  
49 360 higher risk of stillbirth within the circular window than outside the spatial window (Figure 9).  
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### 52 361 **Factors associated with stillbirth**

### 53 54 55 362 ***Model comparison***

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3 363 ICC and LR test were checked, and multilevel model was chosen because the likelihood ratio test  
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5 364 was significant and the ICC was 47%. Therefore, the two-level multilevel logistic regression  
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7  
8 365 model was used to get an unbiased standard error and to make a valid inference. Deviance was  
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10 366 used for model comparison; the final model was the best-fitted model with the lowest deviance  
11  
12 367 (Table 4).

### 15 368 **Random effect model**

17  
18 369 ICC in the empty model indicated that 47% of the total variability for stillbirth was due to  
19  
20 370 differences between clusters/EA, with the remaining unexplained 53% attributable to individual  
21  
22 371 differences. Moreover, the median odds ratio for stillbirth was 5.03 in the null model which  
23  
24 372 indicates that there was variation between clusters. If we randomly select women from two  
25  
26 373 different clusters of women at the cluster with a higher risk of stillbirth had 5.03 times higher  
27  
28 374 odds of experiencing stillbirth as compared with women at cluster with a lower risk of stillbirth.  
29  
30 375 About 15.3 percent of the variability in stillbirth was explained by the full model (Table 4).

### 34 376 ***The fixed effect analysis result***

36  
37 377 In the multilevel logistic regression model, residence, region, religion, wealth status, maternal  
38  
39 378 education, birth order, parity, ANC visit, media exposure, maternal height, contraceptive use,  
40  
41 379 birth interval, mode of delivery, community media exposure, and community women education  
42  
43 380 were significant in the bi-variable analysis at  $p\text{-value} < 0.05$ . However, in the multivariable  
44  
45 381 multilevel logistic regression residence, region, religion, preceding birth interval, cesarean  
46  
47 382 delivery, maternal height, ANC visit, and maternal education were significant predictors of  
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49 383 stillbirth.  
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3 384 The odds of experiencing stillbirth for those women residing in a rural area were 4 .83 times  
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5 385 higher than that of those women residing in urban areas (AOR= 4.83, 95% CI 1.44-16.19).  
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8 386 protestant and catholic religious followers had 89% decreased odds of experiencing stillbirth as  
9  
10 387 compared to orthodox religious followers (AOR= 0.11, 95% CI 0.03- 0.37 ).

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13 388 Educational level of women was significantly associated with experiencing stillbirth, Though  
14  
15 389 women having secondary and higher education have no significant difference in experiencing  
16  
17 390 stillbirth with those having no educational attainment, women having primary education  
18  
19  
20 391 decreases the odds of experiencing stillbirth by 61%as compared to those with no educational  
21  
22 392 attainment (AOR= 0.39, 95% CI 0.20 - 0.74).

23  
24  
25 393 The odds of experiencing stillbirth in Tigray, Afar, Somali, SNNPR, Benishangul, Gambella and  
26  
27 394 Harari were not significantly different from that of experiencing stillbirth in Amhara. Women's  
28  
29 395 in the Oromia region had 75% decreased odds of experiencing stillbirth as compared to women  
30  
31 396 in the Amhara region (AOR= 0.25, 95% 0.07- 0.83). besides, Women who had no antenatal care  
32  
33 397 visit during pregnancy were 2.77 times higher odds of experiencing stillbirth than those who  
34  
35 398 have 4 and above ANC visits (AOR= 2.77, 95% CI 1.70 - 4.51). Women who gave birth through  
36  
37 399 cesarean delivery were 5.07times higher odds of experiencing stillbirth than those women who  
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39 400 gave birth through vaginal delivery (AOR= 5.07, 95% CI 1.65– 15.58).

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44 401 The preceding birth interval was a significant predictor of experiencing stillbirth outcomes.  
45  
46 402 Women having preceding birth interval less than 24 months had 1.93 times higher odds of  
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48 403 experiencing stillbirth compared to women having preceding birth interval 24 months and above  
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50 404 (AOR= 1.93, 95% CI 1.20 – 3.10). also, maternal height less than 150 cm were 2.73 times higher  
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52 405 odds of experiencing stillbirth as compared to those mother's greater than or equal to 150 cm  
53  
54 406 (AOR= 2.73, 95% CI 1.50-4.97) (Table 4).

407

**408 Discussion**

409 In Ethiopia, the stillbirth rate was found to be 9.2 per 1000 birth with marked spatial  
410 heterogeneity. The spatial scan statistics detected a total of three statistically significant SaTScan  
411 clusters areas with a high rate of stillbirth. This could be attributed to the disparity in the  
412 distribution of maternal health service, and the inaccessibility of infrastructure in the border areas  
413 of regions (35). In the multivariable multilevel analysis, the odds of stillbirth were lower among  
414 women who lived in the Oromia region as compared to those in the Amhara region. This might  
415 be due to availability and accessibility of maternal health facility since Oromia regions are  
416 relatively around Addis Ababa and Dire-Dawa in which health facilities are accessible as  
417 compared to other regions and high turnover rate of health professionals in Amhara region and  
418 Addis Ababa is the place of destination for them (36). Catholic or protestant religion followers  
419 were significantly associated with lower odds of stillbirth as compared with orthodox religious  
420 followers. This could be due to miss-perception of religious followers may shape their  
421 reproductive health decision making and practices, thereby govern the women's desire for using  
422 maternal health services (37) like some religious followers consider as giving birth at home as  
423 blessed, using contraceptive as committing sin and not expose their body to health professionals  
424 during delivery this might be the possible reason which needs further qualitative study to explore  
425 the detailed reasons.

426 The study has shown that the odds of stillbirth were higher among women who lived in rural  
427 areas. This was consistent with previous study findings in South Africa(38), African Great lake  
428 Regions(12), Nigeria(19), Northern Ghana(14) and Ethiopia(17). This could be attributed to the

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3 429 disparity in mothers health care access, availability and accessibility of health facilities and  
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5 430 women in urban areas are relatively had improved health-seeking behavior (35) and more aware  
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7 431 of maternal health service but in rural area health facilities may not be easily reachable and may  
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9 432 end up with poor pregnancy outcome during emergency cases (39).

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12 433 This study noted lower odds of stillbirth among women who had primary education as compared  
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14 434 to women with no education. This finding was in line with previous studies done in Kenya(40)  
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16 435 and Nigeria(19). This could be attributed to having maternal education could lead to the  
17  
18 436 corresponding improvement in health-seeking behavior such as the timely decision to seek care  
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20 437 appropriate care during pregnancy, give better care for their health and their fetus, awareness to  
21  
22 438 the danger sign of pregnancy and maternal health service utilization(41).

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24  
25 439 The odds of stillbirth were higher among short stature women. A similar finding was reported in  
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27 440 Pakistan(21). this might be for the reason that short stature women are associated with adverse  
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29 441 pregnancy outcomes like Cephalo pelvic disproportion, contracted pelvis, intra-uterine growth  
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31 442 restriction(IUGR), intra-uterine Fetal death(IUFD) and birth injury hence short stature reflects  
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33 443 longstanding malnutrition or childhood infection that start in utero or during early childhood  
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35 444 this kind of women may end up with poor pregnancy outcome unless we screen them as at-risk  
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37 445 during ANC follow up(42).

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39 446 In addition, having no ANC visit had a significant association with increased stillbirth. This  
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41 447 study could support previous studies done in low-middle countries (43), Ghana(44) and  
42  
43 448 Kenya(40). ANC follow up could help a pregnant woman to seek early treatment for her  
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45 449 potential pregnancy-associated complications, early screening of underlying medical conditions  
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47 450 and may improve birth outcomes by promoting deliveries in health facilities where complications  
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49 451 can be better managed and have access to information related to nutrition, and danger signs of  
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3 452 pregnancy (44, 45). On the other hand, women who did not have longer ANC follow up may not  
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5 453 be benefited from basic ANC packages.  
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8 454 Consistent with studies done in Nigeria based on the 2013 DHS(19) and cross-sectional study in  
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10 455 Gambia(46), cesarean deliveries in this study showed higher odds of stillbirth when compared  
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12 456 with normal vaginal delivery. This may be due to the reason that cesarean sections are probably  
13  
14 457 applied too late in hospital since most of women's are referred from the distant health facility and  
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16 458 there may be delay in referral or transportation problem resulting to not to save the baby's life  
17  
18 459 because the cesarean section is not done with the right time (47, 48).  
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22 460 In this study, having a short inter-pregnancy interval was associated with higher odds of  
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24 461 stillbirth. This was consistent with studies done sub-Saharan Africa (49), Bangladesh (50) and  
25  
26 462 Amhara Region(18). This could be explained by short preceding birth interval are less able to  
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28 463 provide nourishment for the fetus because her body has had less time to recuperate from the  
29  
30 464 previous pregnancy, the uterus had less time to recover and also lactation will deplete maternal  
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32 465 nutrition and may end up with poor pregnancy outcomes (50).  
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37 466 The strength of this study was using weighted data to make it representativeness at national and  
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39 467 regional levels: therefore, it can be generalized to all women who gave birth during the study  
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41 468 period in Ethiopia. Moreover, the use of GIS and SaTScan statistical tests helped to detect  
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43 469 similar and statistically significant hotspot areas of stillbirth and to design effective public health  
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45 470 programs. However, the SaTScan detect only circular clusters, irregular shaped clusters were not  
46  
47 471 detected. Furthermore, the EDHS survey did not incorporate clinically confirmed data rather it  
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49 472 relied on mothers or caregivers report and might have the possibility of social desirability and  
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51 473 recall bias since stillbirth is not culturally acceptable though CSA claim that strong effort was  
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3 474 made to minimize it mainly through extensive training of data collectors, recruiting experienced  
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5 475 data collectors and supervisors this might underestimate our finding.  
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8 476 The findings of this study have valuable policy implications for health program design and  
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10 477 interventions. Stillbirth high-risk areas can be easily identified to make effective local  
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12 478 interventions. In general, these findings are of supreme importance for the minister of health,  
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14 479 regional health bureaus, and NGO's to design intervention programs to reduce stillbirth in  
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16 480 identified hotspot areas.  
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## 19 20 481 **Conclusions**

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23 482 In Ethiopia, stillbirth had spatial variations across the country. Statistically, significant-high  
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25 483 hotspots of stillbirth were found in the central and southern parts of Amhara, west SNNPRs,  
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27 484 south and north Tigray, and south West Somali region. Whereas, cold spot areas were found in  
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29 485 Addis Ababa, central Oromia, and east SNNPRs. Short preceding birth interval, short maternal  
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31 486 stature, ANC visit, rural residence, region, religion, maternal education, and cesarean delivery  
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33 487 were significant predictors of stillbirth.  
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## 36 37 488 **Abbreviations**

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40 489 ANC; Antenatal Care, AOR; Adjusted Odds Ratio, ARR; Annual Rate of Reduction, BMI; Body  
41  
42 490 Mass Index, CI; Confidence Interval, COR; Crude Odds Ratio, CSA; Central Statistical Agency,  
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44 491 DHS; Demographic Health Survey, EA; Enumeration Area, EDHS; Ethiopian Demographic  
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46 492 Health Survey, GIS; Geographic Information System, ICC; Intra-cluster Correlation  
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48 493 Coefficient, IUFD; Intra Uterine Fetal Death, IUGR; Intra Uterine Growth Restriction,  
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50 494 LLR; log-likelihood Ratio, LR; Likelihood Ratio, MOR; Median Odds Ratio, PCV; Proportional  
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3 495 Change in Variance, PHC; Population and Housing census, SBR; Stillbirth Rate, SNNPRs;  
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5 496 Southern Nations and Nationality People Regional state, WHO; World Health Organization.  
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10 497 **Declarations**

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13 498 **Availability of data and materials**

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16 499 Data is available online and you can access it from [www.measuredhs.com](http://www.measuredhs.com).  
17  
18

19 500 **Competing Interests**

20  
21  
22 501 Authors declare that they have no conflict of interest  
23

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25  
26  
27 503 No funding was obtained for this study.  
28  
29

30 504 **Authors' contribution**

31  
32  
33 505 Conceptualization: Getayeneh Antehunegn Tesema

34  
35 506 Data curation: Getayeneh Antehunegn Tesema

36  
37 507 Funding acquisition: Getayeneh Antehunegn Tesema

38  
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41 509 Methodology: Getayeneh Antehunegn Tesema, Lemma Derseh, Solomon Gedlu

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45 511 Resources: Getayeneh Antehunegn Tesema, Lemma Derseh, Solomon Derseh

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3 515 Visualization: Getayeneh Antehunegn Tesema, Lemma Derseh, Solomon Derseh  
4

5 516 Writing: Getayeneh Antehunegn Tesema  
6

7  
8 517 Writing – review and editing: Getayeneh Antehunegn Tesema, Lemma Derseh, Solomon Derseh  
9

## 10 518 **Consent for publication**

11  
12  
13 519 Not applicable  
14  
15

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17  
18  
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20  
21

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25 637 Table 1: Sociodemographic characteristics of women who gave birth within 5 years before the  
26  
27 638 survey in Ethiopia, 2016.

Variables	Category	Unweighted frequency (%)	Weighted frequency (%)
Residence	Urban	1,994 (18.0)	1,226 (10.8)
	Rural	9,091 (82.0)	10,149 (89.2)
Region	Tigray	1,021 (9.2)	709 (6.2)
	Afar	1,102 (9.9)	119 (1.0)
	Amhara	1,004 (9.1)	2,122 (18.7)
	Oromia	2,617 (23.6)	5,280 (46.4)
	Somali	1,623 (14.6)	554 (4.9)
	Benishangul Gumuz	962 (8.7)	133 (1.2)
	SNNPR	1,334 (12.0)	2,402 (21.1)
	Gambella	789 (7.1)	29 (0.3)

	Harari	633 (5.7)	27 (0.2)
Religion	Orthodox	3,127 (28.2)	3,844 (33.8)
	Muslim	5,710 (51.5)	4,696 (41.3)
	Catholic and protestant	2,248 (20.3)	2,835 (24.9)
Maternal education	No education	7,241 (65.3)	7,606 (66.9)
	Primary education	2,708 (24.4)	2,961 (26.0)
	Secondary and higher education	1,136 (10.3)	808 (7.1)
Maternal age	<20 year	395 (3.6)	374 (3.3)
	20-29 year	5,556 (50.1)	5,599 (49.2)
	30-39 year	4,234 (38.2)	4,381 (38.5)
	≥40 year	900 (8.1)	1,021 (9.0)
Husband education	No education	5,331 (51.2)	5,339 (49.6)
	Primary education	3,260 (31.3)	4,139 (38.5)
	Secondary and higher education	1,817 (17.5)	1,284 (11.9)
Maternal occupation status	Had occupation	6,584 (59.4)	6,352 (55.8)
	No occupation	4,501 (40.6)	5,023 (44.2)
Wealth status	Poor	6,081 (54.9)	5,360 (47.1)
	Middle	1,512 (13.6)	2,318 (20.4)
	Rich	3,492 (31.5)	3,697 (32.5)



639 Table 2: pregnancy and health service-related characteristics of women who gave birth within 5  
 640 years preceding the survey in Ethiopia, 2016.

Variable	Category	Unweighted frequency (%)	Weighted frequency (%)
Pregnancy and maternal service-related factors			
Place of delivery	Home	6,737 (60.8)	7,468 (65.7)
	Health facility	4,348 (39.2)	3,907 (34.3)
Parity	Only one birth	1,435 (13.0)	1,419 (12.5)
	2-4 birth	5,042 (45.5)	5,022 (44.1)
	≥5 birth	4,608 (41.5)	4,934 (43.4)
Birth order	1-3	5,806 (52.4)	5,703 (50.1)
	4-5	2,584 (23.3)	2,655 (23.4)
	≥6	2,695 (24.3)	3,017 (26.5)
BMI	Thin	2,981 (26.9)	2,483 (21.8)
	Normal	7,106 (64.1)	8,164 (71.8)
	Overweight	998 (9.0)	728 (6.4)
Maternal height	< 150 cm	1,018 (9.2)	1,228 (10.8)
	≥150 cm	10,067 (90.8)	10,147 (89.2)
ANC visit	No ANC visit	2,321 (20.9)	2,602 (22.9)
	1-3 ANC visit	1,917 (17.3)	2,145 (18.9)
	≥ 4 ANC visit	6,847 (61.8)	6,628 (58.2)
Preceding birth interval	< 24 month	2,347 (21.2)	2,145 (18.9)
	≥24 month	8,738 (78.8)	9,230 (81.1)

Maternal anemia	Not anemic	6,696 (60.4)	7,590 (66.7)
	Anemic	4,389 (39.6)	3,785 (33.3)
Ever use of contraceptive	Yes	4,101 (37.0)	5,238 (46.0)
	No	6,984 (63.0)	6,137 (54.0)
Mode of delivery	Vaginal delivery	10,813 (97.5)	11,181 (98.3)
	Cesarean delivery	272 (2.5)	194 (1.7)
Number of gestation	Single	10,798 (97.4)	11,072 (97.3)
	Twin	287 (2.6)	303 (2.7)
Behavioral and community-level factors			
Smoking cigarettes	Yes	10,976 (99.0)	11,286 (99.2)
	No	109 (1.0)	89 (0.8)
Media exposure	Yes	9,747 (87.9)	10,020 (88.1)
	No	1,338 (12.1)	1,355 (11.9)
Community media exposure	Lower	5,503 (49.6)	4,640 (40.8)
	Higher	5,582 (50.4)	6,735 (59.2)
Community poverty	Lower	6,909 (62.3)	7,617 (67.0)
	Higher	4,176 (37.7)	3,758 (33.0)
Community ANC utilization	Lower	5,387 (48.6)	6,665 (58.6)
	Higher	5,698 (51.4)	4,710 (41.4)
Community women education	Lower	6,909 (62.3)	7,617 (67.0)
	Higher	4,176 (37.7)	3,758 (33.0)

641 Table 3: SaTScan analysis results of stillbirth in Ethiopia, 2016.

Cluster	Enumeration area(cluster)identified	Coordinate/radius	Population	Case	RR	LLR	p-value
1	497, 95, 198, 521, 588, 553, 458, 171, 214, 251, 573, 239, 116, 22, 543, 490, 492, 92, 568, 33, 277, 527	(7.829198 N, 43.706264 E) / 166.48 km	532	17	22.5	13.4	0.00069
2	350, 229, 482, 531, 218, 510, 206, 10, 474, 267, 375, 423, 120, 176, 572, 517, 460, 24, 403, 429, 38, 3, 485, 456, 274, 167, 463, 112, 399, 532	(10.195460 N, 38.150574 E) / 142.05 km	384	14	3.6	8.84	0.04
3	564, 39, 230, 51	(9.555410 N, 40.326165 E) / 34.04 km	50	4	8.83	8.55	0.05

642 Table 4: Multivariable multilevel logistic regression analysis result of both individual and  
643 community-level factors associated with stillbirth in Ethiopia, EDHS 2016

Individual and community- level characteristics	Null model	Model II AOR (95% CI)	Model III AOR (95% CI)	Model IV AOR (95% CI)
<b>Residence</b>				
Urban			1	1
Rural			3.75[1.33, 10.56]	4.83[1.44, 16.19]*
<b>Region</b>				

1			
2			
3	Amhara	1	1
4			
5	Tigray	0.54[0.18, 1.63]	0.63[0.19, 2.17]
6			
7	Afar	0.28[0.08, 0.94]	0.24[0.05, 1.06]
8			
9	Oromia	0.20[0.07, 0.55]	0.25[0.07, 0.83]*
10			
11	Somali	0.84[0.32, 2.21]	0.98[0.27, 3.56]
12			
13	Benishangul Gumuz	0.25[0.07, 0.92]	0.37[0.09, 1.53]
14			
15	SNNPR	0.21[0.06, 0.69]	0.56[0.14, 2.18]
16			
17	Gambella	0.26[0.06, 1.07]	1.02[0.20, 5.22]
18			
19	Harari	0.71[0.19, 2.63]	0.77[0.16, 3.72]
20			
21			
22	<b>Religion</b>		
23			
24	Orthodox	1	1
25			
26	Muslim	0.59[0.31, 1.12]	0.75[0.32, 1.77]
27			
28	Protestant/catholic	0.12[0.04, 0.35]	0.11[0.03, 0.37]**
29			
30			
31	<b>Wealth status</b>		
32			
33	Poor	1.12[0.60, 2.11]	0.87[0.45, 1.69]
34			
35	Middle	1.58[0.78, 3.19]	1.21[0.60, 2.47]
36			
37	Rich	1	1
38			
39	<b>Women's education</b>		
40			
41	No education	1	1
42			
43	Primary education	0.39[0.21, 0.75]	0.39[0.20, 0.74]**
44			
45	Secondary and higher education	0.49[0.18, 1.33]	0.63[0.23, 1.71]
46			
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53	<b>Birth order</b>		
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3	1-3	1
4		1
5	4-5	0.49[0.24, 1.03]
6		0.50[0.24, 1.03]
7	6 and above	0.66[0.25, 1.75]
8		0.66[0.25, 1.73]
9		
10	<b>Parity</b>	
11		
12	Only one birth	1
13		1
14	2-4 birth	0.68[0.37, 1.28]
15		0.65[0.35, 1.22]
16	≥ 5 birth	0.45[0.16, 1.28]
17		0.42[0.15, 1.20]
18		
19	<b>ANC visit</b>	
20		
21	No ANC visit	2.85[1.76, 4.62]
22		2.77[1.70, 4.51]**
23		
24	1-3 visit	1.22[0.68, 2.19]
25		1.11[0.62, 2.00]
26	4 and above visit	1
27		1
28		
29	<b>Media exposure</b>	
30		
31	Yes	1
32		1
33	No	2.11[0.85, 5.24]
34		1.63[0.66, 4.04]
35		
36	<b>Maternal height</b>	
37		
38	< 150 cm	2.66[1.47, 4.79]
39		2.73[1.50, 4.97]**
40	≥ 150 cm	1
41		1
42		
43	<b>Contraceptive use</b>	
44		
45	Yes	0.74[0.43, 1.26]
46		0.72[0.41, 1.24]
47	No	1
48		1
49	<b>Preceding birth interval</b>	
50		
51	< 24 month	1.92[1.19, 3.07]
52		1.93[1.20, 3.10]**
53		
54	≥ 24 month	1
55		1

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2				
3	<b>Mode of delivery</b>			
4				
5	Vaginal delivery	1		1
6				
7	Cesarean delivery	4.00[1.35, 11.85]		5.07[1.65, 15.58]**
8				
9				
10	<b>Community media</b>			
11				
12	<b>exposure</b>			
13				
14	Lower community exposure		1	1
15				
16	Higher community exposure		0.96[0.51, 1.80]	1.02[0.51, 2.04]
17				
18				
19	<b>Community women's</b>			
20				
21	<b>education</b>			
22				
23				
24	Lower community education		1	1
25				
26	Higher community education		1.28[0.61, 2.71]	1.88[0.80, 4.42]
27				
28	<b>Constant</b>	0.003[0.002, 0.005]	0.003[0.001,	0.002[0.0005, 0.0096]
29			0.01]	0.001[0.0002, 0.01]
30				
31				
32				
33	<b>Model comparison and</b>			
34				
35	<b>Random effects</b>			
36				
37	ICC	0.47(0.35, 0.59)		
38				
39	Log-likelihood	-599.02	-551.2	-584.36
40				-540.50
41				
42	Deviance	1198.04	1102.2	1168.72
43				1081
44	PCV	Ref	21.5	9.3
45				15.3
46	MOR	5.03[3.19, 7.13]	5.91[3.44, 8.90]	4.66[2.84, 6.69]
47				5.69[3.31, 8.56]
48				

644 \*AOR; Adjusted Odds Ratio, CI; Confidence Interval, ICC; Intra-class Correlation, MOR;

645 Median Odds Ratio, PCV; Proportional Change in Variance.

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3 **647 Figure legends**

4 648 Figure 1: Map of the study area

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7 649 Figure 2: The rate of stillbirth among reproductive age women across regions in Ethiopia, 2016

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9 650 Figure 3: Spatial distribution of stillbirth among women in Ethiopia, 2016

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11 651 Figure 4: Incremental spatial autocorrelation

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13 652 Figure 5: Global spatial autocorrelation of stillbirth among women in Ethiopia, 2016

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15 653 Figure 6: Cluster and outlier analysis of stillbirth among women in Ethiopia, 2016

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17 654 Figure 7: Getis Ord  $G_i^*$  Statistical hotspot analysis of stillbirth in Ethiopia, 2016

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19 655 Figure 8: Kriging interpolation of stillbirth among women in Ethiopia, 2016

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21 656 Figure 9: SaTScan analysis of hotspot areas of stillbirth in Ethiopia, 2016

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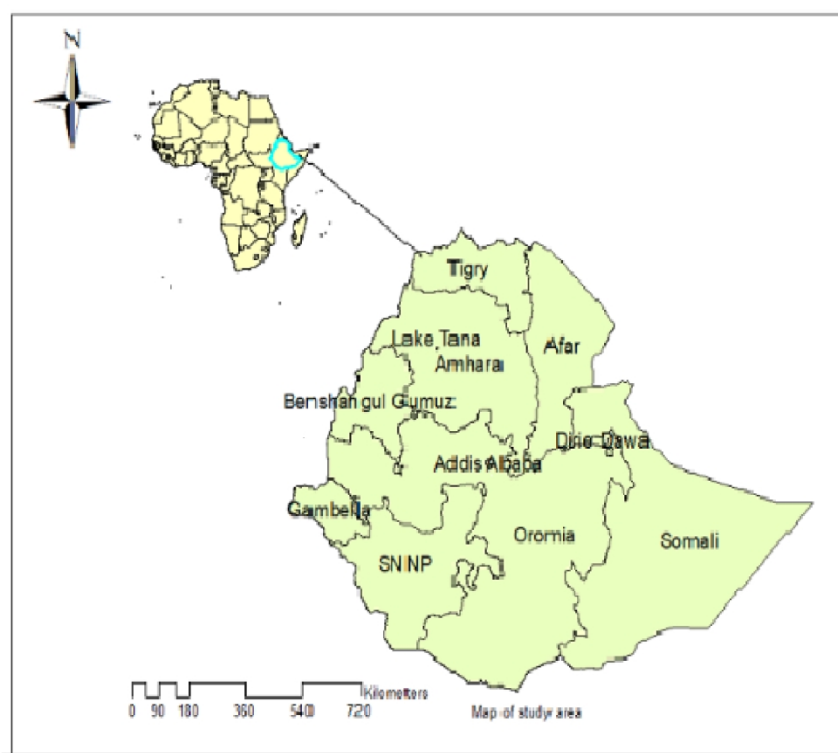


Figure 1: Map of the study area

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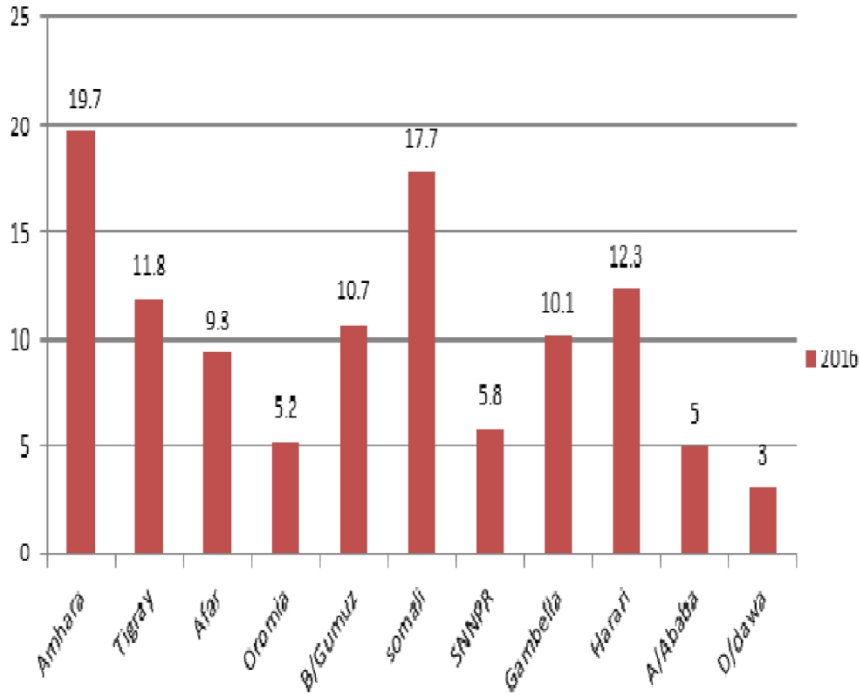


Figure 2: The rate of stillbirth among reproductive-age women across regions in Ethiopia, 2016  
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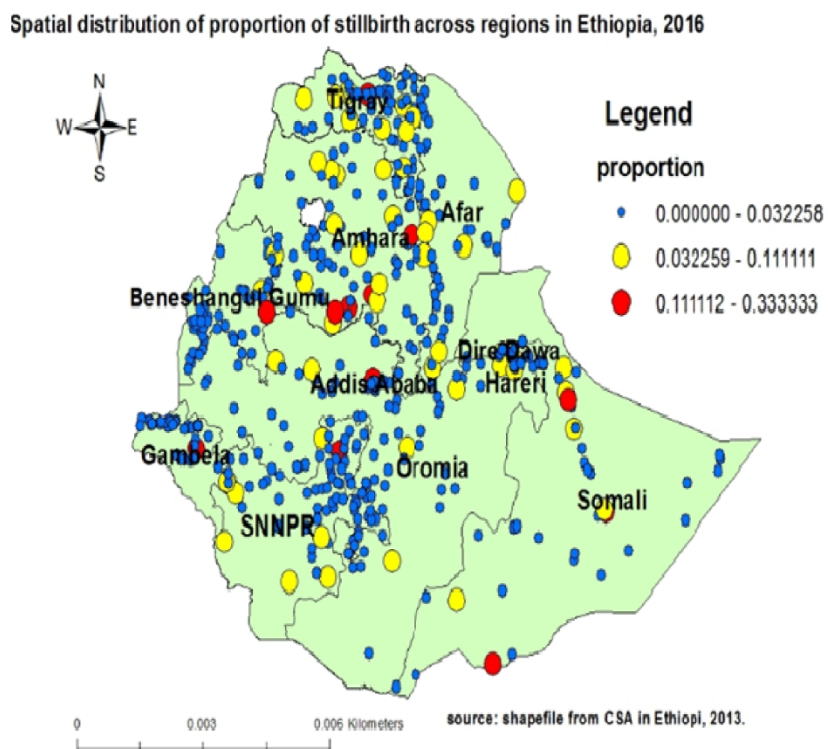


Figure 3: Spatial distribution of stillbirth among women in Ethiopia, 2016

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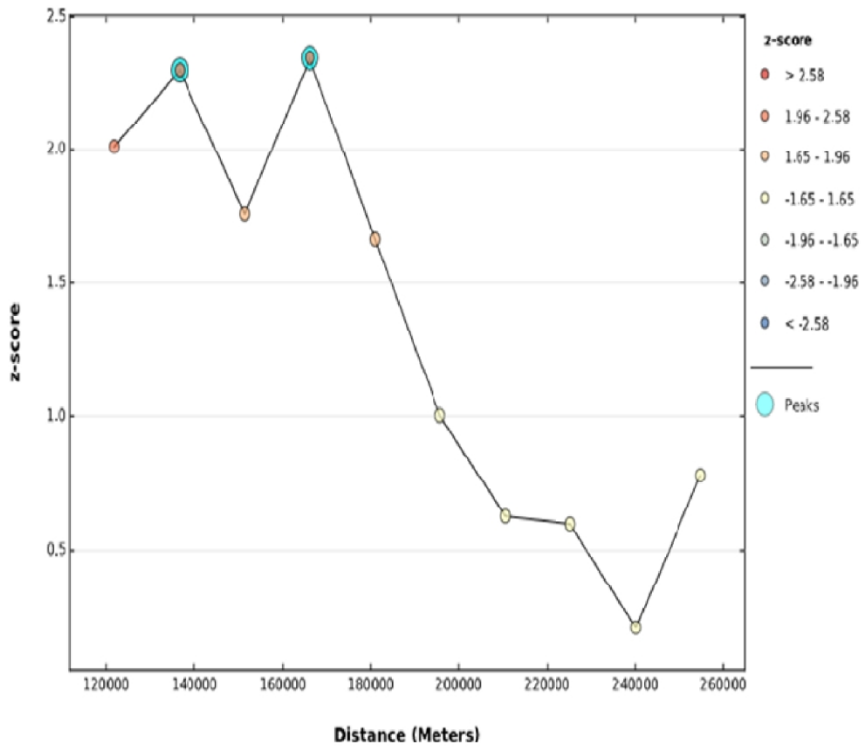


Figure 4: Incremental spatial autocorrelation  
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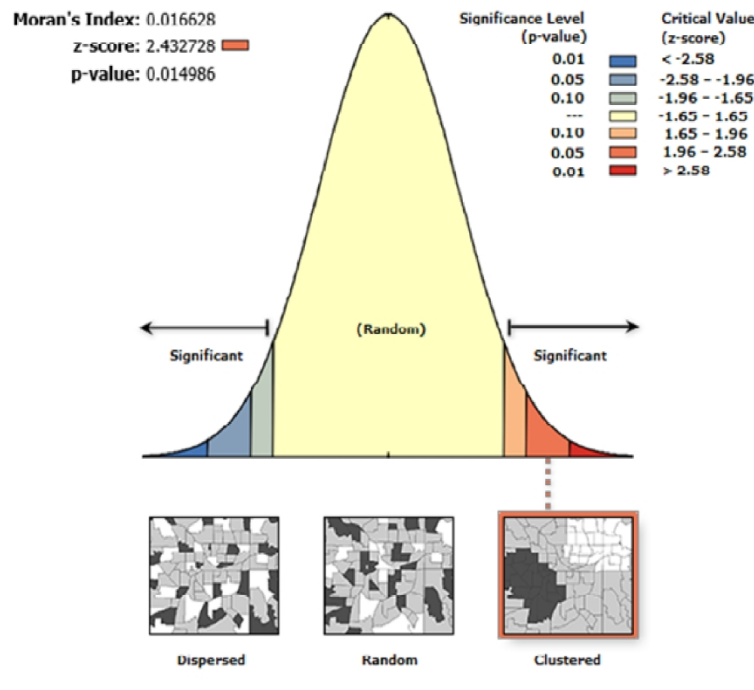


Figure 5: Global spatial autocorrelation of stillbirth among women in Ethiopia, 2016

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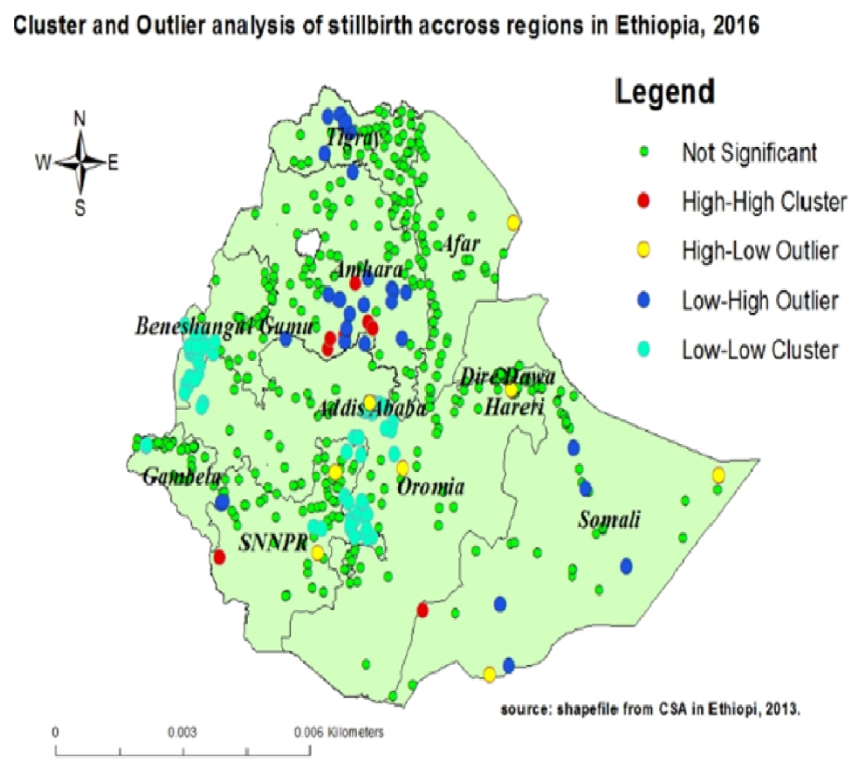


Figure 6: Cluster and outlier analysis of stillbirth among women in Ethiopia, 2016  
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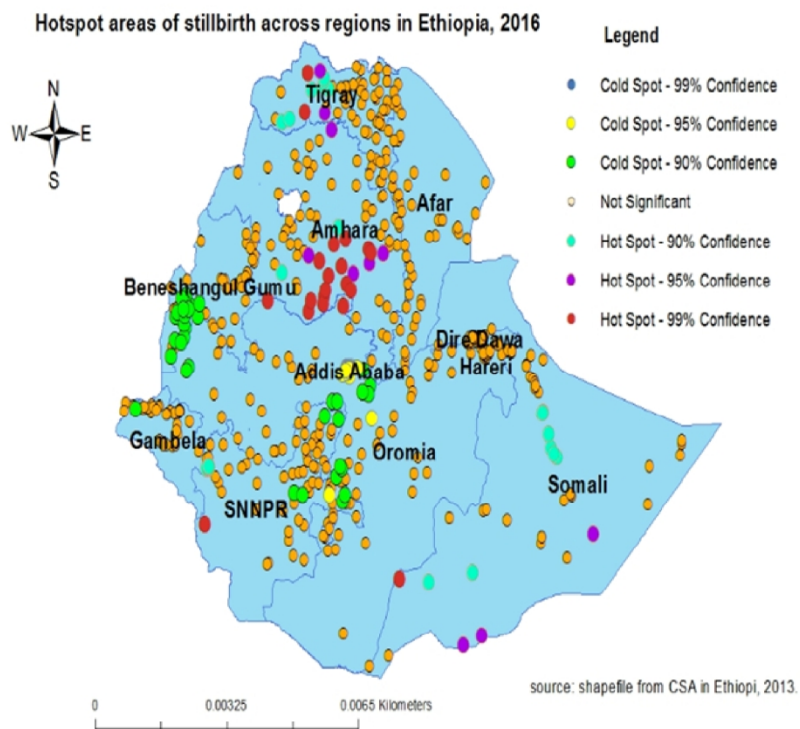


Figure 7: Getis Ord  $G_i^*$  Statistical hotspot analysis of stillbirth in Ethiopia, 2016

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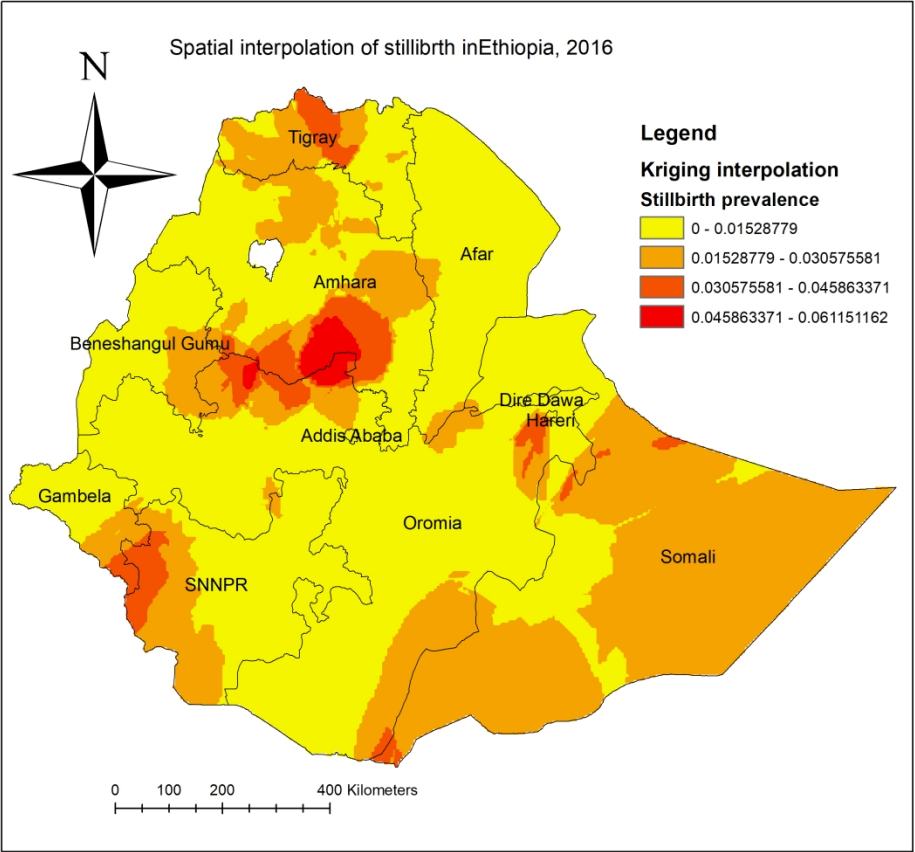


Figure 8: Kriging interpolation of stillbirth among women in Ethiopia, 2016  
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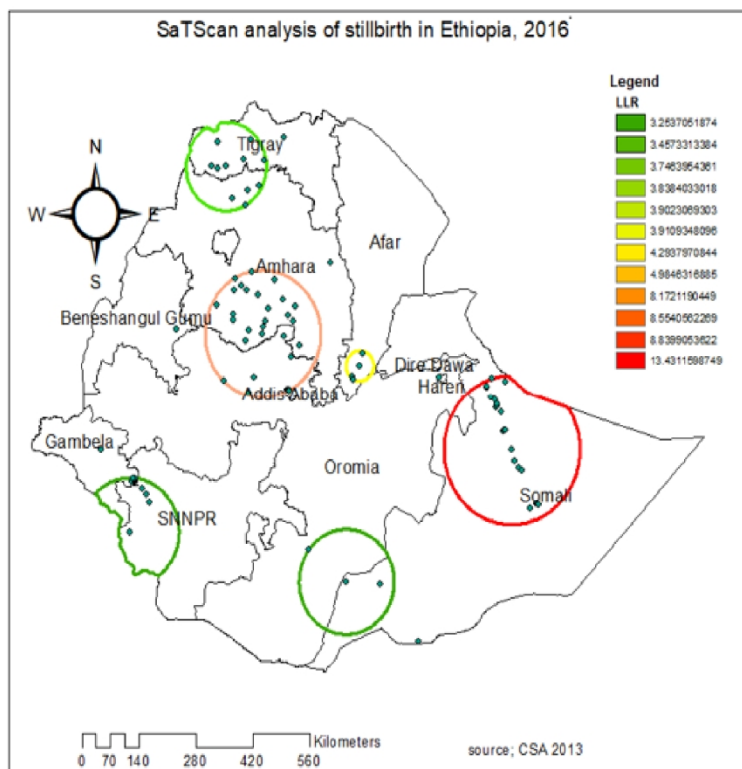


figure 9: SaTScan analysis of hotspot areas of stillbirth in Ethiopia, 2016

215x279mm (300 x 300 DPI)



# BMJ Open

## Spatial distribution of stillbirth and associated factors in Ethiopia: Spatial and Multilevel Analysis

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3 **1 Spatial distribution of stillbirth and associated factors in Ethiopia: Spatial**  
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6 **2 and Multilevel Analysis**  
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## 16 Abstract

17 **Objective:** Although stillbirth rates have been reduced globally, it is still very high in developing  
18 countries. So far, only ten countries carry the burden of over 65% of stillbirths in the world  
19 including Ethiopia in the seventh position. Exploring the spatial distribution is important to  
20 monitor and design effective intervention programs but there is no available study on spatial  
21 distribution and factors associated with a stillbirth at the national level. Therefore, this study  
22 aimed to explore the spatial distribution, and associated factors of stillbirths.

23 **Methods:** Secondary data analysis was conducted based on the 2016 Ethiopian Demographic  
24 and Health Survey data. Weighted samples of 11,375 women were included for analysis. The  
25 Bernoulli model was fitted using spatial scan statistics version 9.6 to identify hotspot areas and  
26 ArcGIS version 10.6 to explore the spatial distribution of stillbirths. For associated factors, a  
27 multilevel logistic regression model that accounts for the hierarchical structure of the data was  
28 fitted using STATA 14.

29 **Result:** There were significant variations of stillbirth across regions of Ethiopia. The SaTScan  
30 spatial analysis identified primary clusters in the Northeast Somali region (LLR=13.4,  $p<0.001$ )  
31 while the secondary cluster was detected in the border area between Oromia and Amhara regions  
32 (LLR=8.8,  $p<0.05$ ). Rural residence (AOR=4.83, 95%CI:1.44-16.19), primary education  
33 (AOR=0.39, 95%CI:0.20-0.74), not having ANC visit(AOR=2.77, 95%CI:1.70-4.51), caesarean  
34 delivery (AOR=5.07, 95%CI: 1.65-15.58), birth interval <24 month (AOR=1.95, 95%CI:  
35 1.20,3.10), and height<150 cm(AOR=2.73, 95%CI:1.45-4.97) were significant predictors of  
36 stillbirths.

37 **Conclusion and recommendation:** In Ethiopia, stillbirths had significant spatial variations  
38 across the country. Residence, maternal stature, preceding birth interval, cesarean delivery,

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3 39 education, and ANC visit were significant predictors of stillbirth. This could have public health  
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5 40 implications to target interventions to identified hotspot areas of stillbirth and the government  
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7  
8 41 should scale up maternal health programs in rural areas  
9

10 42 **Keywords:** stillbirth, Ethiopia, multilevel logistic regression, spatial analysis  
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12 43

### 16 44 **Strength and limitation of the study**

- 19 45 • The study used national survey by weighted the data since some regions were oversampled  
20  
21 46 and some under-sampled to make it nationally representative, the study has the potential to  
22  
23 47 inform policy-makers, planners and programmers, to design appropriate intervention at  
24  
25 48 national and regional levels
- 28 49 • As a study was a cross-sectional study, the study is unable to show a temporal relationship.  
30  
31 50 However, our method used multilevel modeling which took into account the effect of  
32  
33 51 clustering to get reliable estimates and standard error.
- 35 52 • The EDHS survey did not incorporate clinically confirmed data rather it relied on mothers or  
36  
37 53 caregivers report
- 40 54 • The study was based on self-reports of respondents. Therefore, it may have the possibility of  
41  
42 55 social desirability and recall bias
- 44 56 • The SaTScan detect only circular clusters, irregularly shaped clusters were not detected

## 57 BACKGROUND

58 The World Health Organization (WHO) defines stillbirth as fetal death (death before the  
59 complete expulsion or extraction of a product of conception from its mother) in the third  
60 trimester ( $\geq 28$  completed weeks of gestation) or birth weight  $\geq 1000$  grams or length  $\geq 35$   
61 centimeters (1, 2). Globally, stillbirth is a huge public health concern, especially in Sub-Saharan  
62 Africa (SSA) and South Asia (SA) including Ethiopia(3). Around 2.6 million stillbirths occur  
63 annually, 98% of which occur in developing countries(4). An overwhelming majority (67%) of  
64 the world's stillbirth occurred in SSA and SA, and most of the stillbirths occur during the intra-  
65 partum period which is preventable by improving obstetrics services(5).

66 More than half of the 2.6 million stillbirths occur during labor and delivery (6) and is considered  
67 as an indicator of access to and quality of obstetric care(7). According to the most recent global  
68 estimate of WHO, the average global stillbirth rates were 18.4 per 1000 births(8), while  
69 developing countries have the stillbirth rates ten-fold higher than developed countries(9). Sub-  
70 Saharan Africa has the highest stillbirth rate of 28.3 per 1000 births(10). Stillbirth rates have been  
71 varied across countries and remain a huge challenge to achieve Every Newborn Action Plan  
72 (ENAP) of the target of 12 or fewer stillbirths per 1000 births in every country by 2030(1). Even  
73 though many high-income countries and upper-middle-income countries have already met this  
74 target, developing countries particularly Africa will have to more than double present progress to  
75 reach this target(1).

76 Despite the various international and national commitments on improving newborn and maternal  
77 health (11), stillbirth has been grossly under-reported and invisible in policies and programs  
78 worldwide(12). Like many countries in SSA, stillbirth is not routinely recorded and monitored in  
79 Ethiopia. Stillbirth has been reduced more slowly than maternal mortality or under 5 mortality,

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3 80 which remains invisible in global policies with an Annual Average Rate of Reduction (ARR) of  
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5 81 2.0% in comparison to ARR of 3.0% for maternal death or 3.1% for neonatal death(13). The  
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7  
8 82 death of a fetus in uterus or at birth is a devastating experience for the affected mothers and  
9  
10 83 families(14). It has been associated with extensive psychosocial consequences for parents and  
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12 84 family and has been linked to post-traumatic stress disorder, anxiety, depression, suicide, fear of  
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15 85 the next pregnancy and reduced relation with their partner(15, 16).

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17 86 In Ethiopia, a study conducted based on Ethiopian Demographic and Health Survey (EDHS)  
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19  
20 87 2011 revealed that a stillbirth rate of 25.5 per 1000 births with significant variability across  
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22 88 regions and the researchers recommended conducting spatial analysis to investigate the spatial  
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24 89 variability of experiencing stillbirth in Ethiopia(17). A study done at the Amhara region based on  
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26  
27 90 Ethiopian Mini Demographic and Health Survey 2014 reported that stillbirth rates of 85 per 1000  
28  
29 91 births(18). Different studies done on experiencing stillbirth showed that rural residence, parity,  
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31 92 educational status, mode of delivery, ANC utilization, and place of delivery, maternal nutritional  
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33  
34 93 status, and maternal obstetric factors were the significant predictors of experiencing stillbirth (14,  
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36 94 19-21).

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39 95 There is a wide gap of stillbirth rates not only among different countries but also within the  
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41 96 country(17, 22). A high rate of stillbirths has been reported among rural, poor and marginalized  
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43 97 societies that are the least beneficial of maternal health promotion activities and  
44  
45 98 services(12). Thus, the identification of geographic areas with a high rate of stillbirth using  
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48 99 Geographic Information System (GIS) and Spatial Scan statistical analysis (SaTScan) has  
49  
50 100 become fundamental to guide targeted public health interventions. However, previous studies in  
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52 101 Ethiopia have been focused on the prevalence and associated factors of stillbirth (18, 23, 24), by  
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55 102 using standard logistic regression models despite the hierarchical structure of EDHS data. These

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3 103 could result in a biased estimate since the data is nested within-cluster and violates the  
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5 104 independent assumption (17). The findings of these studies are insufficient and limited to capture  
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7  
8 105 the spatial distribution of stillbirth and community-level factors contributing to stillbirth.  
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10 106 Therefore, the current study attempts to explore the spatial distribution and associated factors of  
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12 107 stillbirth in Ethiopia using Spatial and multilevel Analysis.  
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## 15 108 **Method and materials**

### 16 17 18 109 **Study design, setting and period**

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21 110 A community-based cross-sectional study was conducted from January 18 to June 27, 2016. The  
22  
23 111 study was conducted in Ethiopia, which is situated in the Horn of Africa. It has 9 Regional states  
24  
25 112 (Afar, Amhara, Benishangul-Gumuz, Gambela, Harari, Oromia, Somali, Southern Nations,  
26  
27 113 Nationalities, and People's Region (SNNP) and Tigray) and two Administrative Cities (Addis  
28  
29 114 Ababa and Dire-Dawa). In Ethiopia, 84% of the population lives in rural areas and more than 80  
30  
31 115 percent of the country's total population lives in the regional states of Amhara, Oromia, and  
32  
33 116 SNNP(25).Ethiopia is the13<sup>th</sup> in the world and 2<sup>nd</sup> in Africa's most populous country. The  
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37 117 number of hospitals varies from region to region in response to differences in population size  
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39 118 (26).  
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### 43 119 **Sample and population**

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45  
46 120 The source population was all births from reproductive age women within five years before the  
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48 121 survey in Ethiopia, whereas all births from reproductive-age women in the selected enumeration  
49  
50 122 areas within five years before the survey were the study population. The EDHS used a stratified  
51  
52 123 two-stage cluster sampling technique selected in two stages using 2007 the Population and  
53  
54 124 Housing Census as a sampling frame. Stratification was achieved by separating each region into  
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3 125 urban and rural areas. In total, 21 sampling strata have been created. In the first stage, 645 EAs  
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5 126 (202 in the urban area) were selected with probability proportional to the EA size and with  
6  
7 127 independent selection in each sampling stratum. In the second stage, on average 28 households  
8  
9 128 were systematically selected. The detailed sampling procedure was presented in the full EDHS  
10  
11 129 2016 report (27).

## 15 130 **Study variables**

### 18 131 *Outcome variables*

21 132 2016 Ethiopian Demographic and Health Survey (EDHS) asked women to report any pregnancy  
22  
23 133 loss that occurred in the five years preceding the survey. For each pregnancy that did not end in a  
24  
25 134 live birth, the duration of the pregnancy was recorded. Pregnancy losses occurring after seven  
26  
27 135 completed months of gestation were considered as stillbirth (28). The response variable of this  
28  
29 136 study was the occurrence of stillbirth among mothers of childbearing age. The response variable  
30  
31 137 for the  $i^{\text{th}}$  mother is represented by a random variable  $Y_i$  with two possible values coded as 1 and  
32  
33 138 0. So, the response variable of the  $i^{\text{th}}$  mother  $Y_i$  was measured as a dichotomous variable with  
34  
35 139 possible values  $Y_i = 1$ , if  $i^{\text{th}}$  mother had experienced stillbirth and  $Y_i = 0$  if mother had a live  
36  
37 140 birth.

### 42 141 *Independent variables*

44 142 Consistent with the objective of the study and given the hierarchical structure of EDHS data  
45  
46 143 where women were nested within the cluster/community, two levels of independent variables  
47  
48 144 were considered. Level 1 contained individual socio-demographic and economic factors (Age,  
49  
50 145 marital status, religion, maternal education, paternal education, wealth index, maternal  
51  
52 146 occupation, maternal working Status), pregnancy and pregnancy-related factors (Mother's  
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54 147 height, BMI, ANC visit, Parity, Preceding birth interval, contraceptive use, Place of delivery,  
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3 148 Birth order, Mode of delivery, wanted pregnancy, Maternal anemia), and behavioral factors  
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5 149 (Smoking, media exposure). The community-level factors(region, residence, community women  
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7  
8 150 education, community poverty, community media exposure, and community ANC utilization) at  
9  
10 151 level 2, which included the characteristics of the community in which each woman resided. In  
11  
12 152 EDHS data no variable describes the cluster except region and place of residence. Therefore,  
13  
14  
15 153 Individual-level variables were aggregated at the cluster level to generate community-level  
16  
17 154 variables to see whether cluster-level variables had an effect on stillbirth and which were  
18  
19 155 categorized by their proportion as higher or lower based on national median value since it was  
20  
21 156 not normally distributed. Community-level variables used in the analysis were from two sources;  
22  
23  
24 157 direct community-level variables that were used without any manipulation and aggregated  
25  
26 158 community-level variables that were generated by aggregating individual-level variables at the  
27  
28 159 cluster level.

### 31 160 **Data collection procedure**

32  
33  
34 161 The study was conducted based on EDHS data and geographic coordinate data by accessing the  
35  
36 162 data from the DHS program official database [www.measuredhs.com](http://www.measuredhs.com) after permission was  
37  
38  
39 163 granted through an online request by explaining the objective of our study. We used the EDHS  
40  
41 164 2016 birth data (BR) set for the study. Geographic coordinate data (longitude and latitude  
42  
43  
44 165 coordinates) were taken at the cluster level/ enumeration area level.

### 46 166 **Data management and analysis**

47  
48  
49 167 The data were weighted using sampling weight, primary sampling unit, and strata before any  
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52 168 statistical analysis to restore the representativeness of the survey and to take into account the  
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169 sampling design to get reliable statistical estimates. Descriptive and summary statistics were  
170 conducted using STATA version 14 software.

171 In EDHS data, women are nested within a cluster and we expect that women within the same  
172 cluster may be more similar to each other than women in the rest of the country. This violates the  
173 assumption of the traditional regression model which is the independence of observations and  
174 equal variance across clusters. This implies that the need to take into account the between cluster  
175 variability by using an advanced model. Therefore, a multilevel random intercept logistic  
176 regression model was fitted to estimate the association between the individual and community  
177 level variables and the likelihood of experiencing stillbirth. Model comparison was done based  
178 on Deviance(The negative 2 log-likelihood (-2LL)) since the models were nested. Likelihood  
179 ratio test, ICC (Intra-class correlation), MOR (median odds ratio) and PCV (proportional change  
180 in variance) were computed to measure the variation between clusters. The intra-class  
181 correlation coefficient (ICC) quantifies the degree of heterogeneity of stillbirth between clusters  
182 (the proportion of the total observed individual variation in stillbirth that is attributable to  
183 between cluster variations).

184  $ICC = \frac{\sigma^2}{(\sigma^2 + \pi^2/3)}$ (29), but MOR is quantifying the variation or heterogeneity in outcomes  
185 between clusters and is defined as the median value of the odds ratio between the cluster at high  
186 risk of stillbirth and cluster at lower risk when randomly picking out two clusters (EAs).

187  $MOR = \exp(\sqrt{2 * \partial^2 * 0.6745}) \sim MOR = \exp(0.95 * \partial)$ (30)

188  $\partial^2$  indicates that cluster variance

189 PCV measures the total variation attributed to individual-level factors and community-level  
190 factors in the multilevel model as compared to the null model.

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3 191  $PCV = \frac{\text{var}(\text{null model}) - \text{var}(\text{full model})}{\text{var}(\text{null model})}$   
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5  
6 192  $\text{Var}(\text{null model})$   
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8  
9 193 Multilevel random intercept logistic regression was used to analyze factors associated with a  
10  
11 194 stillbirth at two levels to take into account the hierarchical structure of the data, at individual and  
12  
13 195 community (cluster) levels. Four models were constructed for the multilevel logistic regression  
14  
15 196 analysis. The first model (a multilevel random intercept logistic regression model without  
16  
17 197 covariates) was an empty model without any explanatory variables, to determine the extent of  
18  
19 198 cluster variation on stillbirth. The second model (determined the association between the  
20  
21 199 individual level predictors and stillbirth) was adjusted with individual-level variables; the third  
22  
23 200 model (determined the association between community-level predictors and stillbirth) was  
24  
25 201 adjusted for community-level variables while the fourth (individual and community level model)  
26  
27 202 was fitted with both individual and community level variables simultaneously. The final model(a  
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29 203 model with individual and community level factors) was chosen since it had the lowest deviance.  
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34 204 Variables with p-value  $\leq 0.2$  in the bi-variable analysis for both individual and community-level  
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36 205 factors were fitted in the multivariable model. Adjusted Odds Ratio (AOR) with a 95%  
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38 206 Confidence Interval (CI) and p-value  $< 0.05$  in the multivariable model were used to declare  
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40 207 significant predictors of stillbirth. Multi-collinearity was also checked using the variance  
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42 208 inflation factor (VIF) which indicates that there is no multi-collinearity since all variables have  
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44 209  $VIF < 5$  and tolerance greater than 0.1.  
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49 210 ***Spatial analysis***  
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52 211 For the spatial analysis ArcGIS version 10.6 software and SaTScan version 9.6 software.  
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54 212 Incremental spatial autocorrelation was done to get the maximum peak distance where stillbirth  
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3 213 clustering is pronounced. It measures spatial autocorrelation for a series of distances and creates  
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5 214 a line graph of those distances and their corresponding Z-score. Z-scores reflect the intensity of  
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7 215 spatial clustering and statistically significant peak Z-scores. Z-scores indicate where the spatial  
8  
9 216 clustering of stillbirth is more pronounced. The maximum peak distance is the distance where  
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11 217 maximum spatial autocorrelation occurs and this was used as a distance band for hotspot  
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13 218 analysis. Totally 10 distance bands were detected by a beginning distance of 121,803 meters, the  
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15 219 first peak of 136,586.06 meters and the maximum peak (clustering) was observed at  
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17 220 166152.17meters. The maximum peak was used as the distance band for the hotspot analysis.  
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### 22 ***Spatial autocorrelation analysis***

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24  
25 222 The spatial autocorrelation (Global Moran's I) was done to test whether there is spatial clustering  
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27 223 of stillbirth or not. It is a statistic that measures whether stillbirth patterns were dispersed,  
28  
29 224 clustered or randomly distributed in the study area(31). Moran's I is a spatial statistics used to  
30  
31 225 measure spatial autocorrelation by taking the entire data set and produce a single output value  
32  
33 226 which ranges from -1 to +1. Moran's I Values close to -1 indicate dispersed, whereas Moran's I  
34  
35 227 close to +1 indicate disease clustered and disease distributed randomly if I value is zero. A  
36  
37 228 statistically significant Moran's I ( $p < 0.05$ ) leads to rejection of the null hypothesis (stillbirth is  
38  
39 229 randomly distributed) and indicates the presence of spatial autocorrelation.  
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### 44 **Hot spot analysis of stillbirth**

45 230 Anselin Local Moran's I used to investigate the local level cluster locations of stillbirth in terms  
46  
47 231 of positively correlated (high-high and low-low) clusters or negatively correlated (high-low and  
48  
49 232 low-high). A positive value for 'I' indicated that a case had neighboring cases with similar  
50  
51 233 values, part of a cluster. A negative value for 'I' indicated that a case was surrounded by cases  
52  
53 234 with dissimilar values an outlier(32).Spatial scan statistical analysis Bernoulli based model was  
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3 236 employed to test for the presence of statistically significant spatial clusters of stillbirth using  
4  
5 237 Kuldorff's SaTScan version 9.6 software. The spatial scan statistic uses a circular scanning  
6  
7 238 window that moves across the study area. Women with stillbirth were taken as cases and those  
8  
9 239 who have live birth as controls to fit the Bernoulli model. The numbers of cases in each location  
10  
11 240 had Bernoulli distribution and the model required data for cases, controls, and geographic  
12  
13 241 coordinates. The default maximum spatial cluster size of <50% of the population was used, as an  
14  
15 242 upper limit, which allowed both small and large clusters to be detected and ignored clusters that  
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17 243 contained more than the maximum limit.  
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22 244 For each potential cluster, a likelihood ratio test statistic and the p-value was used to determine if  
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24 245 the number of observed stillbirth within the potential cluster was significantly higher than  
25  
26 246 expected or not. The scanning window with maximum likelihood was the most likely performing  
27  
28 247 cluster, and the p-value was assigned to each cluster using Monte Carlo hypothesis testing by  
29  
30 248 comparing the rank of the maximum likelihood from the real data with the maximum likelihood  
31  
32 249 from the random datasets. The primary and secondary clusters were identified and assigned p-  
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34 250 values and ranked based on their likelihood ratio test, based on 999 Monte Carlo  
35  
36 251 replications(33).  
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### 41 ***Spatial interpolation***

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44 253 It is very expensive and laborious to collect reliable data in all areas of the country to know the  
45  
46 254 burden of a certain event. Therefore, part of a certain area can be predicted by using observed  
47  
48 255 data using a method called interpolation. The spatial interpolation technique is used to predict  
49  
50 256 stillbirth on the un-sampled areas in the country based on sampled EAs. There are various  
51  
52 257 deterministic and geostatistical interpolation methods. Among all of the methods, ordinary  
53  
54 258 Kriging and empirical Bayesian Kriging are considered the best method since it incorporates the  
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3 259 spatial autocorrelation and it statistically optimizes the weight(34). Ordinary Kriging spatial  
4  
5 260 interpolation method was used for this study for predictions of stillbirth in unobserved areas of  
6  
7  
8 261 Ethiopia.

### 262 **Patient and public involvement statement**

12 263 Patients and public involvement were not involved in this study since we have conducted a  
13  
14  
15 264 secondary data analysis based on already available DHS data which was collected to provide  
16  
17 265 estimates of common health and health-related indicators. For the original project from which  
18  
19 266 data were obtained, patient and public involvement statements were essential since biomarker  
20  
21  
22 267 data such as anemia, HIV testing, and anthropometric measurements were collected(35).  
23  
24

### 268 **Ethical consideration**

28 269 Ethical clearance was obtained from the Institutional Review Board of Institute of Public Health,  
29  
30 270 CMHS, and the University of Gondar. Permission for data access was obtained from major  
31  
32 271 demographic and health survey through an online request from <http://www.dhsprogram.com>.  
33  
34  
35 272 The data used for this study were publicly available with no personal identifier.  
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## 274 **Result**

### 275 **Socio-demographic and economic characteristics of respondents**

276 A total of 11,375 women who gave birth within five years preceding the survey were included  
277 for the analysis. Of 11,375 of women, 10,149 (89.2%) were rural residents and half of the  
278 respondent were in the age group 20-29 years. Regarding maternal education status, 7,606  
279 (66.9%) had no formal education (Table1).

### 280 **Pregnancy and maternal health service-related characteristics of respondents**

281 Among 11375 respondents who gave birth within five years, two-third 7,468 (65.7%) of the  
282 respondents delivered at home and 194 (1.7%) gave birth through cesarean section. Concerning  
283 ANC utilization, 2,602 (22.9 %) had no ANC visit during pregnancy (Table 2).

284 The overall rate of stillbirth among births from childbearing age women within five years  
285 preceding the survey in Ethiopia was 9.2 [95% CI; 7.9, 11.1] per 1000 birth. Stillbirth rate was  
286 highest in the Amhara region (19.7) and lowest in Diredawa (3.0) (Figure 1).

## 287 **Spatial analysis**

### 288 **Spatial Global autocorrelation**

289 This study revealed that the spatial distribution of stillbirth was found to be non-random in  
290 Ethiopia with Global Moran's I 0.017 ( $p < 0.05$ ). The clustered patterns (on the right sides) show  
291 high rates of stillbirth occurred over the study area. The outputs have automatically generated  
292 keys on the right and left sides of each panel. Given the z-score of 2.4 indicated that there is less  
293 than 1.5% likelihood that this clustered pattern could be the result of chance. The bright red and  
294 blue colors to the end tails indicate an increased significance level (Figure 2).



## 295 **Hotspot analysis of stillbirth**

296 In the cluster and outlier analysis, the significant cluster was detected in Tigray, Amhara,  
297 Oromia, Addis Ababa, SNNPR, Benishangul-Gumuz, Somali and Gambella regions. Hot spot  
298 areas for stillbirth were found in southwest Somali, southern Amhara, and west SNNPR, While  
299 the cold spot regions were found in south and west Benishangul-Gumuz, Addis Ababa,  
300 southwest of Oromia region, west Gambella and Northeast SNNPR. Outliers were found in the  
301 central and southern parts of Amhara, north Tigray, southeast Gambella and Somali regions  
302 (Figure 3).

303 In the Spatial scan statistical analysis, a total of 56 significant clusters were identified of which  
304 22 clusters were primary (most likely clusters) and 34 secondary clusters of stillbirth were  
305 identified. The primary cluster spatial window was located in the northeast Somali region, which  
306 was centered 7.829198 N, 43.706264 E of geographic location with a 166.48 km radius, a  
307 relative risk of 22.5 and Log-Likelihood ratio (LLR) of 13.4, at  $p < 0.001$ . It showed that women  
308 within the spatial window had 22.5 times higher risk for stillbirth than women outside the  
309 window. The secondary clusters scanning window was located between the border area of the  
310 south Amhara region and the north Oromia region, and the southern Afar region (Table 3). The  
311 red circular ring indicates that the most statistically significant spatial window contains the  
312 primary cluster of stillbirth. There was a higher risk of stillbirth within the circular window than  
313 outside the spatial window (Figure 4).

## 314 **Interpolation of stillbirth**

315 North West Tigray, northern and North West Oromia, east and south Amhara, east Benishangul,  
316 East Gambella, Harari, and Northwest SNNPR were detected as predicted most risky areas of  
317 stillbirth compared to other regions. Predicted low-risk areas were found in Oromia, Afar, and

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3 318 Gambella regions. Continuous images produced by interpolating (Kriging interpolation method)  
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5 319 stillbirth among birth from reproductive-age women (Figure 5).  
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### 8 320 **Factors associated with stillbirth**

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10  
11 321 ICC and LR tests were checked, and the multilevel model was. Therefore, the two-level  
12  
13 322 multilevel logistic regression model was used to get an unbiased standard error and to make a  
14  
15 323 valid inference. Deviance was used for model comparison; the final model was the best-fitted  
16  
17 324 model with the lowest deviance (Table 4).  
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20  
21 325 The intra-class correlation coefficient (ICC) was 47% in the empty model indicated that 47% of  
22  
23 326 the total variability for stillbirth was due to differences between clusters/EA, with the remaining  
24  
25 327 unexplained 53% attributable to individual differences. Moreover, the median odds ratio for  
26  
27 328 stillbirth was 5.03 in the null model which indicates that there was variation between clusters. If  
28  
29 329 we randomly select women from two different clusters of women at the cluster with a higher risk  
30  
31 330 of stillbirth had 5.03 times higher odds of experiencing stillbirth as compared with women at  
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33 331 cluster with a lower risk of stillbirth. About 15.3 percent of the variability in stillbirth was  
34  
35 332 explained by the full model (Table 4).  
36  
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40 333 The final multilevel logistic regression model found residence, region, religion, preceding birth  
41  
42 334 interval, cesarean delivery, maternal height, ANC visit, and maternal education were  
43  
44 335 significantly associated with stillbirth. At the community level (level 2), two variables were  
45  
46 336 significantly associated with stillbirth. The odds of experiencing among women residing in rural  
47  
48 337 areas were 4.83 times more likely to that of women residing in the urban area (AOR= 4.83, 95%  
49  
50 338 CI 1.44-16.19).The odds of experiencing stillbirth in Tigray, Afar, Somali, SNNPR,  
51  
52 339 Benishangul, Gambella and Harari were not significantly different from that of experiencing  
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54 340 stillbirth in Amhara. A woman who lives in the Oromia region was 75% decreased odds of  
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3 341 experiencing stillbirth as compared to a woman in the Amhara region (AOR= 0.25, 95% 0.07-  
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5 342 0.83).

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8 343 At the individual level (level 1), Six variables were significantly associated with stillbirth.  
9  
10 344 Women who were protestant and catholic religious followers had 89% decreased odds of  
11  
12 345 experiencing stillbirth as compared to orthodox religious followers (AOR= 0.11, 95% CI 0.03-  
13  
14 346 0.37 ). The educational level of women was significantly associated with experiencing stillbirth.  
15  
16 347 Though women having secondary and higher education have no significant difference in  
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18 348 experiencing stillbirth with those having no educational attainment, women having primary  
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20 349 education decreases the odds of experiencing stillbirth by 61%as compared to those with no  
21  
22 350 educational attainment (AOR= 0.39, 95% CI 0.20 - 0.74).besides, Women who had no antenatal  
23  
24 351 care visit during pregnancy were 2.77 times higher odds of experiencing stillbirth than those who  
25  
26 352 have 4 and above ANC visits (AOR= 2.77, 95% CI 1.70 - 4.51). Women who gave birth through  
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28 353 cesarean delivery were 5.07times higher odds of experiencing stillbirth than those women who  
29  
30 354 gave birth through vaginal delivery (AOR= 5.07, 95% CI 1.65– 15.58).

31  
32 355 The preceding birth interval was a significant predictor of experiencing stillbirth outcomes.  
33  
34 356 Women having preceding birth interval less than 24 months had 1.93 times higher odds of  
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36 357 experiencing stillbirth compared to women having preceding birth interval 24 months and above  
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38 358 (AOR= 1.93, 95% CI 1.20 – 3.10). also, maternal height less than 150 cm were 2.73 times higher  
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40 359 odds of experiencing stillbirth as compared to those mother's greater than or equal to 150 cm  
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42 360 (AOR= 2.73, 95% CI 1.50-4.97) (Table 4).

## 361 Discussion

362 In Ethiopia, the stillbirth rate was found to be 9.2 per 1000 birth with marked spatial  
363 heterogeneity. The spatial distribution of stillbirth was non-random in Ethiopia. The spatial scan  
364 statistics detected a total of three statistically significant SaTScan clusters areas with a high rate  
365 of stillbirth. The SaTScan analysis identified significant hotspot areas of stillbirth in northeast  
366 Somali, south Afar, south Amhara, and north Oromia region. These areas are more of pastoralist  
367 areas where people did not have permanent resident and due to this relatively health facilities are  
368 not accessible and available as compared to agrarian people and cities. Besides, these areas are  
369 more rural, which had a poor network of health facilities. Also, this could be attributed to the  
370 disparity in the distribution of maternal health service, and the inaccessibility of infrastructure in  
371 the border areas of regions(36). Whereas, the cold spot areas of stillbirth were found in south  
372 and west Benishangul-Gumuz, Addis Ababa, southwest of Oromia region, west Gambella and  
373 Northeast SNNPR. This could be these areas were relatively had better availability and  
374 accessibility of health services (Addis Ababa, Dire-Dawa)(37). Therefore, women are more  
375 likely to have antenatal care visits, and institutional delivery, this could contribute to the  
376 decrement of antepartum and intrapartum stillbirth. This result provides public health planners  
377 and programmers for designing effective public health intervention to identified hotspot areas of  
378 stillbirth that need special attention.

379 In the multilevel analysis, different individual and community factors were significantly  
380 associated with stillbirth. Among the community level variables, it was found that the odds of  
381 stillbirth were lower among women who lived in the Oromia region as compared to those in the  
382 Amhara region. This might be due to the availability and accessibility of maternal health  
383 facilities since Oromia regions are relatively around Addis Ababa and Dire-Dawa in which

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3 384 health facilities are accessible as compared to other regions. Also, the high turnover rate of  
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5 385 health professionals in the Amhara region especially physicians didn't stay in the districts and  
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7 386 they prefer to work in the capital city of Ethiopia (Addis Ababa) this could be contributed to the  
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9 387 high rate of intrapartum stillbirth in districts because of lack of skilled health professionals (38).  
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11 388 The study has shown that the odds of stillbirth were higher among women who lived in rural  
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13 389 areas. This was consistent with previous study findings in South Africa(39), African Great lake  
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15 390 Regions(12), Nigeria(19), Northern Ghana(14) and Ethiopia(17). This could be attributed to the  
16  
17 391 disparity in mother's health care access, availability and accessibility of health facilities and  
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19 392 women in urban areas are relatively had improved health-seeking behavior (36). Moreover,  
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21 393 urban residents have better aware of maternal health service but in rural areas, health facilities  
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23 394 may not be easily reachable and may end up with poor pregnancy outcomes during emergency  
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25 395 cases (40).  
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27 396 Amongst the individual-level factors, catholic or protestant religion followers were significantly  
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29 397 associated with lower odds of stillbirth as compared with orthodox religious followers. This  
30  
31 398 might be related to the miss-perception of religious followers and this could shape their  
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33 399 reproductive health decision making and practices, thereby govern the women's desire for using  
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35 400 maternal health services(41). It could also be related to the feeding practice of women.  
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37 401 Commonly orthodox religious followers may not eat animal products during pregnancy  
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39 402 especially in the fasting period this might be related to poor fetal outcomes (42). Animal  
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41 403 products are the main source of micro and macronutrients like folate and iron. Orthodox  
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43 404 religious followers considered giving birth at home are blessed, using contraceptive as sinning  
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45 405 and not expose their body to health professionals during delivery this might be the possible  
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47 406 reason which needs further qualitative study to explore the detailed reasons.  
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3 407 This study noted lower odds of stillbirth among women who had primary education as compared  
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5 408 to women with no education. This finding was in line with previous studies done in Kenya(43)  
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7 409 and Nigeria(19). This could be attributed to having maternal education that could lead to the  
8  
9 410 corresponding improvement in health-seeking behavior. Like the timely decision to seek care  
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11 411 appropriate care during pregnancy, give better care for their health and their fetus, awareness of  
12  
13 412 the danger sign of pregnancy and maternal health service utilization(44).  
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16  
17 413 The odds of stillbirth were higher among short stature women. A similar finding was reported in  
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19 414 Pakistan(21). This might be for the reason that short stature women are associated with adverse  
20  
21 415 pregnancy outcomes like Cephalo pelvic disproportion, contracted pelvis, intra-uterine growth  
22  
23 416 restriction(IUGR), intra-uterine Fetal death(IUFD) and birth injury. Short stature reflects  
24  
25 417 longstanding malnutrition or childhood infection that start in utero or during early childhood,  
26  
27 418 this kind of women may end up with poor pregnancy outcome unless we screen them as at-risk  
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29 419 during ANC follow up(45).  
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34 420 Besides, having no ANC visit had a significant association with increased stillbirth. This study  
35  
36 421 could support previous studies done in low-middle countries (46), Ghana(47) and Kenya(43).  
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38 422 ANC follow up could help a pregnant woman to seek early treatment for her potential  
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40 423 pregnancy-associated complications, early screening of underlying medical conditions and may  
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42 424 improve birth outcomes (47, 48). On the other hand, women who did not have longer ANC  
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44 425 follow up may not be benefited from basic ANC packages.  
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48 426 Consistent with studies done in Nigeria based on the 2013 DHS(19) and cross-sectional study in  
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50 427 Gambia(49), cesarean deliveries in this study showed higher odds of stillbirth when compared  
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52 428 with normal vaginal delivery. This may be due to the reason that cesarean sections are probably  
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54 429 applied too late in hospital since most women are referred to from distant health facilities. there  
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3 430 may be a delay in referral or transportation problems resulting in not to save the baby's life  
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5 431 because the cesarean section is not done at the right time (50, 51).  
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8 432 In this study, having a short inter-pregnancy interval was associated with higher odds of  
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10 433 stillbirth. This was consistent with studies done sub-Saharan Africa (52), Bangladesh (53) and  
11  
12 434 Amhara Region(18). This could be explained by short preceding birth interval are less able to  
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14 435 provide nourishment for the fetus because her body has had less time to recuperate from the  
15  
16 436 previous pregnancy, the uterus had less time to recover. Furthermore, lactation will deplete  
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18 437 maternal nutrition and may end up with poor pregnancy outcomes(53).  
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22 438 The strength of this study was using weighted data to make it representativeness at national and  
23  
24 439 regional levels: therefore, it can be generalized to all women who gave birth during the study  
25  
26 440 period in Ethiopia. Moreover, the use of GIS and SaTScan statistical tests helped to detect  
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28 441 similar and statistically significant hotspot areas of stillbirth and to design effective public health  
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30 442 programs. However, the SaTScan detect only circular clusters, irregularly shaped clusters were  
31  
32 443 not detected. Furthermore, the EDHS survey did not incorporate clinically confirmed data rather  
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34 444 it relied on mothers or caregivers report and might have the possibility of social desirability and  
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36 445 recall bias since stillbirth(27).  
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3 446 The findings of this study have valuable policy implications for health program design and  
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5 447 interventions. Stillbirth high-risk areas can be easily identified to make effective local  
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7 448 interventions. In general, these findings are of supreme importance for the minister of health,  
8  
9 449 regional health bureaus, and NGO's to design intervention programs to reduce stillbirth in  
10  
11 450 identified hotspot areas. To reduce the overall stillbirth rate in Ethiopia, Somali, Afar, Amhara  
12  
13 451 and Oromia regions should emphasize the identified SaTScan clusters through developing local  
14  
15 452 interventional strategies like improving accessibility and availability of maternal health facility.  
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### 19 453 **Conclusions**

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21  
22 454 In Ethiopia, stillbirth had spatial variations across the country. Statistically, significant-high  
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24 455 hotspots of stillbirth were found in the central and southern parts of Amhara, west SNNPRs,  
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26 456 south and north Tigray, and south West Somali region. Whereas, cold spot areas were found in  
27  
28 457 Addis Ababa, central Oromia, and east SNNPRs. Short preceding birth interval, short maternal  
29  
30 458 stature, ANC visit, rural residence, region, religion, maternal education, and cesarean delivery  
31  
32 459 were significant predictors of stillbirth.  
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### 36 460 **Abbreviations**

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39  
40 461 ANC; Antenatal Care, AOR; Adjusted Odds Ratio, ARR; Annual Rate of Reduction, BMI; Body  
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42 462 Mass Index, CI; Confidence Interval, COR; Crude Odds Ratio, CSA; Central Statistical Agency,  
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44 463 DHS; Demographic Health Survey, EA; Enumeration Area, EDHS; Ethiopian Demographic  
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46 464 Health Survey, GIS; Geographic Information System, ICC; Intra-cluster Correlation  
47  
48 465 Coefficient, IUFD; Intra Uterine Fetal Death, IUGR; Intra Uterine Growth Restriction,  
49  
50 466 LLR; log-likelihood Ratio, LR; Likelihood Ratio, MOR; Median Odds Ratio, PCV; Proportional  
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3 467 Change in Variance, PHC; Population and Housing census, SBR; Stillbirth Rate, SNNPRs;  
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5 468 Southern Nations and Nationality People Regional state, WHO; World Health Organization.  
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## 10 469 **Declarations**

## 11 12 13 470 **Availability of data and materials**

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15  
16 471 Data is available online and you can access it from [www.measuredhs.com](http://www.measuredhs.com).  
17  
18

## 19 472 **Competing Interests**

20  
21  
22 473 Authors declare that they have no conflict of interest  
23

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26  
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28  
29

## 30 476 **Authors' contribution**

31  
32  
33 477 Conceptualization: Getayeneh Antehunegn Tesema

34  
35 478 Data curation: Getayeneh Antehunegn Tesema

36  
37 479 Funding acquisition: Getayeneh Antehunegn Tesema

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6  
7  
8 489 Writing: Getayeneh Antehunegn Tesema  
9  
10 490 Writing – review and editing: Getayeneh Antehunegn Tesema, Lemma Derseh Gezie, Solomon  
11  
12 491 Gedlu Nigatu  
13  
14

## 15 492 **Consent for publication**

16  
17  
18 493 Not applicable  
19  
20

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616 Table 1: Socio-demographic characteristics of women who gave birth within 5 years before the  
 617 survey in Ethiopia, 2016.

Variables	Category	Unweighted frequency (%)	Weighted frequency (%)
Residence	Urban	1,994 (18.0)	1,226 (10.8)
	Rural	9,091 (82.0)	10,149 (89.2)
Region	Tigray	1,021 (9.2)	709 (6.2)
	Afar	1,102 (9.9)	119 (1.0)
	Amhara	1,004 (9.1)	2,122 (18.7)
	Oromia	2,617 (23.6)	5,280 (46.4)
	Somali	1,623 (14.6)	554 (4.9)
	Benishangul Gumuz	962 (8.7)	133 (1.2)
	SNNPR	1,334 (12.0)	2,402 (21.1)
	Gambella	789 (7.1)	29 (0.3)
	Harari	633 (5.7)	27 (0.2)
Religion	Orthodox	3,127 (28.2)	3,844 (33.8)
	Muslim	5,710 (51.5)	4,696 (41.3)
	Catholic and protestant	2,248 (20.3)	2,835 (24.9)
Maternal education	No education	7,241 (65.3)	7,606 (66.9)
	Primary education	2,708 (24.4)	2,961 (26.0)
	Secondary and higher education	1,136 (10.3)	808 (7.1)
Maternal age	<20 year	395 (3.6)	374 (3.3)
	20-29 year	5,556 (50.1)	5,599 (49.2)
	30-39 year	4,234 (38.2)	4,381 (38.5)
	≥40 year	900 (8.1)	1,021 (9.0)
Husband education	No education	5,331 (51.2)	5,339 (49.6)
	Primary education	3,260 (31.3)	4,139 (38.5)

	Secondary and higher education	1,817 (17.5)	1,284 (11.9)
Maternal occupation status	Had occupation	6,584 (59.4)	6,352 (55.8)
	No occupation	4,501 (40.6)	5,023 (44.2)
Wealth status	Poor	6,081 (54.9)	5,360 (47.1)
	Middle	1,512 (13.6)	2,318 (20.4)
	Rich	3,492 (31.5)	3,697 (32.5)

618

619 Table 2: pregnancy and health service-related characteristics of women who gave birth within 5  
 620 years preceding the survey in Ethiopia, 2016.

Variable	Category	Unweighted frequency (%)	Weighted frequency (%)
Pregnancy and maternal service-related factors			
Place of delivery	Home	6,737 (60.8)	7,468 (65.7)
	Health facility	4,348 (39.2)	3,907 (34.3)
Parity	Only one birth	1,435 (13.0)	1,419 (12.5)
	2-4 birth	5,042 (45.5)	5,022 (44.1)
	≥5 birth	4,608 (41.5)	4,934 (43.4)
Birth order	1-3	5,806 (52.4)	5,703 (50.1)
	4-5	2,584 (23.3)	2,655 (23.4)
	≥6	2,695 (24.3)	3,017 (26.5)
BMI	Thin	2,981 (26.9)	2,483 (21.8)
	Normal	7,106 (64.1)	8,164 (71.8)
	Overweight	998 (9.0)	728 (6.4)
Maternal height	< 150 cm	1,018 (9.2)	1,228 (10.8)
	≥150 cm	10,067 (90.8)	10,147 (89.2)
ANC visit	No ANC visit	2,321 (20.9)	2,602 (22.9)
	1-3 ANC visit	1,917 (17.3)	2,145 (18.9)
	≥ 4 ANC visit	6,847 (61.8)	6,628 (58.2)

Preceding birth interval	< 24 month	2,347 (21.2)	2,145 (18.9)
	≥24 month	8,738 (78.8)	9,230 (81.1)
Maternal anemia	Not anemic	6,696 (60.4)	7,590 (66.7)
	Anemic	4,389 (39.6)	3,785 (33.3)
Ever use of contraceptive	Yes	4,101 (37.0)	5,238 (46.0)
	No	6,984 (63.0)	6,137 (54.0)
Mode of delivery	Vaginal delivery	10,813 (97.5)	11,181 (98.3)
	Cesarean delivery	272 (2.5)	194 (1.7)
Number of gestation	Single	10,798 (97.4)	11,072 (97.3)
	Twin	287 (2.6)	303 (2.7)
Behavioral and community-level factors			
Smoking cigarettes	Yes	10,976 (99.0)	11,286 (99.2)
	No	109 (1.0)	89 (0.8)
Media exposure	Yes	9,747 (87.9)	10,020 (88.1)
	No	1,338 (12.1)	1,355 (11.9)
Community media exposure	Lower	5,503 (49.6)	4,640 (40.8)
	Higher	5,582 (50.4)	6,735 (59.2)
Community poverty	Lower	6,909 (62.3)	7,617 (67.0)
	Higher	4,176 (37.7)	3,758 (33.0)
Community ANC utilization	Lower	5,387 (48.6)	6,665 (58.6)
	Higher	5,698 (51.4)	4,710 (41.4)
Community women education	Lower	6,909 (62.3)	7,617 (67.0)
	Higher	4,176 (37.7)	3,758 (33.0)

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622 Table 3: SaTScan analysis results of stillbirth in Ethiopia, 2016.

Cluster	Enumeration area(cluster)identified	Coordinate/radius	Population	Case	RR	LLR	p-value
1	497, 95, 198, 521, 588, 553, 458, 171, 214, 251, 573, 239, 116, 22, 543, 490, 492, 92, 568, 33, 277, 527	(7.829198 N, 43.706264 E) / 166.48 km	532	17	22.5	13.4	0.00069



2	350, 229, 482, 531, 218, 510, 206, 10, 474, 267, 375, 423, 120, 176, 572, 517, 460, 24, 403, 429, 38, 3, 485, 456, 274, 167, 463, 112, 399, 532	(10.195460 N, 38.150574 E) / 142.05 km	384	14	3.6	8.84	0.04
3	564, 39, 230, 51	(9.555410 N, 40.326165 E) / 34.04 km	50	4	8.83	8.55	0.05

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624 Table 4: Multivariable multilevel logistic regression analysis result of both individual and  
625 community-level factors associated with stillbirth in Ethiopia, EDHS 2016

Individual and community-level characteristics	Null model	Model II AOR (95% CI)	Model III AOR (95% CI)	Model IV AOR (95% CI)
<b>Residence</b>				
Urban			1	1
Rural			3.75[1.33, 10.56]	4.83[1.44, 16.19]*
<b>Region</b>				
Amhara			1	1
Tigray			0.54[0.18, 1.63]	0.63[0.19, 2.17]
Afar			0.28[0.08, 0.94]	0.24[0.05, 1.06]
Oromia			0.20[0.07, 0.55]	0.25[0.07, 0.83]*
Somali			0.84[0.32, 2.21]	0.98[0.27, 3.56]
Benishangul Gumuz			0.25[0.07, 0.92]	0.37[0.09, 1.53]
SNNPR			0.21[0.06, 0.69]	0.56[0.14, 2.18]
Gambella			0.26[0.06, 1.07]	1.02[0.20, 5.22]
Harari			0.71[0.19, 2.63]	0.77[0.16, 3.72]
<b>Religion</b>				
Orthodox		1		1
Muslim		0.59[0.31, 1.12]		0.75[0.32, 1.77]
Protestant/catholic		0.12[0.04, 0.35]		0.11[0.03, 0.37]**
<b>Wealth status</b>				
Poor		1.12[0.60, 2.11]		0.87[0.45, 1.69]
Middle		1.58[0.78, 3.19]		1.21[0.60, 2.47]
Rich		1		1
<b>Women's education</b>				
No education		1		1

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2				
3	Primary education	0.39[0.21, 0.75]		0.39[0.20, 0.74]**
4	Secondary and higher	0.49[0.18, 1.33]		0.63[0.23, 1.71]
5	education			
6				
7	<b>Birth order</b>			
8	1-3	1		1
9	4-5	0.49[0.24, 1.03]		0.50[0.24, 1.03]
10	6 and above	0.66[0.25, 1.75]		0.66[0.25, 1.73]
11				
12	<b>Parity</b>			
13	Only one birth	1		1
14	2-4 birth	0.68[0.37, 1.28]		0.65[0.35, 1.22]
15	≥ 5 birth	0.45[0.16, 1.28]		0.42[0.15, 1.20]
16				
17	<b>ANC visit</b>			
18	No ANC visit	2.85[1.76, 4.62]		2.77[1.70, 4.51]**
19	1-3 visit	1.22[0.68, 2.19]		1.11[0.62, 2.00]
20	4 and above visit	1		1
21				
22	<b>Media exposure</b>			
23	Yes	1		1
24	No	2.11[0.85, 5.24]		1.63[0.66, 4.04]
25				
26	<b>Maternal height</b>			
27	< 150 cm	2.66[1.47, 4.79]		2.73[1.50, 4.97]**
28	≥ 150 cm	1		1
29				
30	<b>Contraceptive use</b>			
31	Yes	0.74[0.43, 1.26]		0.72[0.41, 1.24]
32	No	1		1
33				
34	<b>Preceding birth interval</b>			
35	≤ 24 month	1.92[1.19, 3.07]		1.93[1.20, 3.10]**
36	> 24 month	1		1
37				
38	<b>Mode of delivery</b>			
39	Vaginal delivery	1		1
40	Cesarean delivery	4.00[1.35, 11.85]		5.07[1.65, 15.58]**
41				
42	<b>Community media exposure</b>			
43	Lower community exposure		1	1
44	Higher community exposure		0.96[0.51, 1.80]	1.02[0.51, 2.04]
45				
46	<b>Community women's education</b>			
47	Lower community education		1	1
48	Higher community education		1.28[0.61, 2.71]	1.88[0.80, 4.42]
49				
50	<b>Constant</b>	0.003[0.002, 0.005]	0.003[0.001, 0.01]	0.002[0.0005, 0.0096]
51				0.001[0.0002, 0.01]
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3 **Model comparison and**  
4 **Random effects**  
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6 ICC	0.47(0.35, 0.59)			
7 Log-likelihood	-599.02	-551.2	-584.36	-540.50
8 Deviance	1198.04	1102.2	1168.72	1081
9 PCV	Ref	21.5	9.3	15.3
10 MOR	5.03[3.19, 7.13]	5.91[3.44, 8.90]	4.66[2.84, 6.69]	5.69[3.31, 8.56]

12 626 \*AOR; Adjusted Odds Ratio, CI; Confidence Interval, ICC; Intra-class Correlation, MOR;

13 627 Median Odds Ration, PCV; Proportional Change in Variance.

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3 **629 Figure legends:**

4 **630 Figure 1: The stillbirth rates across regions in Ethiopia, 2016**

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8 **631 Figure 2: Global spatial autocorrelation of stillbirths in Ethiopia, 2016**

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11 **632 Figure 3: Cluster and Outlier analysis of stillbirths in Ethiopia, 2016 (Source: Central Statistical**  
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13 **633 Agency (CSA), Ethiopia, 2013)**

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16 **634 Figure 4: Spatial Scan Statistical analysis of hotspot areas of stillbirth in Ethiopia, 2016 (Source:**  
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18 **635 Central Statistical Agency (CSA), Ethiopia, 2013)**

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21 **636 Figure 5: Kriging Interpolation of stillbirth in Ethiopia, 2016 (Source: Central Statistical Agency**  
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23 **637 (CSA), Ethiopia, 2013)**

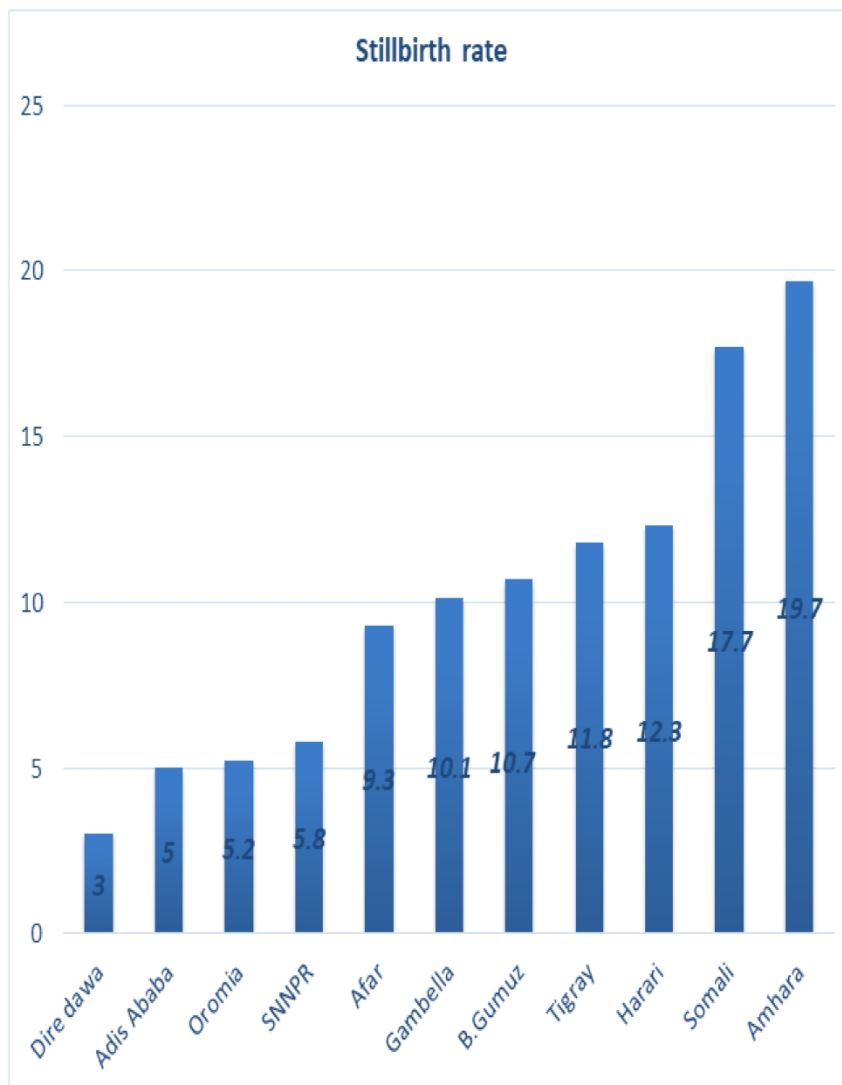


Figure 1: The stillbirth rate across regions in Ethiopia, 2016

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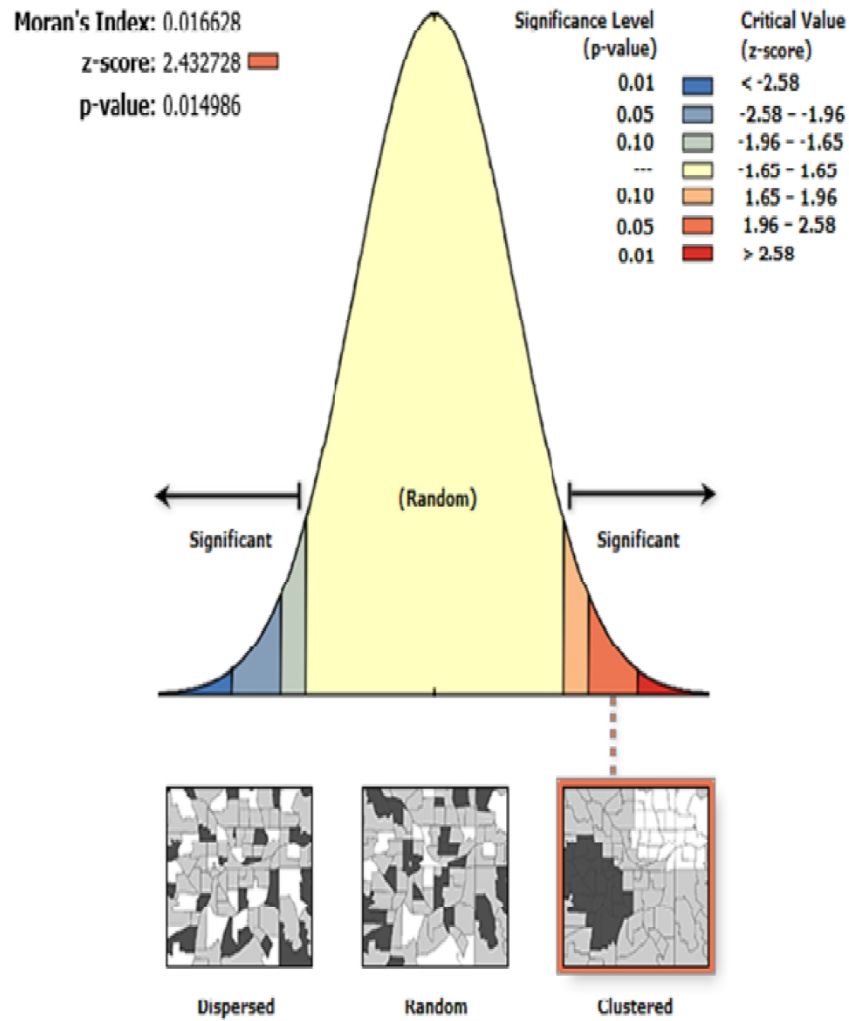


Figure 2: Global spatial autocorrelation of stillbirths in Ethiopia, 2016  
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Cluster and Outlier analysis of stillbirth across regions in Ethiopia, 2016

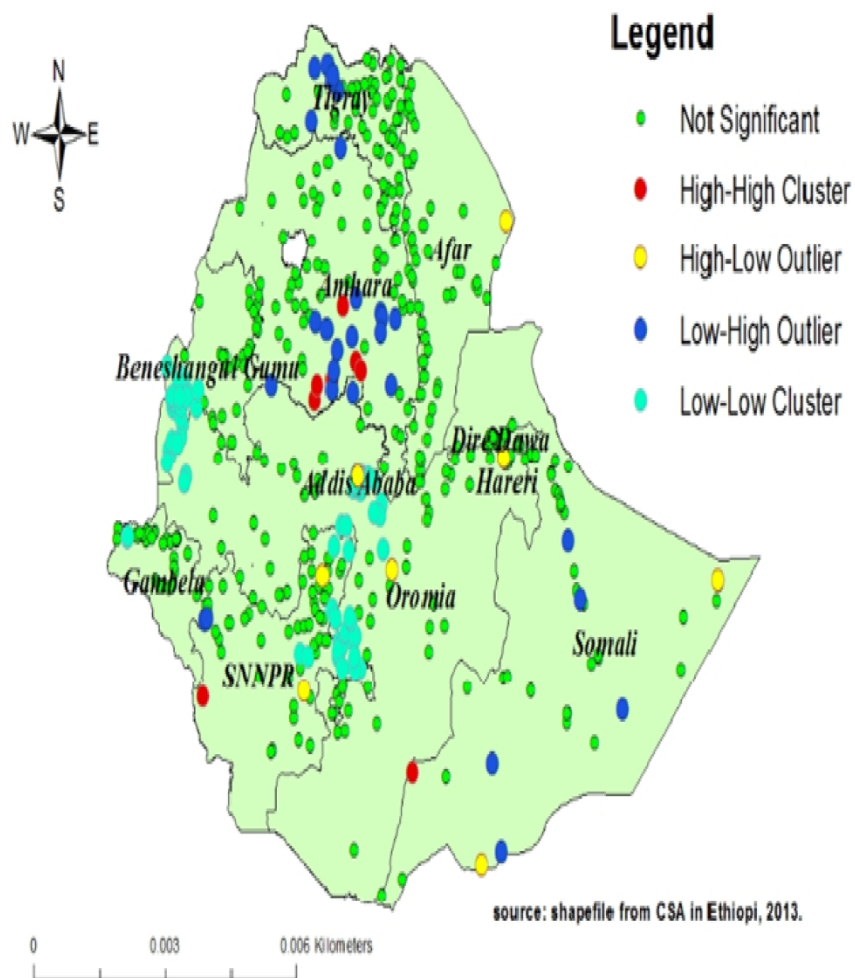
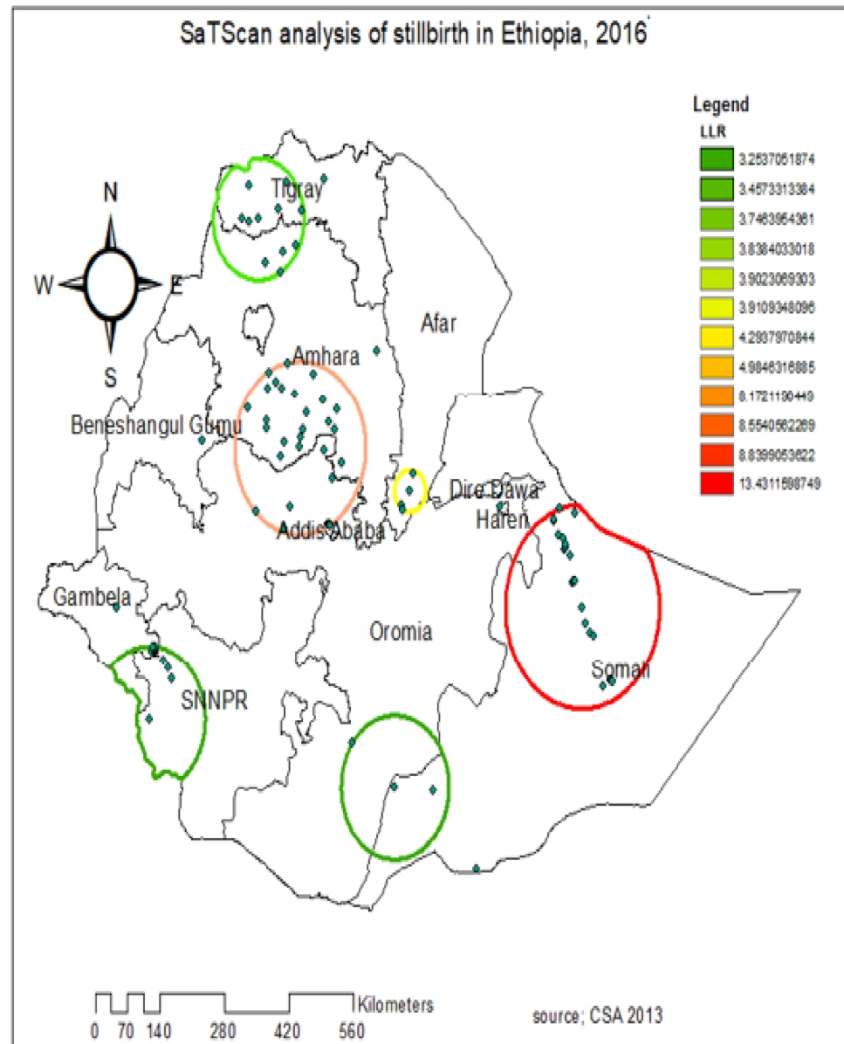


Figure 3: Cluster and Outlier analysis of stillbirths in Ethiopia, 2016 (Source: Central Statistical Agency (CSA), Ethiopia, 2013)

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45 Figure 4: Spatial Scan Statistical analysis of hotspot areas of stillbirth in Ethiopia, 2016 (Source: Central  
46 Statistical Agency (CSA), Ethiopia, 2013)

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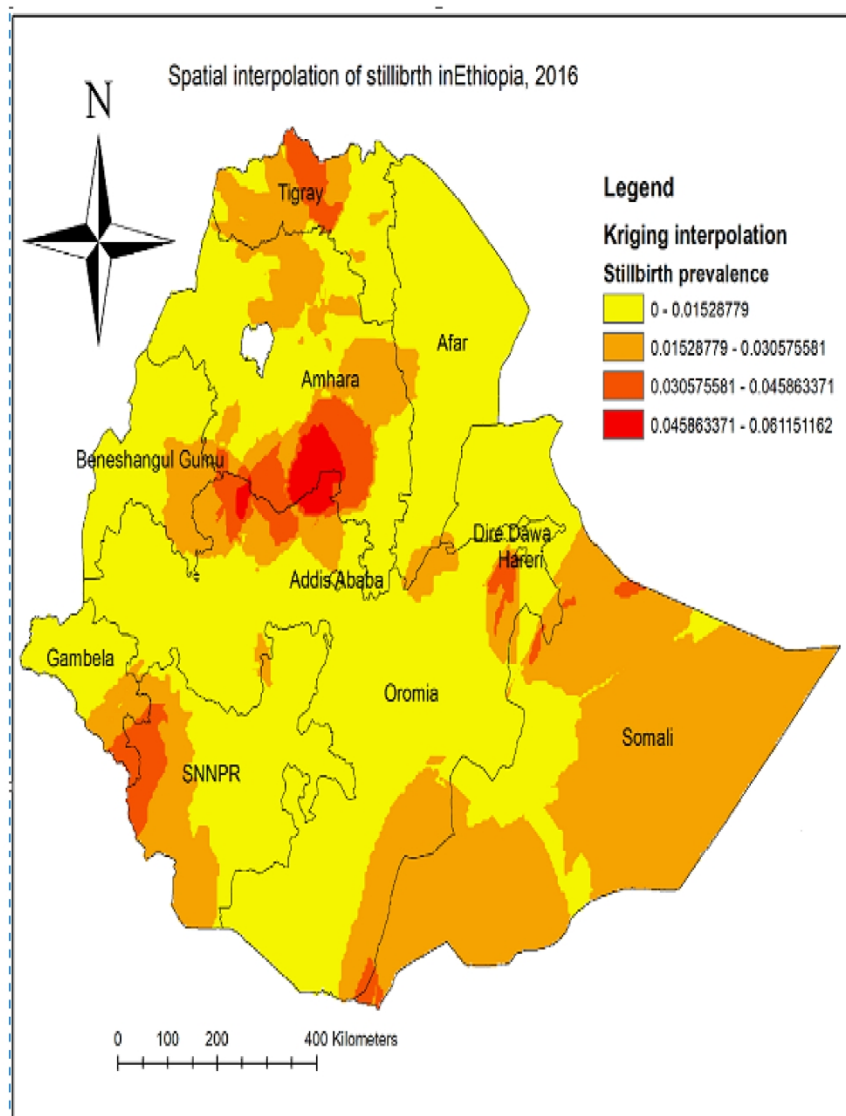


Figure 5: Kriging Interpolation of stillbirth in Ethiopia, 2016 (Source: Central Statistical Agency (CSA), Ethiopia, 2013)

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STROBE Statement—checklist of items that should be included in reports of observational studies

	Item No.	Recommendation	Page No.
<b>Title and abstract</b>	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&3
<b>Introduction</b>			
Background/rationale	2	Explain the scientific background and rationale for the investigation being reported	4, 5 \$6
Objectives	3	State specific objectives, including any pre-specified hypotheses	6
<b>Methods</b>			
Study design	4	Present key elements of study design early in the paper	6
Setting	5	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection	6, 7 \$8
Participants	6	(a) <i>Cohort study</i> —Give the eligibility criteria, and the sources and methods of selection of participants. Describe methods of follow-up	N/A
		<i>Case-control study</i> —Give the eligibility criteria, and the sources and methods of case ascertainment and control selection. Give the rationale for the choice of cases and controls	N/A
		<i>Cross-sectional study</i> —Give the eligibility criteria, and the sources and methods of selection of participants	6 &7
		(b) <i>Cohort study</i> —For matched studies, give matching criteria and number of exposed and unexposed	N/A
		<i>Case-control study</i> —For matched studies, give matching criteria and the number of controls per case	N/A
Variables	7	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable	7 & 8
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	7&8
Bias	9	Describe any efforts to address potential sources of bias	8 & 9
Study size	10	Explain how the study size was arrived at	6&7

Continued on next page

Quantitative variables	11	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why	, 8,9,10 &11
Statistical methods	12	(a) Describe all statistical methods, including those used to control for confounding	8,9,10 &11
		(b) Describe any methods used to examine subgroups and interactions	N/A
		(c) Explain how missing data were addressed	10, 11
		(d) <i>Cohort study</i> —If applicable, explain how loss to follow-up was addressed	N/A
		<i>Case-control study</i> —If applicable, explain how matching of cases and controls was addressed	N/A
		<i>Cross-sectional study</i> —If applicable, describe analytical methods taking account of sampling strategy	8,9 &10
		(e) Describe any sensitivity analyses	N/A
<b>Results</b>			
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	N/A
		(b) Give reasons for non-participation at each stage	N/A
		(c) Consider use of a flow diagram	N/A
Descriptive data	14*	(a) Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders	14
		(b) Indicate number of participants with missing data for each variable of interest	15
		(c) <i>Cohort study</i> —Summarise follow-up time (eg, average and total amount)	N/A
Outcome data	15*	<i>Cohort study</i> —Report numbers of outcome events or summary measures over time	N/A
		<i>Case-control study</i> —Report numbers in each exposure category, or summary measures of exposure	N/A
		<i>Cross-sectional study</i> —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	16 & 17
		(b) Report category boundaries when continuous variables were categorized	14
		(c) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period	N/A

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Other analyses	17	Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses	N/A
<b>Discussion</b>			
Key results	18	Summarise key results with reference to study objectives	22
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	21
Interpretation	20	Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence	18, 19, 20, 21& 22
Generalisability	21	Discuss the generalisability (external validity) of the study results	21
<b>Other information</b>			
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	23

\* cross-sectional studies.

# BMJ Open

## Spatial distribution of stillbirth and associated factors in Ethiopia: Spatial and Multilevel Analysis

Journal:	<i>BMJ Open</i>
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<b>Primary Subject Heading</b>:	Obstetrics and gynaecology
Secondary Subject Heading:	Epidemiology, Health services research, Obstetrics and gynaecology
Keywords:	Stillbirth, Ethiopia, Multilevel analysis, Spatial analysis

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3 **1 Spatial distribution of stillbirth and associated factors in Ethiopia: a spatial and**  
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5  
6 **2 multilevel Analysis**  
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## 16 Abstract

17 **Objective:** Even though the stillbirth rate has reduced globally, it is unacceptably high in  
18 developed countries. To date, only ten countries bear the burden of more than 65% of global  
19 stillbirth rates including Ethiopia in the seventh position. Exploring the spatial distribution of  
20 stillbirths is critical for monitoring and developing successful interventions for public health  
21 action, but there is no available national study on the spatial distribution and associated factors of  
22 stillbirth. Therefore, this study aimed to explore the spatial distribution, and associated factors of  
23 stillbirths.

24 **Methods:** Secondary data analysis was conducted based on the 2016 Ethiopian Demographic and  
25 Health Survey data. Total weighted samples of 11,375 women were included for analysis. The  
26 Bernoulli model was fitted using spatial scan statistics version 9.6 to identify hotspot areas and  
27 ArcGIS version 10.6 to explore the spatial distribution of stillbirths. For associated factors, a  
28 multilevel logistic regression model that accounts for the hierarchical structure of the data was  
29 fitted using STATA version 14 software. Variables with  $p$ -value $<0.2$  were considered for the  
30 multivariable multilevel analysis. In the multivariable multilevel analysis, the Adjusted Odds Ratio  
31 (AOR) with the 95% Confidence Interval (CI) were reported to declare factors significantly  
32 associated with stillbirth.

33 **Result:** The spatial analysis showed that stillbirth has significant spatial variation across regions  
34 in Ethiopia. The SaTScan analysis identified significant primary clusters of stillbirth in the  
35 Northeast Somali region (LLR=13.4,  $p<0.001$ ) while the secondary cluster in the border area of  
36 Oromia and Amhara regions (LLR=8.8,  $p<0.05$ ). In the multilevel analysis; rural residence  
37 (AOR=4.83, 95%CI:1.44-16.19), primary education (AOR=0.39, 95% CI:0.20-0.74), not having  
38 ANC visit (AOR=2.77, 95% CI:1.70-4.51), caesarean delivery (AOR=5.07, 95% CI: 1.65-15.58),



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3 39 birth interval <24 month (AOR=1.95, 95%CI: 1.20 - 3.10), and height <150 cm(AOR=2.73,  
4  
5 40 95%CI:1.45-4.97) were significantly associated with stillbirth.

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7  
8 41 **Conclusion and recommendation:** In Ethiopia, stillbirths had significant spatial variations across  
9  
10 42 the country. Residence, maternal stature, preceding birth interval, cesarean delivery, education,  
11  
12 43 and ANC visit were significantly associated with stillbirth. This could have public health  
13  
14 44 implications to target interventions to identified hotspot areas of stillbirth and the government  
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16 45 should scale up maternal health programs in rural areas.

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18  
19 46 **Keywords:** stillbirth, Ethiopia, multilevel logistic regression, spatial analysis  
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## 23 24 25 26 48 **Strength and limitation of the study**

- 27  
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29 49 • The study was based on the weighted EDHS to restore the representativeness of the data and  
30  
31 50 to get a reliable estimate. Therefore, the study findings have the potential to inform policy-  
32  
33 51 makers, planners and programmers, and to design appropriate intervention at national and  
34  
35 52 regional levels
- 36  
37  
38 53 • As a study was a cross-sectional study, the study was unable to show a temporal relationship.  
39  
40 54 However, multilevel modeling was employed to take into account the clustering effect to get  
41  
42 55 reliable estimates and standard error.
- 43  
44  
45 56 • The EDHS survey did not incorporate clinically confirmed data rather it relied on mothers or  
46  
47 57 caregivers report. Besides, the study was based on self-reports of respondents. Therefore, it  
48  
49 58 may have the possibility of social desirability and recall bias
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52 59 • The SaTScan detect only circular clusters, irregularly shaped clusters were not detected  
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## 60 **BACKGROUND**

61 The World Health Organization (WHO) defines stillbirth as fetal death (death before the complete  
62 expulsion or extraction of a product of conception from its mother) in the third trimester ( $\geq 28$   
63 completed weeks of gestation) or birth weight  $\geq 1000$  grams or length  $\geq 35$  centimeters (1, 2).

64 Stillbirth remains a global public health problem, particularly in Sub-Saharan Africa (SSA) and  
65 South Asia (SA) (3). Globally, 2.6 million stillbirths occurred annually, 98% of which were in  
66 developing countries (4).

67 Most of the stillbirths happen during the intrapartum period, which can be avoided by improving  
68 maternal health care services (5). More than half of the 2.6 million stillbirths occur during labor  
69 and delivery (6) and it is considered as an indicator of access to and quality of obstetric care (7).

70 According to the most recent global estimate of WHO, the average global stillbirth rate was 18.4  
71 per 1000 births (8), while developing countries have the stillbirth rates ten-fold higher than  
72 developed countries (9). SSA has the highest stillbirth rate of 28.3 per 1000 births (10).

73 Stillbirth rates have been varied across countries and remain a huge challenge to achieve Every  
74 Newborn Action Plan (ENAP) of the target of 12 or fewer stillbirths per 1000 births by 2030 (1).

75 Even though many high-income and upper-middle-income countries have already met this target,  
76 developing countries particularly Africa will have to more than double present progress to reach  
77 this target (1). Despite the various international and national commitments on improving newborn

78 and maternal health (11), stillbirth has been grossly under-reported and invisible in policies and  
79 programs worldwide (12). Like many countries in SSA, stillbirth is not routinely recorded and  
80 monitored in Ethiopia. It has reduced more slowly than maternal mortality and under 5 mortality,  
81 which remains invisible in the national policies (13).

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2  
3 82 The death of a fetus in utero or at birth is a devastating experience for the affected mothers and  
4  
5 83 families (14). It has been associated with extensive psychosocial consequences for parents and  
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8 84 family and has been linked to post-traumatic stress disorder, anxiety, depression, suicide, fear of  
9  
10 85 the next pregnancy, and reduced relation with their partner (15, 16). In Ethiopia, a study conducted  
11  
12 86 based on 2011 Ethiopian Demographic and Health Survey (EDHS) reported a stillbirth rate of 25.5  
13  
14 87 per 1000 births with significant variability across regions and the researchers recommended spatial  
15  
16 88 analysis to investigate the spatial variability of experiencing stillbirth in Ethiopia (17). A study  
17  
18 89 done at the Amhara region based on Ethiopian Mini Demographic and Health Survey 2014  
19  
20 90 reported that stillbirth rates of 85 per 1000 births (18). Previous studies on stillbirth showed that  
21  
22 91 rural residence, parity, educational status, mode of delivery, Antenatal Care (ANC) utilization, and  
23  
24 92 place of delivery, maternal nutritional status, and maternal obstetric factors were significantly  
25  
26 93 associated with stillbirth (14, 19-21).

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30  
31 94 Stillbirth rates have been significantly varied across and within the country (17, 22). It is highly  
32  
33 95 concentrated among rural, poor, and marginalized societies (12). Thus, the identification of  
34  
35 96 geographic areas with a high rate of stillbirth using Geographic Information System (GIS) and  
36  
37 97 Spatial Scan statistical analysis (SaTScan) has become fundamental to guide targeted public health  
38  
39 98 interventions. However, previous studies in Ethiopia have been focused on the prevalence and  
40  
41 99 associated factors of stillbirth (18, 23, 24) by using standard logistic regression models despite the  
42  
43 100 hierarchical structure of EDHS data. These could result in a biased estimate since the data were  
44  
45 101 nested within-cluster and violates the independent assumption (17). The findings of these studies  
46  
47 102 are insufficient and limited to capture the spatial distribution of stillbirth and community-level  
48  
49 103 factors associated with stillbirth. Therefore, this study aimed to investigate the spatial distribution  
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51 104 and associated factors of stillbirth in Ethiopia using spatial and multilevel Analysis.  
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## 105 **Method and materials**

### 106 **Study design, setting and period**

107 Secondary data analysis was done based on the EDHS 2016 data. This survey is the fourth survey  
108 conducted in Ethiopia, situated in the Horn of Africa. Ethiopia is the 13<sup>th</sup> in the world and 2<sup>nd</sup> in  
109 Africa's most populous country. It has 9 regional states (Afar, Amhara, Benishangul-Gumuz,  
110 Gambela, Harari, Oromia, Somali, Southern Nations, Nationalities, and People's Region (SNNP)  
111 and Tigray) and two Administrative Cities (Addis Ababa and Dire-Dawa). In Ethiopia, 84% of  
112 the population lives in rural areas and more than 80% of the country's total population lives in the  
113 regional states of Amhara, Oromia, and SNNP(25). The number of hospitals in Ethiopia varies  
114 across regions in response to differences in population size (26).

### 115 **Sample and population**

116 All births from reproductive age women within five years before the survey in Ethiopia were the  
117 source of population, whereas all births from reproductive-age women in the selected Enumeration  
118 Areas (EAs) within five years before the survey was the study population. In EDHS, a two-stage  
119 stratified cluster sampling technique selected in two stages using the 2007 Population and Housing  
120 Census (PHC) as a sampling frame. Stratification was achieved by separating each region into  
121 urban and rural areas. In total, 21 sampling strata have been created. In the first stage, 645 EAs  
122 (202 in urban areas) were chosen with probability sampling proportional to the size of the EAs  
123 with independent selection in each sampling stratum. In the second stage, on average 28  
124 households were systematically selected. The detailed sampling procedure was presented in the  
125 full EDHS 2016 report (27).

## 126 **Study variables**

### 127 *Outcome variables*

128 The 2016 EDHS asked women to report any pregnancy loss that occurred in the five years  
129 preceding the survey. The duration of pregnancy was reported for every pregnancy which did not  
130 result in a live birth. Pregnancy losses occurring after seven completed months of gestation were  
131 considered as stillbirth (28). The response variable for this study was the occurrence of stillbirth  
132 among mothers of childbearing age. The response variable for the  $i^{\text{th}}$  mother was represented by  
133 a random variable  $Y_i$  with two possible values coded as 1 and 0. So, the response variable of the  
134  $i^{\text{th}}$  mother  $Y_i$  was measured as a dichotomous variable with possible values  $Y_i = 1$ , if  $i^{\text{th}}$  mother had  
135 experienced stillbirth and  $Y_i = 0$  if mother had a live birth.

### 136 *Independent variables*

137 Consistent with the objective of the study and given the hierarchical structure of EDHS data where  
138 women were nested within the cluster/community, two levels of independent variables were  
139 considered. Level 1 contained individual socio-demographic and economic factors (age, marital  
140 status, religion, maternal education, paternal education, wealth index, maternal occupation,  
141 maternal working Status), pregnancy and pregnancy-related factors (mother's height, Body Mass  
142 Index (BMI), ANC visit, parity, preceding birth interval, contraceptive use, place of delivery, birth  
143 order, mode of delivery, wanted pregnancy, maternal anemia), and behavioral factors (smoking,  
144 and media exposure). The community-level factors; region, residence, community women  
145 education, community poverty, community media exposure, and community ANC utilization were  
146 considered as level 2 variables. In EDHS data, there is no variable collected at the cluster level  
147 except region and place of residence. Therefore, Individual-level variables were aggregated at the  
148 cluster level to generate community-level variables, to see whether cluster-level variables had an

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2  
3 149 effect on stillbirth and were categorized as higher or lower based on national median value since  
4  
5 150 it was not normally distributed. The community-level variables used in the analysis were from two  
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7  
8 151 sources; direct community-level variables that were used without any manipulation and aggregated  
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10 152 community-level variables created by aggregating individual-level variables at the cluster level.  
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### 13 153 **Data collection procedure**

14  
15  
16 154 The study was conducted based on the 2016 EDHS data and geographic coordinate data by  
17  
18 155 accessing these data from the DHS program official database [www.measuredhs.com](http://www.measuredhs.com) after  
19  
20 156 permission was granted through an online request by explaining the objective of our study. We  
21  
22  
23 157 used the EDHS 2016 Birth Record data (BR) set for this study. Geographic coordinate data  
24  
25 158 (longitude and latitude coordinates) were taken at the cluster level/ enumeration area level.  
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### 28 159 **Data management and analysis**

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31 160 The data were weighted using sampling weight, primary sampling unit, and strata before any  
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33 161 statistical analysis to restore the representativeness of the survey and take into account the  
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36 162 sampling design to get reliable statistical estimates. The sampling statisticians determine how  
37  
38 163 many samples are needed in each region to get reliable estimates, in EDHS, some regions were  
39  
40 164 oversampled, and some regions under sampled. To get statistics that are representative of Ethiopia,  
41  
42  
43 165 the distribution of women in the sample need to be weighted (mathematically adjusted) such that  
44  
45 166 it resembles the true distribution in Ethiopia by using sampling weight (v005), primary sampling  
46  
47 167 unit (v021) and strata (v022). Descriptive and summary statistics were conducted using STATA  
48  
49 168 version 14 software.  
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52 169 In EDHS data, women are nested within a cluster and we expect that women within the same  
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55 170 cluster were more similar to each other than women in the rest of the country. It violates the  
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3 171 standard regression model assumptions, these are the independence of observations and equal  
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5 172 variance across clusters assumptions. This implies that the need to take into account the between  
6  
7 173 cluster variability by using an advanced model. Therefore, a multilevel random intercept logistic  
8  
9 174 regression model was fitted to estimate the association between the individual and community  
10  
11 175 level variables and the likelihood of experiencing stillbirth. Model comparison was done based on  
12  
13 176 Deviance (The negative 2 log-likelihood (-2LL)) since the models were nested. Likelihood Ratio  
14  
15 177 test (LR), Intra-cluster Correlation Coefficient (ICC), Median Odds Ratio (MOR), and  
16  
17 178 Proportional Change in Variance (PCV) were computed to measure the variation between clusters.  
18  
19 179 The ICC quantifies the degree of heterogeneity of stillbirth between clusters (the proportion of the  
20  
21 180 total observed variation in stillbirth that is attributable to between cluster variations).

$$181 \quad ICC = \frac{\sigma^2}{(\sigma^2 + \pi^2/3)} (29)$$

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29 182 MOR is used to quantify the variation or heterogeneity in stillbirth between clusters and is defined  
30  
31 183 as the median value of the odds ratio between the cluster at high risk of stillbirth and cluster at  
32  
33 184 lower risk when randomly picking out two clusters /EAs.

$$34 \quad MOR = \exp(\sqrt{2 * \partial^2 * 0.6745}) \sim MOR = \exp(0.95 * \partial) (30)$$

35  
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38  
39 186  $\partial^2$  indicates that cluster variance

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41  
42 187 PCV measures the total variation of stillbirth attributed to individual-level factors and community-  
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44 188 level factors in the multilevel model as compared to the null model.

$$45 \quad PCV = \frac{\text{var}(\text{null model}) - \text{var}(\text{full model})}{\text{var}(\text{null model})}$$

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53 191 Multilevel random intercept logistic regression was used to analyze factors associated with  
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55 192 stillbirth at two levels to take into account the hierarchical nature of the data, at individual and

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3 193 community levels. Four models were constructed for the multilevel logistic regression analysis.  
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5 194 The first model (a multilevel random intercept logistic regression model without covariates) was  
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8 195 the null model without any explanatory variables, to determine the extent of cluster variation on  
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10 196 stillbirth. The second model (a multilevel model with level 1 independent variables) was adjusted  
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12 197 with individual-level variables; the third model (a multilevel model with level 2 variables) was  
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14 198 adjusted for community-level variables while the fourth model was fitted with both individual and  
15  
16 199 community level variables simultaneously. The final model was the best-fitted model since it had  
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18 200 the lowest deviance value.

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21  
22 201 Variables with p-value  $\leq 0.2$  in the bi-variable analysis for both individual and community-level  
23  
24 202 factors were fitted in the multivariable model. Adjusted Odds Ratio (AOR) with a 95% Confidence  
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26 203 Interval (CI) and p-value  $< 0.05$  in the multivariable model were used to declare significantly  
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28 204 associated factors of stillbirth. Multi-collinearity was checked using the Variance Inflation Factor  
29  
30 205 (VIF) which indicates that there is no multicollinearity because all variables have  $VIF < 5$  and  
31  
32 206 tolerance greater than 0.1.

### 33 34 35 36 207 ***Spatial analysis***

37  
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39 208 For the spatial analysis, ArcGIS version 10.6 software and SaTScan version 9.6 software were  
40  
41 209 used. Incremental spatial autocorrelation was done to get the maximum peak distance where  
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43 210 stillbirth clustering is more pronounced. It measures spatial autocorrelation for a series of  
44  
45 211 distances and creates a line graph of those distances and their corresponding Z-score. The  
46  
47 212 maximum peak distance is the distance where maximum spatial autocorrelation occurs and this  
48  
49 213 was used as a distance band for hotspot analysis. Totally 10 distance bands were detected by a  
50  
51 214 beginning distance of 121,803 meters, the first peak of 136,586.06 meters, and the maximum peak  
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3 215 (clustering) was observed at 166152.17 meters. The maximum peak was used as the distance band  
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5 216 for the hotspot analysis.  
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### 8 217 ***Spatial autocorrelation analysis***

10  
11 218 The spatial autocorrelation (Global Moran's I) was done to test whether there was significant  
12  
13 219 spatial clustering of stillbirth or not. Moran's I is a statistic that measures whether stillbirth patterns  
14  
15 220 were dispersed, clustered, or randomly distributed in the study area (31) by taking the entire data  
16  
17 221 set and produce a single output value which ranges from -1 to +1. Moran's I values close to -1  
18  
19 222 indicate spatial distribution of stillbirth was dispersed, whereas Moran's I close to +1 indicate  
20  
21 223 spatial distribution of stillbirth was clustered and stillbirth distributed randomly if I value is 0. A  
22  
23 224 statistically significant Moran's I (p-value < 0.05) leads to rejection of the null hypothesis (stillbirth  
24  
25 225 is randomly distributed) and indicates the presence of significant spatial autocorrelation/spatial  
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27 226 dependence.  
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### 33 227 **Hot spot analysis of stillbirth**

34  
35 228 Anselin Local Moran's I is used to investigate whether the local level cluster is positively  
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37 229 correlated (high-high and low-low) clusters or negatively correlated (high-low and low-high)  
38  
39 230 regarding the prevalence of stillbirth. A positive Moran's I value indicated that a case had  
40  
41 231 neighboring cases with similar values. A negative value of Moran's I indicated that a case was  
42  
43 232 surrounded by cases with dissimilar values (32). Spatial scan statistical analysis (SaTScan) using  
44  
45 233 the Bernoulli model was employed to test for the presence of statistically significant spatial clusters  
46  
47 234 of stillbirth using Kuldorff's SaTScan version 9.6 software. The spatial scan statistic uses a circular  
48  
49 235 scanning window that moves across the study area. Women who had stillbirth were taken as cases  
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51 236 and those who had a live birth as controls to fit the Bernoulli model. The numbers of cases in each  
52  
53 237 location had Bernoulli distribution and the model required data for cases, controls, and geographic  
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3 238 coordinates. The default maximum spatial cluster size of <50% of the population was used, as an  
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5 239 upper limit, which allowed both small and large clusters to be detected and ignored clusters that  
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8 240 contained more than the maximum limit.  
9

10 241 For each potential cluster, a likelihood ratio test statistic and the p-value was used to determine if  
11  
12 242 the number of observed stillbirth within the potential cluster was significantly higher than expected  
13  
14  
15 243 or not. The scanning window with maximum likelihood was the most likely performing cluster,  
16  
17 244 and the p-value was assigned to each cluster using Monte Carlo hypothesis testing by comparing  
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19  
20 245 the rank of the maximum likelihood from the real data with the maximum likelihood from the  
21  
22 246 random datasets. The primary and secondary clusters were identified and assigned p-values and  
23  
24 247 ranked based on their likelihood ratio test, based on 999 Monte Carlo replications(33).  
25  
26

### 27 248 *Spatial interpolation*

29  
30 249 It is very expensive and laborious to collect reliable data in all areas of the country to know the  
31  
32 250 burden of a certain event. Therefore, part of a certain area can be predicted by using observed data  
33  
34  
35 251 using a method called interpolation. The spatial interpolation technique was used to predict  
36  
37 252 stillbirth on the un-sampled areas in the country based on sampled EAs measurements. There are  
38  
39 253 various deterministic and geostatistical interpolation methods. Among all of the methods, ordinary  
40  
41  
42 254 Kriging and empirical Bayesian Kriging are considered the best method since it incorporates the  
43  
44 255 spatial autocorrelation and it statistically optimizes the weight (34). Ordinary Kriging spatial  
45  
46 256 interpolation method was selected for this study for predictions of stillbirth in unobserved areas of  
47  
48  
49 257 Ethiopia since it had the smallest Root Mean Square Error (RMSE) value and residuals.  
50

### 51 258 **Patient and public involvement statement**

52  
53 259 Patients and public involvement were not involved in this study since we have conducted a  
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55  
56 260 secondary data analysis based on already available DHS data which was collected to provide  
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3 261 estimates of common health and health-related indicators. For the original project from which data  
4  
5 262 were obtained, patient and public involvement statements were essential since biomarker data such  
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7  
8 263 as anemia, HIV testing, and anthropometric measurements were collected (35).  
9

## 10 11 264 **Ethical consideration**

12  
13  
14 265 Ethical clearance was obtained from the Institutional Review Board of Institute of Public Health,  
15  
16 266 CMHS, and the University of Gondar. Permission for data access was obtained from major  
17  
18 267 demographic and health survey through an online request from <http://www.dhsprogram.com>. The  
19  
20  
21 268 data used for this study were publicly available with no personal identifier.  
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## 270 **Result**

### 271 **Socio-demographic and economic characteristics of respondents**

272 A total of 11,375 women who gave birth within five years preceding the survey were included for  
273 the analysis. Of 11,375 of women, 10,149 (89.2%) were rural residents, and a half (49.2%) of the  
274 respondent were aged 20-29 years. Regarding maternal education status, 7,606 (66.9%) had no  
275 formal education (Table 1).

### 276 **Pregnancy and maternal health service-related characteristics of respondents**

277 Among 11375 women, two-third (65.7%) of the women were delivered at home and 194 (1.7%)  
278 gave birth via cesarean section. About 2,602 (22.9 %) had no ANC visit during pregnancy (Table  
279 2). The overall rate of stillbirth in Ethiopia was found to be 9.2 [95% CI; 7.9, 11.1] per 1000 births.  
280 It was highest in the Amhara region and lowest in Diredawa (Figure 1).

## 281 **Spatial analysis**

### 282 **Spatial Global autocorrelation**

283 The spatial analysis revealed that the spatial distribution of stillbirth was significantly varied across  
284 the country with Global Moran's I value of 0.017 ( $p < 0.05$ ). The clustered patterns (on the right  
285 sides) show high rates of stillbirth occurred over the study area. The outputs have automatically  
286 generated keys on the right and left sides of each panel. Given the z-score of 2.4 indicated that  
287 there is less than 1.5% likelihood that this clustered pattern could be the result of chance. The  
288 bright red and blue colors to the end tails indicate an increased significance level (Figure 2).

## 289 **Hotspot analysis of stillbirth**

290 In the cluster and outlier analysis, the significant cluster was detected in Tigray, Amhara, Oromia,  
291 Addis Ababa, SNNPR, Benishangul-Gumuz, Somali, and Gambella regions. Hot spot areas for  
292 stillbirth were found in southwest Somali, southern Amhara, and west SNNPR, while the cold spot  
293 areas of stillbirth were found in the south and west Benishangul-Gumuz, Addis Ababa, southwest  
294 of Oromia region, west Gambella and Northeast SNNPR regions. The outliers were found in the  
295 central and southern parts of Amhara, north Tigray, southeast Gambella, and Somali regions  
296 (Figure 3).

297 In the Spatial scan statistical analysis, a total of 56 significant clusters of stillbirth were identified,  
298 of which 22 clusters were primary (most likely clusters) and 34 were secondary clusters. The  
299 primary cluster spatial window was located in the northeast Somali region centered at 7.829198  
300 N, 43.706264 E of geographic location with a 166.48 km radius, a Relative Risk (RR) of 22.5 and  
301 Log-Likelihood ratio (LLR) of 13.4, at  $p < 0.001$ . It showed that women within the spatial window  
302 had 22.5 times higher risk of experiencing stillbirth than women outside the window. The  
303 secondary cluster scanning spatial window was located in the border area of the south Amhara  
304 region and the north Oromia region, and southern Afar region (Table 3). The red circular ring  
305 indicates that the most statistically significant spatial window contains the primary cluster of  
306 stillbirth. Women within the circular window had a higher likelihood of experiencing stillbirth  
307 than women outside the spatial window (Figure 4).

## 308 **Interpolation of stillbirth**

309 North West Tigray, northern and North West Oromia, east and south Amhara, east Benishangul,  
310 East Gambella, Harari, and Northwest SNNPR were detected as predicted most risky areas of

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3 311 stillbirth compared to other regions. The predicted low-risk areas of stillbirth were identified in  
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5 312 Oromia, Afar, and Gambella regions (Figure 5).  
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### 8 313 **Factors associated with stillbirth**

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10  
11 314 ICC and LR tests were checked, and the multilevel model was the best-fitted model for the data.  
12  
13 315 Therefore, the two-level multilevel logistic regression model was used to get an unbiased standard  
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15 316 error and to make a valid inference. Deviance was used for model comparison and the final model  
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17 317 was the best-fitted model with the lowest deviance value (Table 4).  
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20  
21 318 The ICC-value was 47% in the null model, it showed that 47% of the total variability for stillbirth  
22  
23 319 was attributable to the between clusters/EA variability, with the remaining 53% attributable to the  
24  
25 320 individual differences. Moreover, in the null model, the MOR was 5.03 (95% CI: 3.19-7.13) and  
26  
27 321 PCV was 15.3%, it revealed that if we randomly select women from two different clusters, women  
28  
29 322 at the cluster with a higher risk of stillbirth had 5.03 times higher odds of experiencing stillbirth  
30  
31 323 as compared with women at cluster with a lower risk of stillbirth. About 15.3% of the variability  
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33 324 in stillbirth was explained by the full model (Table 4).  
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36  
37 325 In the multivariable multilevel logistic regression model; residence, region, religion, preceding  
38  
39 326 birth interval, cesarean delivery, maternal height, ANC visit, and maternal education were  
40  
41 327 significantly associated with stillbirth. At the community level (level 2), two variables were  
42  
43 328 significantly associated with stillbirth. The odds of experiencing stillbirth among women residing  
44  
45 329 in rural areas were 4.83 times (AOR= 4.83, 95% CI: 1.44-16.19) higher than women residing in  
46  
47 330 urban areas. The odds of experiencing stillbirth among women in Tigray, Afar, Somali, SNNPR,  
48  
49 331 Benishangul, Gambella, and Harari regions were not significantly different from that of  
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51 332 experiencing stillbirth in Amhara region. The odds of experiencing stillbirth among women who  
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3 333 live in the Oromia region were decreased by 75% (AOR= 0.25, 95% CI: 0.07- 0.83) compared to  
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5 334 women in the Amhara region.

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8 335 At the individual level, six variables were significantly associated with stillbirth. Women who  
9  
10 336 were protestant and catholic religious followers had 89% (AOR= 0.11, 95% CI: 0.03- 0.37)  
11  
12 337 decreased odds of experiencing stillbirth than orthodox Christian religious followers. Women's  
13  
14 338 educational level was significantly associated with stillbirth. Though women attained secondary  
15  
16 339 education and higher had no significant difference in experiencing stillbirth, the odds of  
17  
18 340 experiencing stillbirth among women who attained primary education were decreased by 61%  
19  
20 341 (AOR= 0.39, 95% CI: 0.20 - 0.74) compared to women who didn't have formal education.  
21  
22 342 Besides, women who had no ANC visits during pregnancy had 2.77 times (AOR= 2.77, 95% CI:  
23  
24 343 1.70 - 4.51) higher odds of experiencing stillbirth than women who had 4 and above ANC visits  
25  
26 344 during pregnancy. Women who gave birth via cesarean delivery had 5.07 times (AOR= 5.07, 95%  
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28 345 CI: 1.65– 15.58) higher odds of experiencing stillbirth than women who gave birth through vaginal  
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30 346 delivery.

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36 347 The preceding birth interval was a significant predictor of stillbirth. Women having preceding birth  
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38 348 interval less than 24 months had 1.93 times (AOR= 1.93, 95% CI: 1.20 – 3.10) higher odds of  
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40 349 experiencing stillbirth compared to women having preceding birth interval 24 months and above.  
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42 350 Besides, mothers whose height less than 150 cm had 2.73 times (AOR= 2.73, 95% CI: 1.50 -  
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44 351 4.97) higher odds of experiencing stillbirth compared to those mothers whose height greater than  
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46 352 or equal to 150 cm (Table 4).  
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## 353 Discussion

354 The stillbirth rate in Ethiopia was 9.2 per 1000 births with marked spatial heterogeneity. The  
355 spatial distribution of stillbirth was significantly varied across the country. The SaTScan analysis  
356 detected a total of three statistically significant spatial windows with high stillbirth rates. The  
357 significant hotspot areas of stillbirth were identified in the northeast Somali, south Afar, south  
358 Amhara, and north Oromia regions. The possible explanation might be due to the reason that these  
359 areas are more of pastoralist areas where people did not have permanent residence, due to this  
360 relatively health facilities are not accessible and available in these areas compared to agrarian  
361 people and cities. Besides, these areas are more rural, which had a poor network of health facilities.  
362 Also, this could be attributed to the disparity in the distribution of maternal health service, and the  
363 inaccessibility of infrastructure in the border areas of regions (36). Whereas, the cold spot areas  
364 of stillbirth were found in south and west Benishangul-Gumuz, Addis Ababa, southwest of Oromia  
365 region, west Gambella and Northeast SNNPR. This could be due to these areas are relatively had  
366 better availability and accessibility of health services (Addis Ababa, Dire-Dawa) (37). Therefore,  
367 women are more likely to use ANC and institutional delivery services, this could contribute to the  
368 decrement of antepartum and intrapartum stillbirth. This result gives insight for public health  
369 planners and programmers for designing effective public health interventions to identified hotspot  
370 areas of stillbirth.

371 In the multilevel analysis, different individual and community factors were significantly associated  
372 with stillbirth. Among the community level variables, it was found that the odds of stillbirth  
373 women residing in the Oromia region were lower than in the Amhara region. This might be due to  
374 the availability and accessibility of maternal health facilities since Oromia regions are relatively  
375 around Addis Ababa and Dire-Dawa in which health facilities are accessible compared to other



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3 376 regions. However, the high turnover of health professionals in the Amhara region, particularly  
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5 377 physicians did not remain in the districts and choose to work in the capital city of Ethiopia (Addis  
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7 378 Ababa), which may lead to the high intrapartum stillbirth rate in the districts due to the lack of  
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10 379 trained health professionals (38). The study has shown that the odds of stillbirth were higher among  
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12 380 women who lived in rural areas. This was consistent with previous study findings in South Africa  
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14 381 (39), African Great lake Regions (12), Nigeria (19), Northern Ghana (14), and Ethiopia (17). This  
15  
16 382 could be attributed to the disparity in the mother's health care access, availability, and accessibility  
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18 383 of health facilities. Women in urban areas are relatively had improved health-seeking behavior  
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20 384 than rural residents (36). Moreover, urban residents have better aware of maternal health services  
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22 385 but in rural areas, health facilities may not be easily reachable and may end up with poor pregnancy  
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24 386 outcomes during emergency cases (40).

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28 387 Amongst the individual-level factors, catholic and protestant religious followers were significantly  
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30 388 associated with lower odds of stillbirth compared to orthodox religious followers. This might be  
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32 389 related to the miss-perception of religious followers and could shape their reproductive health  
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34 390 decision making and practices, thereby govern the women's desire for using maternal health  
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36 391 services (41). It could also be related to the feeding practice of women. Commonly orthodox  
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38 392 religious followers may not eat animal products during pregnancy especially in the fasting period  
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40 393 this could result in poor fetal outcomes (42). Animal products are the main source of micro and  
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42 394 macronutrients like folate and iron. Orthodox religious followers considered giving birth at home  
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44 395 are blessed, using contraceptive as sinning and not expose their body to health professionals during  
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46 396 delivery this might be the possible reason which needs further qualitative study to explore the  
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48 397 detailed reasons.  
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3 398 This study noted lower odds of stillbirth among women who attained primary education compared  
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5 399 to women who had no formal education. This finding was in line with previous studies done in  
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8 400 Kenya (43) and Nigeria (19). It might be attributed to the reality that education can improve health  
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10 401 care seeing behavior such as timely decision to seek health care during pregnancy, give better care  
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12 402 for their health and their fetus, awareness of the danger sign of pregnancy, and maternal health  
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15 403 service utilization (44).

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17 404 The odds of stillbirth were higher among short stature women. A similar finding was reported in  
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19 405 Pakistan (21). This might be because short stature women are prone to adverse pregnancy  
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21 406 outcomes like Cephalo-Pelvic Disproportion (CPD), contracted pelvis, Intra-uterine Growth  
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23 407 Restriction (IUGR), Intra-uterine Fetal Death (IUFD) and birth injury. Short stature reflects  
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25 408 longstanding malnutrition or childhood infection that start in utero or during early childhood, this  
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27 409 kind of women may end up with poor pregnancy outcome unless we screen them as at-risk during  
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29 410 ANC follow up (45).

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34 411 Besides, having no ANC visit had a significant association with increased stillbirth. It was  
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36 412 consistent with previous findings in low-middle income countries (46), Ghana (47), and Kenya  
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38 413 (43). ANC follow up could help pregnant women to seek early treatment for her potential  
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40 414 pregnancy-associated complications and early screening of underlying medical conditions, this  
41  
42 415 could improve birth outcome (47, 48). On the other hand, women who did not have longer ANC  
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44 416 follow up may not be benefited from basic ANC packages.

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48 417 Consistent with studies done in Nigeria (19) and Gambia (49), caesarean deliveries in this study  
49  
50 418 showed higher odds of stillbirth when compared with normal vaginal delivery. This might be  
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52 419 because in developing countries including Ethiopia maternal health services were not available  
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54 420 and reachable, particularly caesarean section is done at tertiary hospitals. Though caesarean section

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3 421 is applied to save the life of new-born in high-risk pregnancies, in Ethiopia, more than 84% of the  
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5 422 population are rural residents and tertiary hospitals are not accessible due to transportation  
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7 423 problems resulting in not to save the baby's life because the caesarean section is not done at the  
8  
9 424 right time. Therefore, high-risk deliveries like birth asphyxia, malpresentation, fetal stress and  
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11 425 Antepartum Haemorrhage (APH) that needs caesarean delivery are referred from health centers  
12  
13 426 and health posts and may not reach at the right time to conduct caesarean section this could  
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15 427 contribute for the increased risk of stillbirth (50, 51). Overall, in Ethiopia, since majority of the  
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17 428 pregnant women are from rural areas caesarean sections are applied too late in hospitals since most  
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19 429 women are referred to from distant health facilities.  
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24 430 In this study, having a short inter-pregnancy interval was associated with higher odds of stillbirth.  
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26 431 This was consistent study findings in SSA (52), Bangladesh (53), and Amhara Region (18). This  
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28 432 could be explained by women who had short preceding birth interval are less able to provide  
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30 433 nourishment for the fetus because her body had less time to recuperate from the previous  
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32 434 pregnancy, and the uterus had less time to recover. Furthermore, lactation will deplete maternal  
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34 435 nutrition and may end up with poor pregnancy outcomes (53).  
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39 436 The strength of this study was using weighted data to make it representativeness at national and  
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41 437 regional levels: therefore, it can be generalized to all women who gave birth during the study  
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43 438 period in Ethiopia. Moreover, the use of GIS and SaTScan statistical tests helped to detect similar  
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45 439 and statistically significant hotspot areas of stillbirth and to design effective public health  
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47 440 programs. However, the SaTScan detect only circular clusters, irregularly shaped clusters were not  
48  
49 441 detected. Furthermore, the EDHS survey did not incorporate clinically confirmed data rather it  
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51 442 relied on mothers or caregivers report and might have the possibility of social desirability and  
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53 443 recall bias since stillbirth (27).  
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3 444 The findings of this study have valuable policy implications for health program design and  
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5 445 interventions. Stillbirth high-risk areas can be easily identified to make effective local  
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7 446 interventions. In general, these findings are of supreme importance for the minister of health,  
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10 447 regional health bureaus, and NGO's to design intervention programs to reduce stillbirth in  
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12 448 identified hotspot areas. To reduce the overall stillbirth rate in Ethiopia, Somali, Afar, Amhara,  
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14 449 and Oromia regions should emphasize the identified SaTScan clusters through developing local  
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16 450 interventional strategies like improving accessibility and availability of maternal health facility.  
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## 19 451 **Conclusions**

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22 452 In Ethiopia, stillbirth had spatial variations across the country. Statistically significant hotspot  
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24 453 areas of stillbirth were found in the central and southern parts of Amhara, west SNNPRs, south  
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26 454 and north Tigray, and south West Somali region. Whereas, cold spot areas were found in Addis  
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28 455 Ababa, central Oromia, and east SNNPRs. Short preceding birth interval, short maternal stature,  
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30 456 ANC visit, rural residence, region, religion, maternal education, and cesarean delivery were  
31  
32 457 significant predictors of stillbirth. This could have public health implications to target interventions  
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34 458 to identified hotspot areas of stillbirth and the government should scale up maternal health  
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36 459 programs in rural areas.  
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## 41 460 **Abbreviations**

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44 461 ANC; Antenatal Care, AOR; Adjusted Odds Ratio, ARR; Annual Rate of Reduction, BMI; Body  
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46 462 Mass Index, CI; Confidence Interval, COR; Crude Odds Ratio, CSA; Central Statistical Agency,  
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48 463 DHS; Demographic Health Survey, EA; Enumeration Area, EDHS; Ethiopian Demographic  
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50 464 Health Survey, GIS; Geographic Information System, ICC; Intra-cluster Correlation Coefficient,  
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52 465 IUFD; Intra Uterine Fetal Death, IUGR; Intra Uterine Growth Restriction, LLR; log-  
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3 466 likelihood Ratio, LR; Likelihood Ratio, MOR; Median Odds Ratio, PCV; Proportional Change in  
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5 467 Variance, PHC; Population and Housing census, SBR; Stillbirth Rate, SNNPRs; Southern Nations  
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7  
8 468 and Nationality People Regional state, WHO; World Health Organization.  
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## 12 469 **Declarations**

### 15 470 **Availability of data and materials**

18 471 Data is available online and you can access it from [www.measuredhs.com](http://www.measuredhs.com).  
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20

### 21 472 **Competing Interests**

24 473 Authors declare that they have no conflict of interest  
25  
26

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31  
32

### 33 476 **Authors' contribution**

36 477 Conceptualization: Getayeneh Antehunegn Tesema  
37

38 478 Data curation: Getayeneh Antehunegn Tesema  
39

40 479 Funding acquisition: Getayeneh Antehunegn Tesema  
41

42 480 Investigation: Getayeneh Antehunegn Tesema, Lemma Derseh, Solomon Gedlu  
43

44 481 Methodology: Getayeneh Antehunegn Tesema, Lemma Derseh, Solomon Gedlu  
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47 482 Project administration: Getayeneh Antehunegn Tesema, Lemma Derseh, Solomon Gedlu  
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49 483 Resources: Getayeneh Antehunegn Tesema, Lemma Derseh, Solomon Gedlu  
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51 484 Software: Getayeneh Antehunegn Tesema, Lemma Derseh, Solomon Gedlu  
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54 485 Supervision: Getayeneh Antehunegn Tesema, Lemma Derseh, Solomon Gedlu  
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3 486 Validation: Getayeneh Antehunegn Tesema, Lemma Derseh, Solomon Gedlu  
4  
5 487 Visualization: Getayeneh Antehunegn Tesema, Lemma Derseh, Solomon Gedlu  
6  
7  
8 488 Writing: Getayeneh Antehunegn Tesema  
9  
10 489 Writing – review and editing: Getayeneh Antehunegn Tesema, Lemma Derseh, Solomon Gedlu  
11  
12

### 13 490 **Consent for publication**

14  
15  
16 491 Not applicable  
17

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23  
24

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614 Table 1: Socio-demographic characteristics of women who gave birth within 5 years before the  
 615 survey in Ethiopia, 2016.

Variables	Category	Unweighted frequency (%)	Weighted frequency (%)
Residence	Urban	1,994 (18.0)	1,226 (10.8)
	Rural	9,091 (82.0)	10,149 (89.2)
Region	Tigray	1,021 (9.2)	709 (6.2)
	Afar	1,102 (9.9)	119 (1.0)
	Amhara	1,004 (9.1)	2,122 (18.7)
	Oromia	2,617 (23.6)	5,280 (46.4)
	Somali	1,623 (14.6)	554 (4.9)
	Benishangul Gumuz	962 (8.7)	133 (1.2)
	SNNPR	1,334 (12.0)	2,402 (21.1)
	Gambella	789 (7.1)	29 (0.3)
	Harari	633 (5.7)	27 (0.2)
Religion	Orthodox	3,127 (28.2)	3,844 (33.8)
	Muslim	5,710 (51.5)	4,696 (41.3)
	Catholic and protestant	2,248 (20.3)	2,835 (24.9)
Maternal education	No education	7,241 (65.3)	7,606 (66.9)
	Primary education	2,708 (24.4)	2,961 (26.0)
	Secondary and higher education	1,136 (10.3)	808 (7.1)
Maternal age	<20 year	395 (3.6)	374 (3.3)
	20-29 year	5,556 (50.1)	5,599 (49.2)
	30-39 year	4,234 (38.2)	4,381 (38.5)
	≥40 year	900 (8.1)	1,021 (9.0)
Husband education	No education	5,331 (51.2)	5,339 (49.6)
	Primary education	3,260 (31.3)	4,139 (38.5)

	Secondary and higher education	1,817 (17.5)	1,284 (11.9)
Maternal occupation status	Had occupation	6,584 (59.4)	6,352 (55.8)
	No occupation	4,501 (40.6)	5,023 (44.2)
Wealth status	Poor	6,081 (54.9)	5,360 (47.1)
	Middle	1,512 (13.6)	2,318 (20.4)
	Rich	3,492 (31.5)	3,697 (32.5)

616

617 Table 2: pregnancy and health service-related characteristics of women who gave birth within 5  
618 years preceding the survey in Ethiopia, 2016.

Variable	Category	Unweighted frequency (%)	Weighted frequency (%)
Pregnancy and maternal service-related factors			
Place of delivery	Home	6,737 (60.8)	7,468 (65.7)
	Health facility	4,348 (39.2)	3,907 (34.3)
Parity	Only one birth	1,435 (13.0)	1,419 (12.5)
	2-4 birth	5,042 (45.5)	5,022 (44.1)
	≥5 birth	4,608 (41.5)	4,934 (43.4)
Birth order	1-3	5,806 (52.4)	5,703 (50.1)
	4-5	2,584 (23.3)	2,655 (23.4)
	≥6	2,695 (24.3)	3,017 (26.5)
BMI	Thin	2,981 (26.9)	2,483 (21.8)
	Normal	7,106 (64.1)	8,164 (71.8)
	Overweight	998 (9.0)	728 (6.4)
Maternal height	< 150 cm	1,018 (9.2)	1,228 (10.8)
	≥150 cm	10,067 (90.8)	10,147 (89.2)
ANC visit	No ANC visit	2,321 (20.9)	2,602 (22.9)
	1-3 ANC visit	1,917 (17.3)	2,145 (18.9)
	≥ 4 ANC visit	6,847 (61.8)	6,628 (58.2)

Preceding birth interval	< 24 month	2,347 (21.2)	2,145 (18.9)
	≥24 month	8,738 (78.8)	9,230 (81.1)
Maternal anemia	Not anemic	6,696 (60.4)	7,590 (66.7)
	Anemic	4,389 (39.6)	3,785 (33.3)
Ever use of contraceptive	Yes	4,101 (37.0)	5,238 (46.0)
	No	6,984 (63.0)	6,137 (54.0)
Mode of delivery	Vaginal delivery	10,813 (97.5)	11,181 (98.3)
	Cesarean delivery	272 (2.5)	194 (1.7)
Number of gestation	Single	10,798 (97.4)	11,072 (97.3)
	Twin	287 (2.6)	303 (2.7)
Behavioral and community-level factors			
Smoking cigarettes	Yes	10,976 (99.0)	11,286 (99.2)
	No	109 (1.0)	89 (0.8)
Media exposure	Yes	9,747 (87.9)	10,020 (88.1)
	No	1,338 (12.1)	1,355 (11.9)
Community media exposure	Lower	5,503 (49.6)	4,640 (40.8)
	Higher	5,582 (50.4)	6,735 (59.2)
Community poverty	Lower	6,909 (62.3)	7,617 (67.0)
	Higher	4,176 (37.7)	3,758 (33.0)
Community ANC utilization	Lower	5,387 (48.6)	6,665 (58.6)
	Higher	5,698 (51.4)	4,710 (41.4)
Community women education	Lower	6,909 (62.3)	7,617 (67.0)
	Higher	4,176 (37.7)	3,758 (33.0)

619

620 Table 3: SaTScan analysis results of stillbirth in Ethiopia, 2016.

Cluster	Enumeration area(cluster)identified	Coordinate/radius	Population	Case	RR	LLR	p-value
1	497, 95, 198, 521, 588, 553, 458, 171, 214, 251, 573, 239, 116, 22, 543, 490, 492, 92, 568, 33, 277, 527	(7.829198 N, 43.706264 E) / 166.48 km	532	17	22.5	13.4	0.00069

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2	350, 229, 482, 531, 218, 510, 206, 10, 474, 267, 375, 423, 120, 176, 572, 517, 460, 24, 403, 429, 38, 3, 485, 456, 274, 167, 463, 112, 399, 532	(10.195460 N, 38.150574 E) / 142.05 km	384	14	3.6	8.84	0.04
3	564, 39, 230, 51	(9.555410 N, 40.326165 E) / 34.04 km	50	4	8.83	8.55	0.05

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622 Table 4: Multivariable multilevel logistic regression analysis result of both individual and  
 623 community-level factors associated with stillbirth in Ethiopia, EDHS 2016

Individual and community-level characteristics	Null model	Model II AOR (95% CI)	Model III AOR (95% CI)	Model IV AOR (95% CI)
<b>Residence</b>				
Urban			1	1
Rural			3.75[1.33, 10.56]	4.83[1.44, 16.19]*
<b>Region</b>				
Amhara			1	1
Tigray			0.54[0.18, 1.63]	0.63[0.19, 2.17]
Afar			0.28[0.08, 0.94]	0.24[0.05, 1.06]
Oromia			0.20[0.07, 0.55]	0.25[0.07, 0.83]*
Somali			0.84[0.32, 2.21]	0.98[0.27, 3.56]
Benishangul Gumuz			0.25[0.07, 0.92]	0.37[0.09, 1.53]
SNNPR			0.21[0.06, 0.69]	0.56[0.14, 2.18]
Gambella			0.26[0.06, 1.07]	1.02[0.20, 5.22]
Harari			0.71[0.19, 2.63]	0.77[0.16, 3.72]
<b>Religion</b>				
Orthodox		1		1
Muslim		0.59[0.31, 1.12]		0.75[0.32, 1.77]
Protestant/catholic		0.12[0.04, 0.35]		0.11[0.03, 0.37]**
<b>Wealth status</b>				
Poor		1.12[0.60, 2.11]		0.87[0.45, 1.69]
Middle		1.58[0.78, 3.19]		1.21[0.60, 2.47]
Rich		1		1
<b>Women's education</b>				
No education		1		1

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3	Primary education	0.39[0.21, 0.75]		0.39[0.20, 0.74]**	
4	Secondary and higher	0.49[0.18, 1.33]		0.63[0.23, 1.71]	
5	education				
6					
7	<b>Birth order</b>				
8					
9	1-3	1		1	
10	4-5	0.49[0.24, 1.03]		0.50[0.24, 1.03]	
11	6 and above	0.66[0.25, 1.75]		0.66[0.25, 1.73]	
12					
13	<b>Parity</b>				
14	Only one birth	1		1	
15	2-4 birth	0.68[0.37, 1.28]		0.65[0.35, 1.22]	
16	≥ 5 birth	0.45[0.16, 1.28]		0.42[0.15, 1.20]	
17					
18	<b>ANC visit</b>				
19	No ANC visit	2.85[1.76, 4.62]		2.77[1.70, 4.51]**	
20	1-3 visit	1.22[0.68, 2.19]		1.11[0.62, 2.00]	
21	4 and above visit	1		1	
22					
23	<b>Media exposure</b>				
24	Yes	1		1	
25	No	2.11[0.85, 5.24]		1.63[0.66, 4.04]	
26					
27	<b>Maternal height</b>				
28	< 150 cm	2.66[1.47, 4.79]		2.73[1.50, 4.97]**	
29	≥150 cm	1		1	
30					
31	<b>Contraceptive use</b>				
32	Yes	0.74[0.43, 1.26]		0.72[0.41, 1.24]	
33	No	1		1	
34					
35	<b>Preceding birth interval</b>				
36	<24 month	1.92[1.19, 3.07]		1.93[1.20, 3.10]**	
37	≥24 month	1		1	
38					
39	<b>Mode of delivery</b>				
40	Vaginal delivery	1		1	
41	Cesarean delivery	4.00[1.35, 11.85]		5.07[1.65, 15.58]**	
42					
43	<b>Community media exposure</b>				
44	Lower community exposure		1	1	
45	Higher community exposure		0.96[0.51, 1.80]	1.02[0.51, 2.04]	
46					
47	<b>Community women's</b>				
48	<b>education</b>				
49	Lower community education		1	1	
50	Higher community education		1.28[0.61,2.71]	1.88[0.80, 4.42]	
51					
52	<b>Constant</b>	0.003[0.002, 0.005]	0.003[0.001, 0.01]	0.002[0.0005,0.0096]	0.001[0.0002, 0.01]
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3 **Model comparison and**  
4 **Random effects**

6 ICC	0.47(0.35, 0.59)			
7 Log-likelihood	-599.02	-551.2	-584.36	-540.50
8 Deviance	1198.04	1102.2	1168.72	1081
10 PCV	Ref	21.5	9.3	15.3
11 MOR	5.03[3.19, 7.13]	5.91[3.44, 8.90]	4.66[2.84, 6.69]	5.69[3.31, 8.56]

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13 624 \*AOR; Adjusted Odds Ratio, CI; Confidence Interval, ICC; Intra-class Correlation, MOR;

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15 625 Median Odds Ration, PCV; Proportional Change in Variance.

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3 **627 Figure legends:**

4 **628** Figure 1: The stillbirth rates across regions in Ethiopia, 2016

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8 **629** Figure 2: Global spatial autocorrelation of stillbirths in Ethiopia, 2016

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11 **630** Figure 3: Cluster and Outlier analysis of stillbirths in Ethiopia, 2016 (Source: Central Statistical  
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13 **631** Agency (CSA), Ethiopia, 2013)

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16 **632** Figure 4: Spatial Scan Statistical analysis of hotspot areas of stillbirth in Ethiopia, 2016 (Source:  
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18 **633** Central Statistical Agency (CSA), Ethiopia, 2013)

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21 **634** Figure 5: Kriging Interpolation of stillbirth in Ethiopia, 2016 (Source: Central Statistical Agency  
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23 **635** (CSA), Ethiopia, 2013)



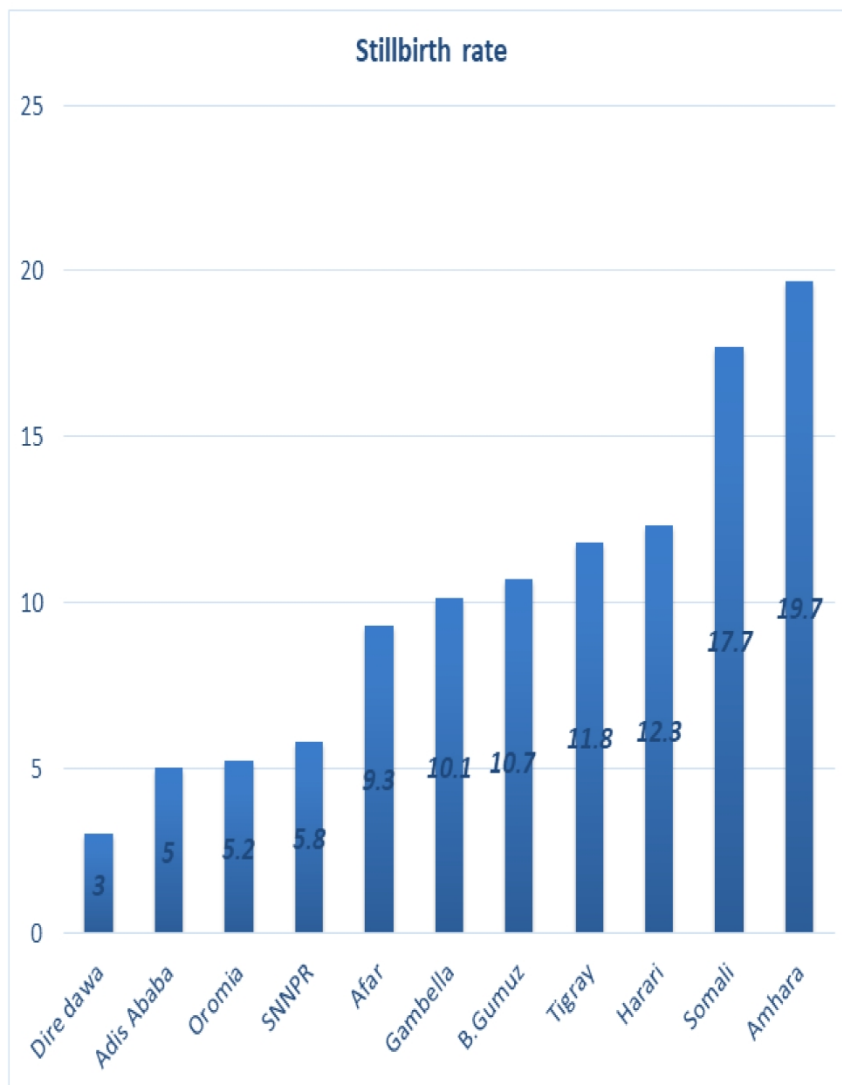


Figure 1: The stillbirth rate across regions in Ethiopia, 2016

215x279mm (600 x 600 DPI)

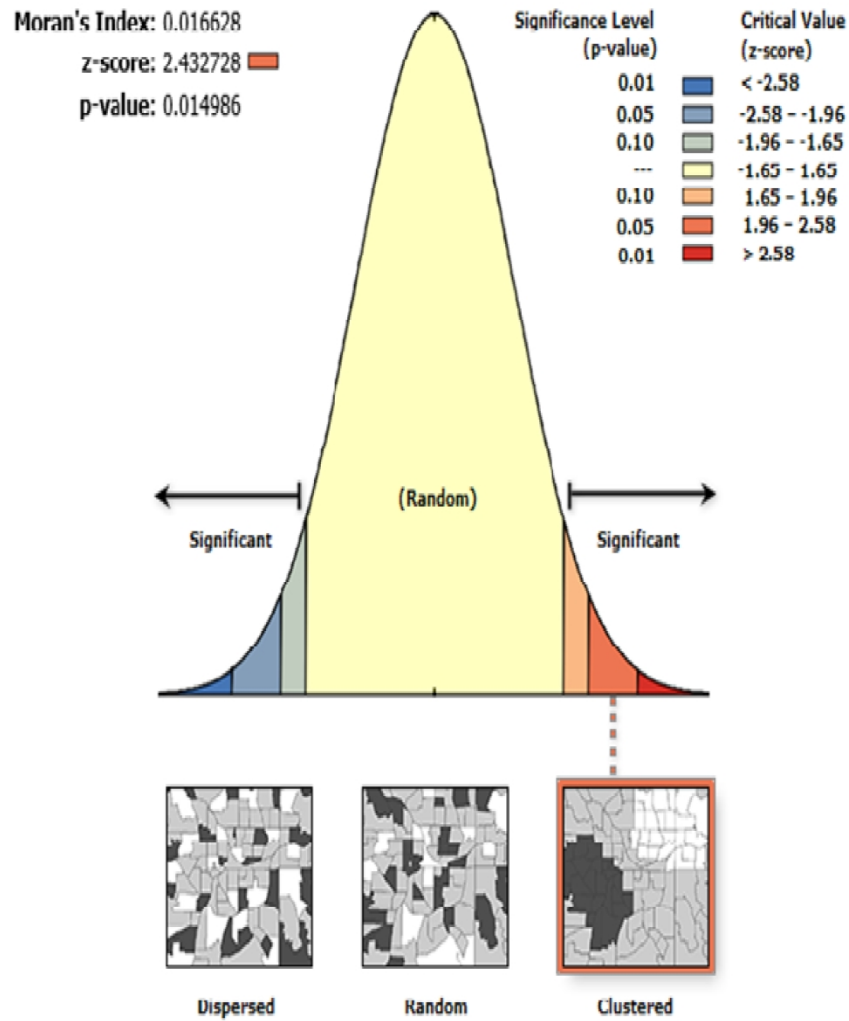


Figure 2: Global spatial autocorrelation of stillbirths in Ethiopia, 2016

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Cluster and Outlier analysis of stillbirth across regions in Ethiopia, 2016

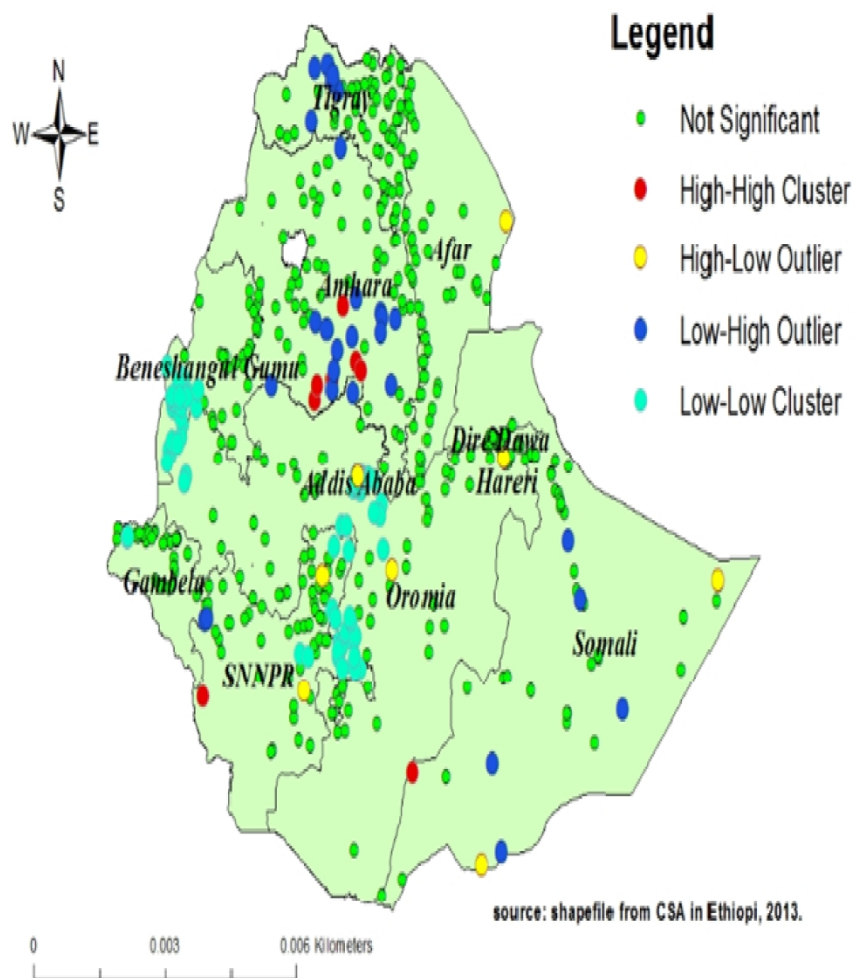
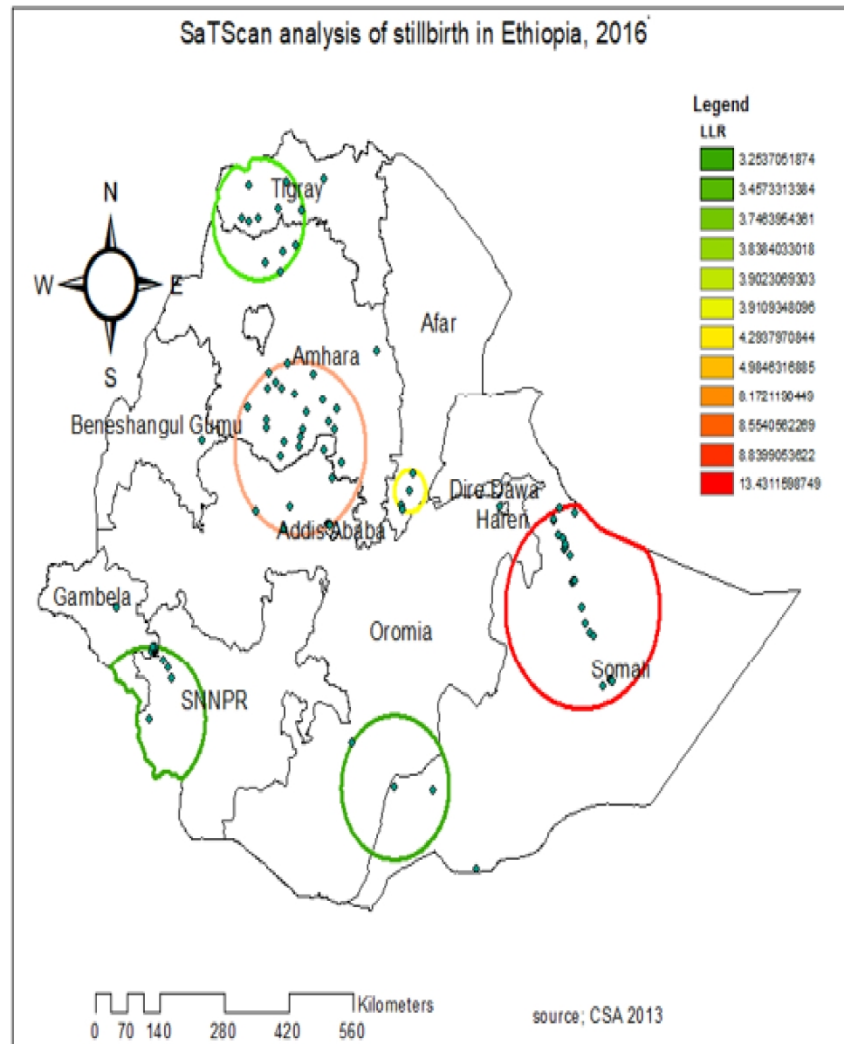


Figure 3: Cluster and Outlier analysis of stillbirths in Ethiopia, 2016 (Source: Central Statistical Agency (CSA), Ethiopia, 2013)

215x279mm (600 x 600 DPI)



45 Figure 4: Spatial Scan Statistical analysis of hotspot areas of stillbirth in Ethiopia, 2016 (Source: Central  
46 Statistical Agency (CSA), Ethiopia, 2013)

47 215x279mm (600 x 600 DPI)

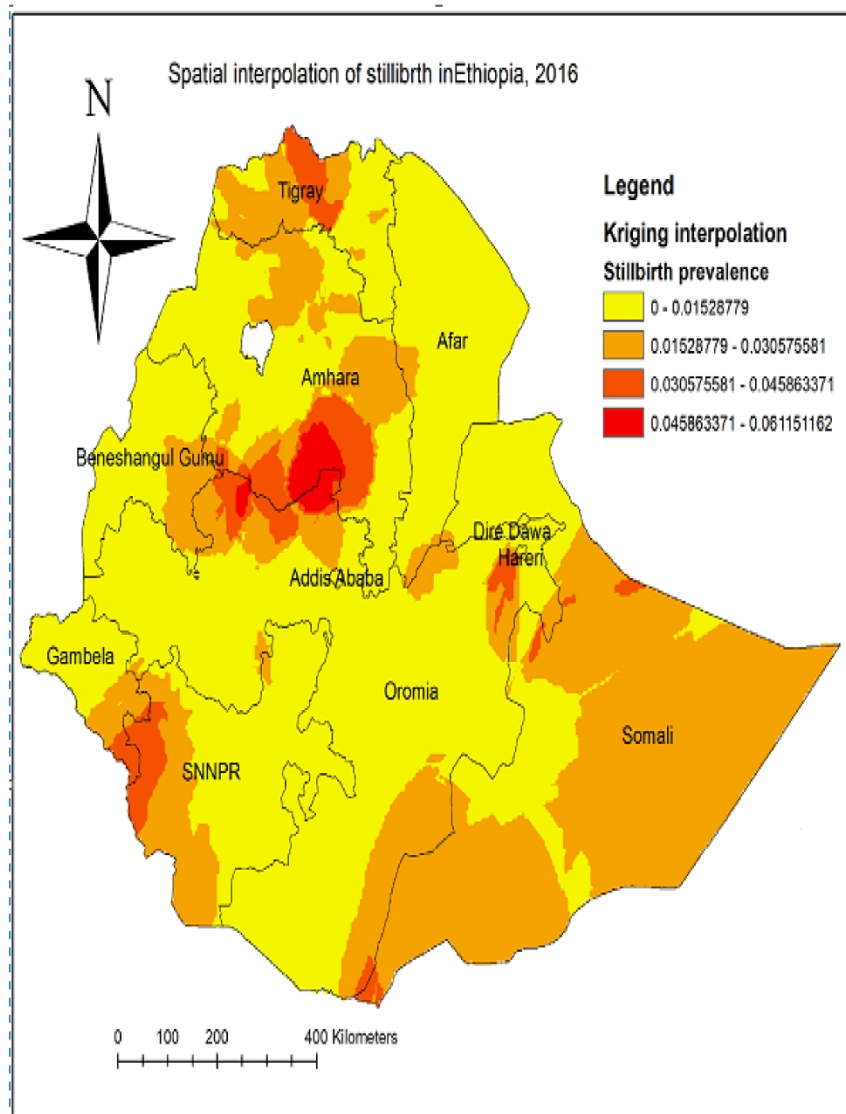


Figure 5: Kriging Interpolation of stillbirth in Ethiopia, 2016 (Source: Central Statistical Agency (CSA), Ethiopia, 2013)

215x279mm (600 x 600 DPI)

## STROBE Statement—checklist of items that should be included in reports of observational studies

	Item No.	Recommendation	Page No.
<b>Title and abstract</b>	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&3
<b>Introduction</b>			
Background/rationale	2	Explain the scientific background and rationale for the investigation being reported	4, 5 & 6
Objectives	3	State specific objectives, including any pre-specified hypotheses	6
<b>Methods</b>			
Study design	4	Present key elements of study design early in the paper	6
Setting	5	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection	6, 7 & 8
Participants	6	(a) <i>Cohort study</i> —Give the eligibility criteria, and the sources and methods of selection of participants. Describe methods of follow-up	N/A
		<i>Case-control study</i> —Give the eligibility criteria, and the sources and methods of case ascertainment and control selection. Give the rationale for the choice of cases and controls	N/A
		<i>Cross-sectional study</i> —Give the eligibility criteria, and the sources and methods of selection of participants	6 & 7
		(b) <i>Cohort study</i> —For matched studies, give matching criteria and number of exposed and unexposed	N/A
		<i>Case-control study</i> —For matched studies, give matching criteria and the number of controls per case	N/A
Variables	7	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable	7 & 8
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	7&8
Bias	9	Describe any efforts to address potential sources of bias	8 & 9
Study size	10	Explain how the study size was arrived at	6&7

Continued on next page

Quantitative variables	11	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why	, 8,9,10 &11
Statistical methods	12	(a) Describe all statistical methods, including those used to control for confounding	8,9,10 &11
		(b) Describe any methods used to examine subgroups and interactions	N/A
		(c) Explain how missing data were addressed	10, 11
		(d) <i>Cohort study</i> —If applicable, explain how loss to follow-up was addressed	N/A
		<i>Case-control study</i> —If applicable, explain how matching of cases and controls was addressed	N/A
		<i>Cross-sectional study</i> —If applicable, describe analytical methods taking account of sampling strategy	8,9 &10
		(e) Describe any sensitivity analyses	N/A
<b>Results</b>			
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	N/A
		(b) Give reasons for non-participation at each stage	N/A
		(c) Consider use of a flow diagram	N/A
Descriptive data	14*	(a) Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders	14
		(b) Indicate number of participants with missing data for each variable of interest	15
		(c) <i>Cohort study</i> —Summarise follow-up time (eg, average and total amount)	N/A
Outcome data	15*	<i>Cohort study</i> —Report numbers of outcome events or summary measures over time	N/A
		<i>Case-control study</i> —Report numbers in each exposure category, or summary measures of exposure	N/A
		<i>Cross-sectional study</i> —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	16 & 17
		(b) Report category boundaries when continuous variables were categorized	14
		(c) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period	N/A

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Other analyses	17	Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses	N/A
<b>Discussion</b>			
Key results	18	Summarise key results with reference to study objectives	22
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	21
Interpretation	20	Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence	18, 19, 20, 21& 22
Generalisability	21	Discuss the generalisability (external validity) of the study results	21
<b>Other information</b>			
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	23

\* cross-sectional studies.



# BMJ Open

## Spatial distribution of stillbirth and associated factors in Ethiopia: Spatial and Multilevel Analysis

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<b>Primary Subject Heading</b>:	Obstetrics and gynaecology
Secondary Subject Heading:	Epidemiology, Health services research, Obstetrics and gynaecology
Keywords:	Stillbirth, Ethiopia, Multilevel analysis, Spatial analysis

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3 **1 Spatial distribution of stillbirth and associated factors in Ethiopia: Spatial and**  
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6 **2 Multilevel Analysis**  
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15

## 16 Abstract

17 **Objective:** Despite the stillbirth rate has been reduced globally, it is still unacceptably high in  
18 developing countries. Today, only ten countries share the burden of more than 65% of global  
19 stillbirth rates including Ethiopia. Ethiopia ranks the seventh position concerning the stillbirth rate.  
20 Exploring the spatial distribution of stillbirth is critical for developing successful interventions and  
21 monitoring public health programs, but there is no study on the spatial distribution and associated  
22 factors of stillbirth in Ethiopia. Therefore, this study aimed to explore the spatial distribution and  
23 associated factors of stillbirth.

24 **Methods:** Secondary data analysis was conducted based on the 2016 Ethiopian Demographic and  
25 Health Survey (EDHS) data. A total weighted sample of 11,375 women was included for analysis.  
26 The Bernoulli model was fitted using SaTScan version 9.6 to identify hotspot areas and ArcGIS  
27 version 10.6 to explore the spatial distribution of stillbirth. For associated factors, a multilevel  
28 binary logistic regression model was fitted using STATA version 14 software. Variables with a p-  
29 value of less than 0.2 were considered for the multivariable multilevel analysis. In the  
30 multivariable multilevel analysis, the Adjusted Odds Ratio (AOR) with the 95% Confidence  
31 Interval (CI) were reported to declare significantly associated factors of stillbirth.

32 **Result:** The spatial analysis showed that stillbirth has significant spatial variation across the  
33 country. The SaTScan analysis identified significant primary clusters of stillbirth in the Northeast  
34 Somali region (LLR=13.4,  $p<0.001$ ) while the secondary cluster in the border area of Oromia and  
35 Amhara regions (LLR=8.8,  $p<0.05$ ). In the multilevel analysis; rural residence (AOR=4.83,  
36 95%CI:1.44-16.19), primary education (AOR=0.39, 95% CI:0.20-0.74), not having ANC visit  
37 (AOR=2.77, 95% CI:1.70-4.51), caesarean delivery (AOR=5.07, 95% CI: 1.65-15.58), birth

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3 38 interval <24 month (AOR=1.95, 95%CI: 1.20 - 3.10), and height <150 cm(AOR=2.73,  
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5 39 95%CI:1.45-4.97) were significantly associated with stillbirth.  
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7

8 **Conclusion and recommendation:** In Ethiopia, stillbirth had significant spatial variations across  
9  
10 41 the country. Residence, maternal stature, preceding birth interval, cesarean delivery, education,  
11  
12 42 and ANC visit were significantly associated with stillbirth. Therefore, public health interventions  
13  
14 43 targeting the hotspot areas of stillbirth through enhancing maternal health care service utilization,  
15  
16 44 and maternal education are crucial to reducing stillbirth in Ethiopia.  
17  
18

19 45 **Keywords:** Stillbirth, Ethiopia, Multilevel analysis, Spatial analysis  
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## 26 47 **Strength and limitation of the study**

- 27  
28  
29 48 • The study was done based on the weighted EDHS data to secure the representativeness of the  
30  
31 49 data and to get a reliable estimate. Therefore, the study findings have the potential to inform  
32  
33 50 policy-makers and programmers, and also aid to design appropriate intervention at national  
34  
35 51 and regional levels  
36  
37  
38 52 • As the study was a cross-sectional study, it was unable to show a temporal relationship.  
39  
40 53 However, multilevel modeling was employed to take into account the clustering effect to get  
41  
42 54 reliable estimates and standard error.  
43  
44  
45 55 • The EDHS survey did not incorporate clinically confirmed data rather it relied on mothers or  
46  
47 56 caregiver's verbal autopsy. Therefore, it may have the possibility of social desirability and  
48  
49 57 recall bias  
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52 58 • The SaTScan detected only circular clusters. However, irregularly shaped clusters were not  
53  
54 59 detected.  
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## 60 **BACKGROUND**

61 The World Health Organization (WHO) defines stillbirth as fetal death (death before the complete  
62 expulsion or extraction of a product of conception from its mother) in the third trimester ( $\geq 28$   
63 completed weeks of gestation) or birth weight  $\geq 1000$  grams or length  $\geq 35$  centimeter(1, 2).

64 Stillbirth remains a global public health problem, particularly in Sub-Saharan Africa (SSA) and  
65 South Asia (SA) (3). Globally, an estimated 2.6 million stillbirths occurred annually, 98% of which  
66 were in developing countries (4).

67 Most of the stillbirths happen during the intrapartum period, which can be avoided by improving  
68 maternal health care services (5). More than half of the 2.6 million stillbirths occur during labor  
69 and delivery (6), and it is considered as an indicator of poor access to and quality of obstetric care  
70 (7). According to the most recent global estimate of WHO, the average global stillbirth rate was  
71 18.4 per 1000 births (8), while developing countries have the stillbirth rates ten-fold higher than  
72 developed countries (9). SSA has the stillbirth rates of 28.3 per 1000 births (10).

73 Stillbirth rates have been varied across countries and remain a huge challenge to achieve the Every  
74 Newborn Action Plan (ENAP) target of 12 or fewer stillbirths per 1000 births by 2030 (1). Even  
75 though many high-income and upper-middle-income countries have already met this target,  
76 developing countries particularly Africa will have to register more than double the present progress  
77 to reach this target (1). Despite the various international and national commitments on improving  
78 newborn and maternal health (11), stillbirth has been grossly under-reported and invisible in  
79 policies and programs worldwide (12). Like many countries in SSA, stillbirth is not routinely  
80 recorded and monitored in Ethiopia. It has reduced more slowly than maternal mortality and under  
81 5 mortality, which remains invisible in the national policies (13).

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2  
3 82 The death of a fetus in utero or at birth is a devastating experience for the affected mothers and  
4  
5 83 families (14). It has been associated with extensive psychosocial consequences for parents and  
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8 84 family and has been linked to post-traumatic stress disorder, anxiety, depression, suicide, fear of  
9  
10 85 the next pregnancy, and reduced relation with their partner (15, 16). In Ethiopia, a study conducted  
11  
12 86 based on 2011 Ethiopian Demographic and Health Survey (EDHS) reported a stillbirth rate of 25.5  
13  
14 87 per 1000 births with significant variability across regions and researchers recommended spatial  
15  
16 88 analysis to investigate the spatial variability of experiencing stillbirth in Ethiopia (17). A study  
17  
18 89 done at the Amhara region based on the Ethiopian Mini Demographic and Health Survey 2014  
19  
20 90 reported that stillbirth rates of 85 per 1000 births (18). Previous studies on stillbirth showed that  
21  
22 91 rural residence, parity, educational status, mode of delivery, Antenatal Care (ANC) utilization,  
23  
24 92 place of delivery, maternal nutritional status, and maternal obstetric factors were significantly  
25  
26 93 associated with stillbirth (14, 19-21).

27  
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30  
31 94 Stillbirth rates have been significantly varied across and within the country (17, 22). It is highly  
32  
33 95 concentrated among rural, poor, and marginalized societies (12). Thus, the identification of  
34  
35 96 geographic areas with a high rate of stillbirth using Geographic Information System (GIS) and  
36  
37 97 Spatial Scan statistical analysis (SaTScan) has become fundamental to guide targeted public health  
38  
39 98 interventions. However, previous studies in Ethiopia have been focused on the prevalence and  
40  
41 99 associated factors of stillbirth (18, 23, 24) by using standard logistic regression models despite the  
42  
43 100 hierarchical structure of EDHS data. These could result in a biased estimate since the data were  
44  
45 101 nested within-cluster and violates the independent assumption (17). The findings of these studies  
46  
47 102 are insufficient and limited to capture the spatial distribution of stillbirth and community-level  
48  
49 103 factors associated with stillbirth. Therefore, this study aimed to investigate the spatial distribution  
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51 104 and associated factors of stillbirth in Ethiopia using spatial and multilevel Analysis.  
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## 105 **Method and materials**

### 106 **Study design, setting and period**

107 Secondary data analysis was done based on the EDHS 2016 data. This survey was the fourth survey  
108 conducted in the country. Ethiopia is situated in the Horn of Africa. It is the 13<sup>th</sup> in the world and  
109 2<sup>nd</sup> in Africa's most populous country. There are 9 regional states (Afar, Amhara, Benishangul-  
110 Gumuz, Gambela, Harari, Oromia, Somali, Southern Nations, Nationalities, and People's Region  
111 (SNNP) and Tigray) and two Administrative Cities (Addis Ababa and Dire-Dawa) in its territory.  
112 In Ethiopia, 84% of the population lives in rural areas and more than 80% of the country's total  
113 population lives in the regional states of Amhara, Oromia, and SNNP(25). The number of hospitals  
114 in Ethiopia varies across regions in response to differences in population size (26).

### 115 **Sample and population**

116 All births from reproductive age women within five years before the survey in Ethiopia were the  
117 source of population, whereas all births from reproductive-age women in the selected Enumeration  
118 Areas (EAs) within five years before the survey was the study population. In EDHS, a two-stage  
119 stratified cluster sampling technique was employed using the 2007 Population and Housing Census  
120 (PHC) as a sampling frame. Stratification was achieved by separating each region into urban and  
121 rural areas. In total, 21 sampling strata have been created. In the first stage, 645 EAs (202 in urban  
122 areas) were chosen with probability sampling proportional to the size of the EAs with independent  
123 selection in each sampling stratum. In the second stage, on average 28 households were  
124 systematically selected. The detailed sampling procedure was presented in the full EDHS 2016  
125 report (27).



## 126 **Study variables**

### 127 *Outcome variables*

128 The 2016 EDHS asked women to report any pregnancy loss that occurred in the last five years  
129 preceding the survey. The duration of pregnancy was reported for every pregnancy separately  
130 which did not result in a live birth. Pregnancy losses occurring after seven completed months of  
131 gestation were considered as stillbirth (28). The response variable for this study was the occurrence  
132 of stillbirth among mothers of childbearing age (15-49 years). The response variable for the  $i^{\text{th}}$   
133 mother was represented by a random variable  $Y_i$  with two possible values coded as 1 and 0. So,  
134 the response variable of the  $i^{\text{th}}$  mother  $Y_i$  was measured as a dichotomous variable with possible  
135 values  $Y_i = 1$ , if  $i^{\text{th}}$  mother had experienced stillbirth and  $Y_i = 0$  if the mother had a live birth.

### 136 *Independent variables*

137 Consistent with the objective of the study and given the hierarchical structure of EDHS data where  
138 women were nested within the cluster/community, two levels of independent variables were  
139 considered. Level 1 contained individual socio-demographic and economic factors (age, marital  
140 status, religion, maternal education, paternal education, wealth index, maternal occupation,  
141 maternal working Status), pregnancy and pregnancy-related factors (mother's height, Body Mass  
142 Index (BMI), ANC visit, parity, preceding birth interval, contraceptive use, place of delivery, birth  
143 order, mode of delivery, wanted pregnancy, maternal anemia), and behavioral factors (smoking,  
144 and media exposure). The community-level factors; region, residence, community women  
145 education, community poverty, community media exposure, and community ANC utilization were  
146 considered as level 2 variables. In EDHS data, there is no variable collected at the cluster level  
147 except region and place of residence. Therefore, Individual-level variables were aggregated at the  
148 cluster level to generate community-level variables, to see whether cluster-level variables had an

1  
2  
3 149 effect on stillbirth and were categorized as higher or lower based on national median value since  
4  
5 150 it was not normally distributed. The community-level variables used in the analysis were from two  
6  
7  
8 151 sources; direct community-level variables that were used without any manipulation (residence and  
9  
10 152 region), and aggregated community-level variables (community media exposure, community  
11  
12 153 poverty, community ANC utilization and community women education) created by aggregating  
13  
14  
15 154 individual-level variables at the cluster level.

### 16 17 18 155 **Data collection procedure**

19  
20  
21 156 The study was conducted based on the 2016 EDHS data and geographic coordinate data by  
22  
23 157 accessing these data from the DHS program official database [www.measuredhs.com](http://www.measuredhs.com) after  
24  
25 158 permission was granted through an online request by explaining the objective of our study. We  
26  
27  
28 159 used the EDHS 2016 Birth Record data (BR) set for this study. Geographic coordinate data  
29  
30 160 (longitude and latitude coordinates) were taken at the cluster level/ enumeration area level. During  
31  
32 161 the period of data collection, there was no conflict across the country. A total of 645 enumeration  
33  
34 162 areas were selected and the data was collected in all of the selected EAs but the geographic  
35  
36  
37 163 coordinate file of 21 enumeration areas was wrongly recorded (the latitude and longitude were  
38  
39 164 recorded as 0) and when we locate these EAs the point was located out of Ethiopia and therefore  
40  
41 165 we drop the 21 EAs for the spatial analysis but for the associated factors we have used all the 645  
42  
43  
44 166 EAs. Regarding the spatial analysis, we have done Kriging interpolation technique to predict  
45  
46 167 stillbirth on the unsampled areas since it optimizes the prediction level by considering the distance  
47  
48 168 decline effect (inverse distance weighting) therefore, it predicts the stillbirth prevalence on the  
49  
50  
51 169 unsampled areas located between the sampled areas where the measurement was taken. If we have  
52  
53 170 done extrapolation it may prone to bias because it predicts beyond the distance limit whereas for  
54  
55 171 our study we have used interpolation to predict stillbirth on the unsampled areas.

## 172 **Data management and analysis**

173 The data were weighted using sampling weight, primary sampling unit, and strata before any  
174 statistical analysis to restore the representativeness of the survey and take into account the  
175 sampling design to get reliable statistical estimates. The sampling statisticians determined how  
176 many samples are needed in each region to get reliable estimates, in EDHS, some regions were  
177 oversampled, and some regions under sampled. To get statistics that are representative of Ethiopia,  
178 the distribution of women in the sample need to be weighted (mathematically adjusted) such that  
179 it resembles the true distribution in Ethiopia by using sampling weight (v005), primary sampling  
180 unit (v021), and strata (v022). Descriptive and summary statistics were conducted using STATA  
181 version 14 software.

### 182 ***Spatial analysis***

183 For the spatial analysis, ArcGIS version 10.6 software and SaTScan version 9.6 software were  
184 used. Incremental spatial autocorrelation was done to get the maximum peak distance where  
185 stillbirth clustering is more pronounced. It measures spatial autocorrelation for a series of  
186 distances and creates a line graph of those distances and their corresponding Z-score. The  
187 maximum peak distance is the distance where maximum spatial autocorrelation occurs and this  
188 was used as a distance band for hotspot analysis. Totally 10 distance bands were detected by a  
189 beginning distance of 121,803 meters, the first peak of 136,586.06 meters, and the maximum peak  
190 (clustering) was observed at 166152.17 meters. The maximum peak was used as the distance band  
191 for the hotspot analysis.

### 192 ***Spatial autocorrelation analysis***

1  
2  
3 193 The spatial autocorrelation (Global Moran's I) was done to test whether there was significant  
4  
5 194 spatial clustering of stillbirth or not. Moran's I is a statistic that measures whether stillbirth patterns  
6  
7  
8 195 were dispersed, clustered, or randomly distributed in the study area (29) by taking the entire data  
9  
10 196 set and produce a single output value which ranges from -1 to +1. Moran's I values close to -1  
11  
12 197 indicate spatial distribution of stillbirth was dispersed, whereas Moran's I close to +1 indicate  
13  
14 198 spatial distribution of stillbirth was clustered and stillbirth distributed randomly if I value is 0. A  
15  
16 199 statistically significant Moran's I (p-value < 0.05) leads to rejection of the null hypothesis (stillbirth  
17  
18 200 is randomly distributed) and indicates the presence of significant spatial autocorrelation/spatial  
19  
20  
21 201 dependence.

### 22 23 24 202 **Hot spot analysis of stillbirth**

25  
26 203 Anselin Local Moran's I is used to investigate whether the local level cluster is positively  
27  
28 204 correlated (high-high and low-low) clusters or negatively correlated (high-low and low-high)  
29  
30 205 regarding the prevalence of stillbirth. A positive Moran's I value indicated that a case had  
31  
32 206 neighboring cases with similar values. A negative value of Moran's I indicated that a case was  
33  
34 207 surrounded by cases with dissimilar values (30). Spatial scan statistical analysis (SaTScan) using  
35  
36 208 the Bernoulli model was employed to test for the presence of statistically significant spatial clusters  
37  
38 209 of stillbirth using Kuldorff's SaTScan version 9.6 software. The spatial scan statistic uses a circular  
39  
40 210 scanning window that moves across the study area. Women who had a stillbirth were taken as  
41  
42 211 cases and those who had a live birth as controls to fit the Bernoulli model. The numbers of cases  
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44 212 in each location had Bernoulli distribution and the model required data for cases, controls, and  
45  
46 213 geographic coordinates. The default maximum spatial cluster size of <50% of the population was  
47  
48 214 used, as an upper limit, which allowed both small and large clusters to be detected and ignored  
49  
50 215 clusters that contained more than the maximum limit.

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3 216 For each potential cluster, a likelihood ratio test statistic and the p-value was used to determine if  
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5 217 the number of observed stillbirth within the potential cluster was significantly higher than expected  
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7  
8 218 or not. The scanning window with maximum likelihood was the most likely performing cluster,  
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10 219 and the p-value was assigned to each cluster using Monte Carlo hypothesis testing by comparing  
11  
12 220 the rank of the maximum likelihood from the real data with the maximum likelihood from the  
13  
14 221 random datasets. The primary and secondary clusters were identified and assigned p-values and  
15  
16 222 ranked based on their likelihood ratio test, based on 999 Monte Carlo replications(31). In the  
17  
18  
19 223 Bernoulli model in the SaTScan analysis, we used the Monte Carlo hypothesis testing procedure  
20  
21 224 for the statistical inference of the clusters detected. Under the null hypothesis, we generate a large  
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23  
24 225 number of data sets by randomly permuting the locations of observations. Then, we calculate the  
25  
26 226 maximum values of test statistics for each data set. In that way, we obtain empirical null  
27  
28 227 distributions of the proposed test statistics. The Monte Carlo-based p-value for the detected cluster  
29  
30  
31 228 is the rank of the maximum value of the test statistics from the real data set among all data sets  
32  
33 229 divided by the number of all data sets. Just Monte Carlo testing to detect whether the identified  
34  
35 230 clusters are significant or not.

### 38 231 *Spatial interpolation*

41 232 It is very expensive and laborious to collect reliable data in all areas of the country to know the  
42  
43 233 burden of a certain event. Therefore, part of a certain area can be predicted by using observed data  
44  
45  
46 234 using a method called interpolation. The spatial interpolation technique was used to predict  
47  
48 235 stillbirth on the un-sampled areas in the country based on sampled EAs measurements. There are  
49  
50 236 various deterministic and geostatistical interpolation methods. Among all of the methods, ordinary  
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53 237 Kriging and empirical Bayesian Kriging are considered the best method since it incorporates the  
54  
55 238 spatial autocorrelation and it statistically optimizes the weight (32). Ordinary Kriging spatial

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3 239 interpolation method was selected for this study for predictions of stillbirth in unobserved areas of  
4  
5 240 Ethiopia since it had the smallest Root Mean Square Error (RMSE) value and residuals.  
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### 8 241 **Associated factors of stillbirth**

9  
10 242 In EDHS data, women are nested within a cluster and we expect that women within the same  
11  
12 243 cluster were more similar to each other than women in the rest of the country. It violates the  
13  
14 244 standard regression model assumptions, these are the independence of observations and equal  
15  
16 245 variance across clusters assumptions. This implies that the need to take into account the between  
17  
18 246 cluster variability by using an advanced model. Therefore, a multilevel random intercept logistic  
19  
20 247 regression model was fitted to estimate the association between the individual and community  
21  
22 248 level variables and the likelihood of experiencing stillbirth. Model comparison was done based on  
23  
24 249 Deviance (The negative 2 log-likelihood ( $-2LL$ )) since the models were nested. Likelihood Ratio  
25  
26 250 test (LR), and Intra-cluster Correlation Coefficient (ICC) were computed to measure the variation  
27  
28 251 between clusters. The ICC quantifies the degree of heterogeneity of stillbirth between clusters (the  
29  
30 252 proportion of the total observed variation in stillbirth that is attributable to between cluster  
31  
32 253 variations) (33).  
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38 254 Multilevel random intercept logistic regression was used to analyze factors associated with a  
39  
40 255 stillbirth at two levels to take into account the hierarchical nature of the data, at individual and  
41  
42 256 community levels. Four models were constructed for the multilevel logistic regression analysis.  
43  
44 257 The first model (a multilevel random intercept logistic regression model without covariates) was  
45  
46 258 the null model without any explanatory variables, to determine the extent of cluster variation on  
47  
48 259 stillbirth. The second model (a multilevel model with level 1 independent variables) was adjusted  
49  
50 260 with individual-level variables; the third model (a multilevel model with level 2 variables) was  
51  
52 261 adjusted for community-level variables while the fourth model was fitted with both individual and  
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3 262 community level variables simultaneously. The final model was the best-fitted model since it had  
4  
5 263 the lowest deviance value.  
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7

8 264 Variables with p-value  $\leq 0.2$  in the bi-variable analysis for both individual and community-level  
9  
10 265 factors were fitted in the multivariable model. Adjusted Odds Ratio (AOR) with a 95% Confidence  
11  
12 266 Interval (CI) and p-value  $< 0.05$  in the multivariable model were used to declare significantly  
13  
14 267 associated factors of stillbirth. Multi-collinearity was checked using the Variance Inflation Factor  
15  
16 268 (VIF) which indicates that there is no multicollinearity because all variables have  $VIF < 5$  and  
17  
18 269 tolerance greater than 0.1.  
19  
20

### 21 22 270 **Patient and public involvement statement**

23  
24 271 Patients and public involvement have not happened in this study since we have conducted a  
25  
26 272 secondary data analysis based on already available DHS data which was collected to provide  
27  
28 273 estimates of common health and health-related indicators. For the original project data were  
29  
30 274 obtained by engaging patients and public involvement statements which were essential since  
31  
32 275 biomarker data such as anemia, HIV testing, and anthropometric measurements were collected  
33  
34 276 (34).  
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### 39 277 **Ethical consideration**

40  
41  
42 278 Ethical clearance was obtained from the Institutional Review Board of Institute of Public Health,  
43  
44 279 CMHS, and the University of Gondar. Permission for data access was obtained from major  
45  
46 280 demographic and health survey through an online request from <http://www.dhsprogram.com>. The  
47  
48 281 data used for this study were publicly available with no personal identifier.  
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## 283 **Result**

### 284 **Socio-demographic and economic characteristics of respondents**

285 A total of 11,375 women who gave birth within five years preceding the survey were included for  
286 the analysis. Of 11,375 of women, 10,149 (89.2%) were rural residents, and a half (49.2%) of the  
287 respondents were aged 20-29 years. Regarding maternal education status, 7,606 (66.9%) had no  
288 formal education (Table 1).

### 289 **Pregnancy and maternal health service-related characteristics of respondents**

290 Two-third (65.7%) of the women gave birth at home and 194 (1.7%) gave birth via cesarean  
291 section. Two thousand six hundred two (22.9 %) women had no ANC visit during pregnancy  
292 (Table 2). The overall rate of stillbirth in Ethiopia was found to be 9.2 [95% CI; 7.9, 11.1] per  
293 1000 births. It was highest in the Amhara region and lowest in Diredawa (Figure 1).

## 294 **Spatial analysis**

### 295 **Spatial Global autocorrelation**

296 The spatial analysis revealed that the spatial distribution of stillbirth was significantly varied across  
297 the country with Global Moran's I value of 0.017 ( $p < 0.05$ ). The z-score was 2.4 indicated that  
298 there is less than 1.5% likelihood that this clustered pattern could be the result of chance (Figure  
299 2).

### 300 **Hotspot analysis of stillbirth**

301 In the cluster and outlier analysis; the significant cluster was detected in Tigray, Amhara, Oromia,  
302 Addis Ababa, SNNPR, Benishangul-Gumuz, Somali, and Gambella regions. Hot spot areas of  
303 stillbirth were found in Southwest Somali, Southern Amhara, and West SNNPR, while the cold



1  
2  
3 304 spot areas of stillbirth were found in the South and West Benishangul-Gumuz, Addis Ababa,  
4  
5 305 Southwest of Oromia region, West Gambella, and Northeast SNNPR regions. The outliers were  
6  
7 306 found in the central and southern parts of Amhara, North Tigray, Southeast Gambella, and Somali  
8  
9 307 regions (Figure 3).

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11  
12 308 In the Spatial scan statistical analysis, a total of 56 significant clusters of stillbirth were identified,  
13  
14 309 of which 22 clusters were primary (most likely clusters) and 34 were secondary clusters. The  
15  
16 310 primary cluster spatial window was located in the Northeast Somali region centered at 7.829198  
17  
18 311 N, 43.706264 E of geographic location with a 166.48 km radius, a Relative Risk (RR) of 22.5, and  
19  
20 312 a Log-Likelihood Ratio (LLR) of 13.4, at  $p < 0.001$ . It showed that women within the spatial  
21  
22 313 window had a 22.5 times higher risk of experiencing stillbirth than women outside the window.  
23  
24 314 The secondary cluster scanning spatial window was located in the border area of the South Amhara  
25  
26 315 region and the North Oromia region, and Southern Afar region (Table 3 and Figure 4). The red  
27  
28 316 circular ring indicates that the most statistically significant spatial window contains the primary  
29  
30 317 cluster of stillbirth. Women within the circular window had a higher likelihood of experiencing  
31  
32 318 stillbirth than women outside the spatial window (Figure 4).

### 319 **Interpolation of stillbirth**

320 Northwest Tigray, Northern and Northwest Oromia, East and South Amhara, East Benishangul,  
321 East Gambella, Harari, and Northwest SNNPR were predicted as the riskiest areas of stillbirth  
322 compared to other regions. Whereas, the predicted low-risk areas of stillbirth were identified in  
323 Oromia, Afar, and Gambella regions (Figure 5).

### 324 **Factors associated with stillbirth**

325 ICC and LR tests were checked, and the multilevel model was the best-fitted model for the data.  
326 Therefore, the two-level multilevel logistic regression model was used to get an unbiased standard  
327 error and to make a valid inference. Deviance was used for model comparison and the final model  
328 was the best-fitted model with the lowest deviance value (Table 4).

329 The ICC-value was 47% in the null model, it showed that 47% of the total variability for stillbirth  
330 was attributable to the between clusters/EA variability, with the remaining 53% attributable to the  
331 individual differences (Table 4).

332 In the multivariable multilevel logistic regression model; residence, region, religion, preceding  
333 birth interval, cesarean delivery, maternal height, ANC visit, and maternal education were  
334 significantly associated with stillbirth. At the community level (level 2), two variables were  
335 significantly associated with stillbirth. The odds of experiencing stillbirth among women residing  
336 in rural areas were 4.83 times (AOR= 4.83, 95% CI: 1.44-16.19) higher than women residing in  
337 urban areas. The odds of experiencing stillbirth among women in Tigray, Afar, Somali, SNNPR,  
338 Benishangul, Gambella, and Harari regions were not significantly different from that of  
339 experiencing stillbirth in the Amhara region. The odds of experiencing stillbirth among women  
340 who live in the Oromia region were decreased by 75% (AOR= 0.25, 95% CI: 0.07- 0.83) compared  
341 to women in the Amhara region.

342 At the individual level, six variables were significantly associated with stillbirth. Women who  
343 were protestant and catholic religious followers had 89% (AOR= 0.11, 95% CI: 0.03- 0.37)  
344 decreased odds of experiencing stillbirth than orthodox Christian religious followers. Women's  
345 educational level was significantly associated with stillbirth. Though women attained secondary  
346 education and higher had no significant difference in experiencing stillbirth, the odds of

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3 347 experiencing stillbirth among women who attained primary education were decreased by 61%  
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5 348 (AOR= 0.39, 95% CI: 0.20 - 0.74) compared to women who didn't have formal education.  
6  
7 349 Besides, women who had no ANC visits during pregnancy had 2.77 times (AOR= 2.77, 95% CI:  
8  
9 350 1.70 - 4.51) higher odds of experiencing stillbirth than women who had 4 and above ANC visits  
10  
11 351 during pregnancy. Women who gave birth via cesarean delivery had 5.07 times (AOR= 5.07, 95%  
12  
13 352 CI: 1.65– 15.58) higher odds of experiencing stillbirth than women who gave birth through vaginal  
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15 353 delivery.  
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19 354 The preceding birth interval was a significant predictor of stillbirth. Women having preceding birth  
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21 355 interval less than 24 months had 1.93 times (AOR= 1.93, 95% CI: 1.20 – 3.10) higher odds of  
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23 356 experiencing stillbirth compared to women having preceding birth interval 24 months and above.  
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26 357 Besides, mothers whose height less than 150 cm had 2.73 times (AOR= 2.73, 95% CI: 1.50 -  
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28 358 4.97) higher odds of experiencing stillbirth compared to those mothers whose height greater than  
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30 359 or equal to 150 cm (Table 4).  
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## 360 **Discussion**

361 The stillbirth rate in Ethiopia was 9.2 per 1000 births with marked spatial heterogeneity. The  
362 spatial distribution of stillbirth was significantly varied across the country. The SaTScan analysis  
363 detected a total of three statistically significant spatial windows with high stillbirth rates. The  
364 significant hotspot areas of stillbirth were identified in the Northeast Somali, South Afar, South  
365 Amhara, and North Oromia regions. The possible explanation might be due to the reason that these  
366 areas are more of pastoralist areas where people did not have permanent residence, due to this  
367 relatively health facilities are not accessible and available in these areas compared to agrarian  
368 people and cities. Besides, these areas are more rural, which had a poor network of health facilities.

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3 369 Also, this could be attributed to the disparity in the distribution of maternal health service, and the  
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5 370 inaccessibility of infrastructure in the border areas of regions (35). Whereas, the cold spot areas  
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7 371 of stillbirth were found in South and West Benishangul-Gumuz, Addis Ababa, Southwest of  
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9 372 Oromia region, West Gambella, and Northeast SNNPR. This could be due to these areas are  
10  
11 372 Oromia region, West Gambella, and Northeast SNNPR. This could be due to these areas are  
12  
13 373 relatively had better availability and accessibility of health services (Addis Ababa, Dire-Dawa)  
14  
15 374 (36). Therefore, women are more likely to use ANC and institutional delivery services, this could  
16  
17 375 contribute to the decrement of antepartum and intrapartum stillbirth. This result gives insight for  
18  
19 376 public health planners and programmers for designing effective public health interventions to  
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21 377 identified hotspot areas of stillbirth.  
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24 378 In the multilevel analysis, different individual and community factors were significantly associated  
25  
26 379 with stillbirth. Among the community level variables, it was found that the odds of stillbirth among  
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28 380 women residing in the Oromia region were lower than in the Amhara region. This might be due to  
29  
30 381 the availability and accessibility of maternal health facilities since the Oromia region is relatively  
31  
32 382 around Addis Ababa and Dire-Dawa in which health facilities are accessible compared to other  
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34 383 regions. Besides, the high turnover of health professionals in the Amhara region, particularly  
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36 384 physicians did not remain at the district level and choose to work in the capital city (Addis Ababa).  
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38 385 These may lead to a high intrapartum stillbirth rate in the region due to the lack of trained health  
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40 386 professionals (37). The study has shown that the odds of stillbirth was higher among women who  
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42 387 lived in rural areas. This was consistent with previous study findings in South Africa (38), African  
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44 388 Great lake Regions (12), Nigeria (19), Northern Ghana (14), and Ethiopia (17). This could be  
45  
46 389 attributed to the disparity in the mother's health care access seek, availability, and accessibility of  
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48 390 health facilities. Women in urban areas are relatively had improved health-seeking behavior than  
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50 391 rural residents (35). Moreover, urban residents have better aware of maternal health services but  
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3 392 in rural areas, health facilities may not be easily reachable and may end up with poor pregnancy  
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5 393 outcomes during emergency cases (39).

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8 394 Amongst the individual-level factors, catholic and protestant religious followers were significantly  
9  
10 395 associated with lower odds of stillbirth compared to orthodox religious followers. This might be  
11  
12 396 related to the miss-perception of religious followers towards maternal health care service  
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14 397 utilization as religion shapes their reproductive health decision making and practices, thereby  
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16 398 govern the women's desire for using maternal health services (40). It could also be related to the  
17  
18 399 feeding practice of women. Commonly orthodox religious followers may not eat animal products  
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20 400 during pregnancy especially in the fasting period this could result in poor fetal outcome(41).  
21  
22 401 Animal products are the main source of micro and macronutrients like folate and iron. Orthodox  
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24 402 religious followers considered giving birth at home are blessed, using contraceptive as sinning and  
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26 403 not expose their body to health professionals during delivery this might be the possible reason  
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28 404 which needs further qualitative study to explore the detailed reasons.  
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34 405 This study noted lower odds of stillbirth among women who attained primary education compared  
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36 406 to women who had no formal education. This finding was in line with previous studies done in  
37  
38 407 Kenya (42) and Nigeria (19). It might be attributed to the reality that education can improve health  
39  
40 408 care seeing behavior such as timely decision to seek health care during pregnancy, give better care  
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42 409 for their health and their fetus, awareness of the danger sign of pregnancy, and maternal health  
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44 410 service utilization (43).  
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48 411 The odds of stillbirth were higher among short stature women. A similar finding was reported in  
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50 412 Pakistan (21). This might be because short stature women are prone to adverse pregnancy  
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52 413 outcomes like Cephalo-Pelvic Disproportion (CPD), contracted pelvis, Intra-uterine Growth  
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54 414 Restriction (IUGR), Intra-uterine Fetal Death (IUFD), and birth injury. Short stature reflects  
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3 415 longstanding malnutrition or childhood infection that start in uretro or during early childhood, this  
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5 416 kind of women may end up with poor pregnancy outcome unless we screen them as at-risk during  
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8 417 ANC follow up (44).  
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10 418 Besides, having no ANC visit had a significant association with increased stillbirth. It was  
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12  
13 419 consistent with previous findings in low-middle income countries (45), Ghana (46), and Kenya  
14  
15 420 (42). ANC follow up could help pregnant women to seek early treatment for her potential  
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17 421 pregnancy-associated complications and early screening of underlying medical conditions, this  
18  
19 422 could improve birth outcome (46, 47). On the other hand, women who did not have longer ANC  
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22 423 follow up may not be benefited from basic ANC packages.  
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25 424 Consistent with studies done in Nigeria (19) and Gambia (48), caesarean deliveries in this study  
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27 425 showed higher odds of stillbirth when compared with normal vaginal delivery. This might be  
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29 426 because in developing countries including Ethiopia maternal health services were not available  
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31 427 and reachable, particularly caesarean section is done at tertiary hospitals. Though caesarean section  
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33 428 is applied to save the life of new-born in high-risk pregnancies. In Ethiopia, more than 84% of the  
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35 429 population are rural residents and tertiary hospitals are not accessible due to transportation  
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37 430 problems which resulting not saving the fetus's life because the caesarean section is not done at  
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39 431 the right time. Therefore, high-risk deliveries like birth asphyxia, malpresentation, fetal stress, and  
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41 432 Antepartum Haemorrhage (APH) that needs caesarean delivery are referred from health centers  
42  
43 433 and health posts and may not reach at the right time to conduct caesarean section. This could  
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45 434 increase the risk of stillbirth (49, 50). Overall, in Ethiopia, since the majority of pregnant women  
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47 435 are from rural areas caesarean sections are applied too late in hospitals since most women are  
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50 436 referred from distant health facilities.  
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3 437 C-section delivery is mainly done to save the life of the baby as well as the mother when the C-  
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5 438 section has done timely but in Ethiopia, more than 84% of the population are rural residents and  
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7 439 health care facilities are not easily accessible and available. Only the health posts and the health  
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9 440 centers are relatively accessible and they are too far to get services from hospitals where C-section  
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11 441 has done. So, in the real scenario in developing countries including Ethiopia, the majority of the  
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13 442 deliveries have happened at health centers and home, when the pregnancies are complicated like  
14  
15 443 (birth asphyxia, fetal distress, and APH) they referred them to the hospitals but the hospitals are  
16  
17 444 not easily reachable and transportation is not easily accessible. Therefore, even if the women reach  
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19 445 at hospital and C-section done the newborns might die because the C-section was too late since  
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21 446 they delay the decision or transportation.  
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26 447 In this study, having a short inter-pregnancy interval was associated with higher odds of stillbirth.  
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28 448 This was consistent study findings in SSA (51), Bangladesh (52), and Amhara Region (18). This  
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30 449 could be explained by women who had short preceding birth interval are less able to provide  
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32 450 nourishment for the fetus because her body had less time to recuperate from the previous  
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34 451 pregnancy, and the uterus had less time to recover. Furthermore, lactation will deplete maternal  
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36 452 nutrition and may end up with poor pregnancy outcomes (52).  
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41 453 The strength of this study was using weighted data to make it representativeness at national and  
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43 454 regional levels. Therefore, it can be generalized to all women who gave birth during the study  
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45 455 period in Ethiopia. Moreover, the use of GIS and SaTScan statistical tests helped to detect similar  
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47 456 and statistically significant hotspot areas of stillbirth and will help to design effective public health  
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49 457 programs. However, the SaTScan detect only circular clusters, irregularly shaped clusters were not  
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51 458 detected. Furthermore, the EDHS survey did not incorporate clinically confirmed data rather it  
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3 459 relied on mothers or caregivers verbal autopsy and might have the possibility of social desirability  
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5 460 and recall bias (27).  
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8  
9 461 The findings of this study have valuable policy implications for health program design and  
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11 462 interventions. Stillbirth high-risk areas can be easily identified to make effective local  
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13 463 interventions. In general, these findings are of supreme importance for the minister of health,  
14  
15 464 regional health bureaus, and NGO's to design intervention programs to reduce stillbirth in  
16  
17 465 identified hotspot areas. To reduce the overall stillbirth rate in Ethiopia, Somali, Afar, Amhara,  
18  
19 466 and Oromia regions should emphasize the identified SaTScan clusters through developing local  
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21 467 interventional strategies like improving accessibility and availability of maternal health facility.  
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## 25 468 **Conclusions**

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27  
28 469 In Ethiopia, stillbirth had spatial variations across the country. Statistically significant hotspot  
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30 470 areas of stillbirth were found in the Central and Southern parts of Amhara, West SNNPRs, South  
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32 471 and North Tigray, and Southwest Somali region. Whereas, cold spot areas were found in Addis  
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34 472 Ababa, Central Oromia, and East SNNPRs. Short preceding birth interval, short maternal stature,  
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36 473 ANC visit, rural residence, region, religion, maternal education, and cesarean delivery were  
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38 474 significant predictors of stillbirth. Therefore, public health programs should target the hotspot  
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40 475 areas of stillbirth by enhancing maternal health care service utilization, and maternal education to  
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42 476 reduce the incidence of stillbirth in the country.  
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## 47 477 **Abbreviations**

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50 478 ANC; Antenatal Care, AOR; Adjusted Odds Ratio, ARR; Annual Rate of Reduction, BMI; Body  
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52 479 Mass Index, CI; Confidence Interval, COR; Crude Odds Ratio, CSA; Central Statistical Agency,  
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54 480 DHS; Demographic Health Survey, EA; Enumeration Area, EDHS; Ethiopian Demographic  
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3 481 Health Survey, GIS; Geographic Information System, ICC; Intra-cluster Correlation Coefficient,  
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5 482 IUFD; Intra Uterine Fetal Death, IUGR; Intra Uterine Growth Restriction, LLR; log-  
6  
7 483 likelihood Ratio, LR; Likelihood Ratio, PHC; Population and Housing census, SBR; Stillbirth  
8  
9 484 Rate, SNNPRs; Southern Nations and Nationality People Regional state, WHO; World Health  
10  
11 485 Organization.

## 16 486 **Declarations**

### 19 487 **Availability of data and materials**

20 488 Data is available online and you can access it from [www.measuredhs.com](http://www.measuredhs.com).

### 23 489 **Competing Interests**

24 490 Authors declare that they have no conflict of interest

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28 492 No funding was obtained for this study.

### 31 493 **Authors' contribution**

32 494 Conceptualization: Getayeneh Antehunegn Tesema

33 495 Data curation: Getayeneh Antehunegn Tesema

34 496 Funding acquisition: Getayeneh Antehunegn Tesema

35 497 Investigation: Getayeneh Antehunegn Tesema, Lemma Derseh, Solomon Gedlu

36 498 Methodology: Getayeneh Antehunegn Tesema, Lemma Derseh, Solomon Gedlu

37 499 Project administration: Getayeneh Antehunegn Tesema, Lemma Derseh, Solomon Gedlu

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9  
10 504 Visualization: Getayeneh Antehunegn Tesema, Lemma Derseh, Solomon Gedlu  
11  
12 505 Writing: Getayeneh Antehunegn Tesema  
13  
14 506 Writing – review and editing: Getayeneh Antehunegn Tesema, Lemma Derseh, Solomon Gedlu  
15  
16

### 17 507 **Consent for publication**

18  
19  
20 508 Not applicable  
21  
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28

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628 Table 1: Socio-demographic characteristics of women who gave birth within 5 years before the  
 629 survey in Ethiopia, 2016.

Variables	Category	Unweighted frequency (%)	Weighted frequency (%)
Residence	Urban	1,994 (18.0)	1,226 (10.8)
	Rural	9,091 (82.0)	10,149 (89.2)
Region	Tigray	1,021 (9.2)	709 (6.2)
	Afar	1,102 (9.9)	119 (1.0)
	Amhara	1,004 (9.1)	2,122 (18.7)
	Oromia	2,617 (23.6)	5,280 (46.4)
	Somali	1,623 (14.6)	554 (4.9)
	Benishangul Gumuz	962 (8.7)	133 (1.2)
	SNNPR	1,334 (12.0)	2,402 (21.1)
	Gambella	789 (7.1)	29 (0.3)
	Harari	633 (5.7)	27 (0.2)
Religion	Orthodox	3,127 (28.2)	3,844 (33.8)
	Muslim	5,710 (51.5)	4,696 (41.3)
	Catholic and protestant	2,248 (20.3)	2,835 (24.9)
Maternal education	No education	7,241 (65.3)	7,606 (66.9)
	Primary education	2,708 (24.4)	2,961 (26.0)
	Secondary and higher education	1,136 (10.3)	808 (7.1)
Maternal age	<20 year	395 (3.6)	374 (3.3)
	20-29 year	5,556 (50.1)	5,599 (49.2)
	30-39 year	4,234 (38.2)	4,381 (38.5)
	≥40 year	900 (8.1)	1,021 (9.0)
Husband education	No education	5,331 (51.2)	5,339 (49.6)
	Primary education	3,260 (31.3)	4,139 (38.5)

	Secondary and higher education	1,817 (17.5)	1,284 (11.9)
Maternal occupation status	Had occupation	6,584 (59.4)	6,352 (55.8)
	No occupation	4,501 (40.6)	5,023 (44.2)
Wealth status	Poor	6,081 (54.9)	5,360 (47.1)
	Middle	1,512 (13.6)	2,318 (20.4)
	Rich	3,492 (31.5)	3,697 (32.5)

630

631 Table 2: pregnancy and health service-related characteristics of women who gave birth within 5  
632 years preceding the survey in Ethiopia, 2016.

Variable	Category	Unweighted frequency (%)	Weighted frequency (%)
Pregnancy and maternal service-related factors			
Place of delivery	Home	6,737 (60.8)	7,468 (65.7)
	Health facility	4,348 (39.2)	3,907 (34.3)
Parity	Only one birth	1,435 (13.0)	1,419 (12.5)
	2-4 birth	5,042 (45.5)	5,022 (44.1)
	≥5 birth	4,608 (41.5)	4,934 (43.4)
Birth order	1-3	5,806 (52.4)	5,703 (50.1)
	4-5	2,584 (23.3)	2,655 (23.4)
	≥6	2,695 (24.3)	3,017 (26.5)
BMI	Thin	2,981 (26.9)	2,483 (21.8)
	Normal	7,106 (64.1)	8,164 (71.8)
	Overweight	998 (9.0)	728 (6.4)
Maternal height	< 150 cm	1,018 (9.2)	1,228 (10.8)
	≥150 cm	10,067 (90.8)	10,147 (89.2)
ANC visit	No ANC visit	2,321 (20.9)	2,602 (22.9)
	1-3 ANC visit	1,917 (17.3)	2,145 (18.9)
	≥ 4 ANC visit	6,847 (61.8)	6,628 (58.2)

Preceding birth interval	< 24 month	2,347 (21.2)	2,145 (18.9)
	≥24 month	8,738 (78.8)	9,230 (81.1)
Maternal anemia	Not anemic	6,696 (60.4)	7,590 (66.7)
	Anemic	4,389 (39.6)	3,785 (33.3)
Ever use of contraceptive	Yes	4,101 (37.0)	5,238 (46.0)
	No	6,984 (63.0)	6,137 (54.0)
Mode of delivery	Vaginal delivery	10,813 (97.5)	11,181 (98.3)
	Cesarean delivery	272 (2.5)	194 (1.7)
Number of gestation	Single	10,798 (97.4)	11,072 (97.3)
	Twin	287 (2.6)	303 (2.7)
Behavioral and community-level factors			
Smoking cigarettes	Yes	10,976 (99.0)	11,286 (99.2)
	No	109 (1.0)	89 (0.8)
Media exposure	Yes	9,747 (87.9)	10,020 (88.1)
	No	1,338 (12.1)	1,355 (11.9)
Community media exposure	Lower	5,503 (49.6)	4,640 (40.8)
	Higher	5,582 (50.4)	6,735 (59.2)
Community poverty	Lower	6,909 (62.3)	7,617 (67.0)
	Higher	4,176 (37.7)	3,758 (33.0)
Community ANC utilization	Lower	5,387 (48.6)	6,665 (58.6)
	Higher	5,698 (51.4)	4,710 (41.4)
Community women education	Lower	6,909 (62.3)	7,617 (67.0)
	Higher	4,176 (37.7)	3,758 (33.0)

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634 Table 3: SaTScan analysis results of stillbirth in Ethiopia, 2016.

Cluster	Enumeration area(cluster)identified	Coordinate/radius	Population	Case	RR	LLR	p-value
1	497, 95, 198, 521, 588, 553, 458, 171, 214, 251, 573, 239, 116, 22, 543, 490, 492, 92, 568, 33, 277, 527	(7.829198 N, 43.706264 E) / 166.48 km	532	17	22.5	13.4	0.00069



2	350, 229, 482, 531, 218, 510, 206, 10, 474, 267, 375, 423, 120, 176, 572, 517, 460, 24, 403, 429, 38, 3, 485, 456, 274, 167, 463, 112, 399, 532	(10.195460 N, 38.150574 E) / 142.05 km	384	14	3.6	8.84	0.04
3	564, 39, 230, 51	(9.555410 N, 40.326165 E) / 34.04 km	50	4	8.83	8.55	0.05

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636 Table 4: Multivariable multilevel logistic regression analysis result of both individual and  
637 community-level factors associated with stillbirth in Ethiopia, EDHS 2016

Individual and community-level characteristics	Null model	Model II AOR (95% CI)	Model III AOR (95% CI)	Model IV AOR (95% CI)
<b>Residence</b>				
Urban			1	1
Rural			3.75[1.33, 10.56]	4.83[1.44, 16.19]*
<b>Region</b>				
Amhara			1	1
Tigray			0.54[0.18, 1.63]	0.63[0.19, 2.17]
Afar			0.28[0.08, 0.94]	0.24[0.05, 1.06]
Oromia			0.20[0.07, 0.55]	0.25[0.07, 0.83]*
Somali			0.84[0.32, 2.21]	0.98[0.27, 3.56]
Benishangul Gumuz			0.25[0.07, 0.92]	0.37[0.09, 1.53]
SNNPR			0.21[0.06, 0.69]	0.56[0.14, 2.18]
Gambella			0.26[0.06, 1.07]	1.02[0.20, 5.22]
Harari			0.71[0.19, 2.63]	0.77[0.16, 3.72]
<b>Religion</b>				
Orthodox		1		1
Muslim		0.59[0.31, 1.12]		0.75[0.32, 1.77]
Protestant/catholic		0.12[0.04, 0.35]		0.11[0.03, 0.37]**
<b>Wealth status</b>				
Poor		1.12[0.60, 2.11]		0.87[0.45, 1.69]
Middle		1.58[0.78, 3.19]		1.21[0.60, 2.47]
Rich		1		1
<b>Women's education</b>				
No education		1		1

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3	Primary education	0.39[0.21, 0.75]		0.39[0.20, 0.74]**	
4	Secondary and higher	0.49[0.18, 1.33]		0.63[0.23, 1.71]	
5	education				
6					
7	<b>Birth order</b>				
8					
9	1-3	1		1	
10	4-5	0.49[0.24, 1.03]		0.50[0.24, 1.03]	
11	6 and above	0.66[0.25, 1.75]		0.66[0.25, 1.73]	
12					
13	<b>Parity</b>				
14	Only one birth	1		1	
15	2-4 birth	0.68[0.37, 1.28]		0.65[0.35, 1.22]	
16	≥ 5 birth	0.45[0.16, 1.28]		0.42[0.15, 1.20]	
17					
18	<b>ANC visit</b>				
19	No ANC visit	2.85[1.76, 4.62]		2.77[1.70, 4.51]**	
20	1-3 visit	1.22[0.68, 2.19]		1.11[0.62, 2.00]	
21	4 and above visit	1		1	
22					
23	<b>Media exposure</b>				
24	Yes	1		1	
25	No	2.11[0.85, 5.24]		1.63[0.66, 4.04]	
26					
27	<b>Maternal height</b>				
28	< 150 cm	2.66[1.47, 4.79]		2.73[1.50, 4.97]**	
29	≥150 cm	1		1	
30					
31	<b>Contraceptive use</b>				
32	Yes	0.74[0.43, 1.26]		0.72[0.41, 1.24]	
33	No	1		1	
34					
35	<b>Preceding birth interval</b>				
36	<24 month	1.92[1.19, 3.07]		1.93[1.20, 3.10]**	
37	≥24 month	1		1	
38					
39	<b>Mode of delivery</b>				
40	Vaginal delivery	1		1	
41	Cesarean delivery	4.00[1.35, 11.85]		5.07[1.65, 15.58]**	
42					
43	<b>Community media exposure</b>				
44	Lower community exposure		1	1	
45	Higher community exposure		0.96[0.51, 1.80]	1.02[0.51, 2.04]	
46					
47	<b>Community women's</b>				
48	<b>education</b>				
49	Lower community education		1	1	
50	Higher community education		1.28[0.61,2.71]	1.88[0.80, 4.42]	
51					
52	<b>Constant</b>	0.003[0.002, 0.005]	0.003[0.001, 0.01]	0.002[0.0005,0.0096]	0.001[0.0002, 0.01]
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3 **Model comparison and**  
4 **Random effects**

6 ICC	0.47(0.35, 0.59)			
7 Log-likelihood	-599.02	-551.2	-584.36	-540.50
8 Deviance	1198.04	1102.2	1168.72	1081

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10 638 \*AOR; Adjusted Odds Ratio, CI; Confidence Interval, ICC; Intra-class Correlation

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For peer review only

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3 **640 Figure legends:**

4 **641** Figure 1: The stillbirth rates across regions in Ethiopia, 2016

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8 **642** Figure 2: Global spatial autocorrelation of stillbirths in Ethiopia, 2016

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11 **643** Figure 3: Cluster and Outlier analysis of stillbirths in Ethiopia, 2016 (Source: Central Statistical  
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13 **644** Agency (CSA), Ethiopia, 2013)

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16 **645** Figure 4: Spatial Scan Statistical analysis of hotspot areas of stillbirth in Ethiopia, 2016 (Source:  
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19 **646** Central Statistical Agency (CSA), Ethiopia, 2013)

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22 **647** Figure 5: Kriging Interpolation of stillbirth in Ethiopia, 2016 (Source: Central Statistical Agency  
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24 **648** (CSA), Ethiopia, 2013)

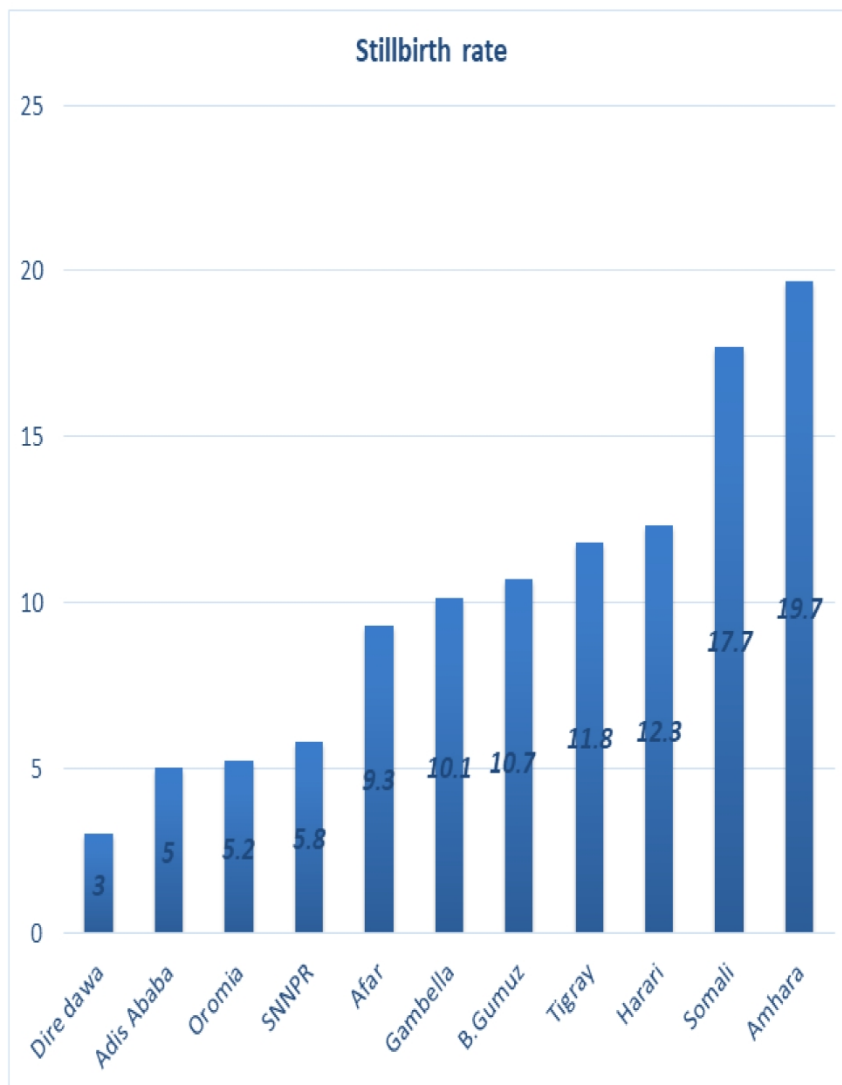


Figure 1: The stillbirth rate across regions in Ethiopia, 2016

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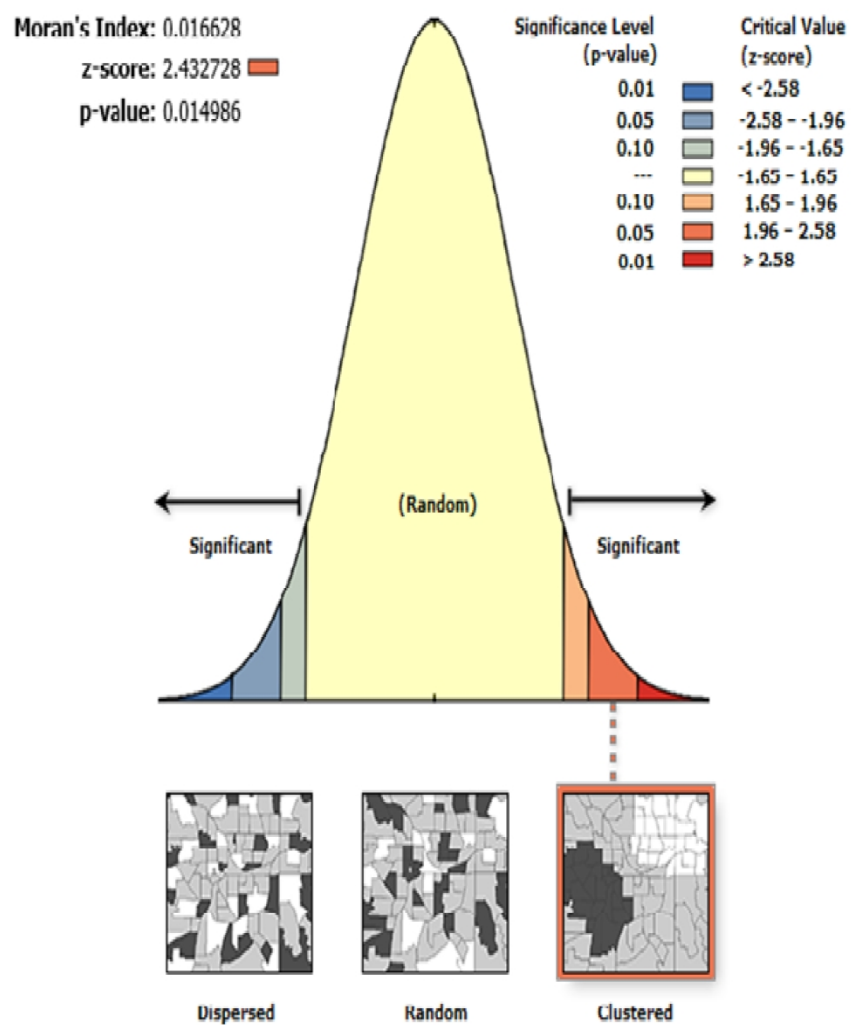


Figure 2: Global spatial autocorrelation of stillbirths in Ethiopia, 2016  
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Cluster and Outlier analysis of stillbirth across regions in Ethiopia, 2016

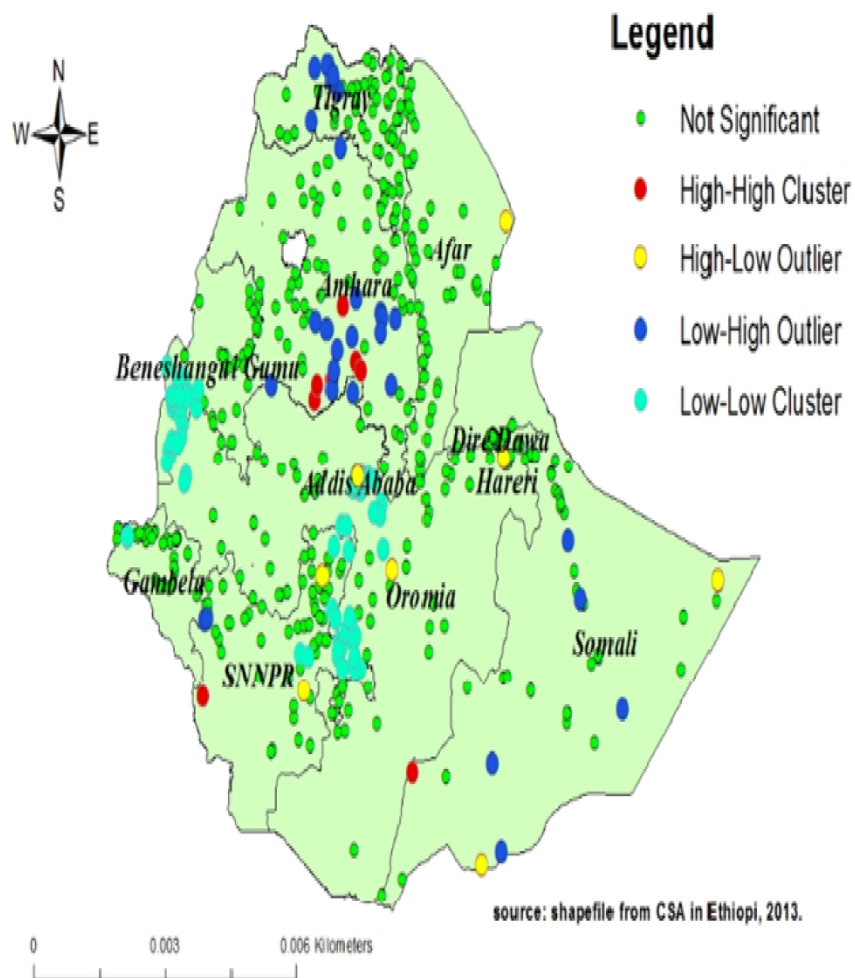


Figure 3: Cluster and Outlier analysis of stillbirths in Ethiopia, 2016 (Source: Central Statistical Agency (CSA), Ethiopia, 2013)

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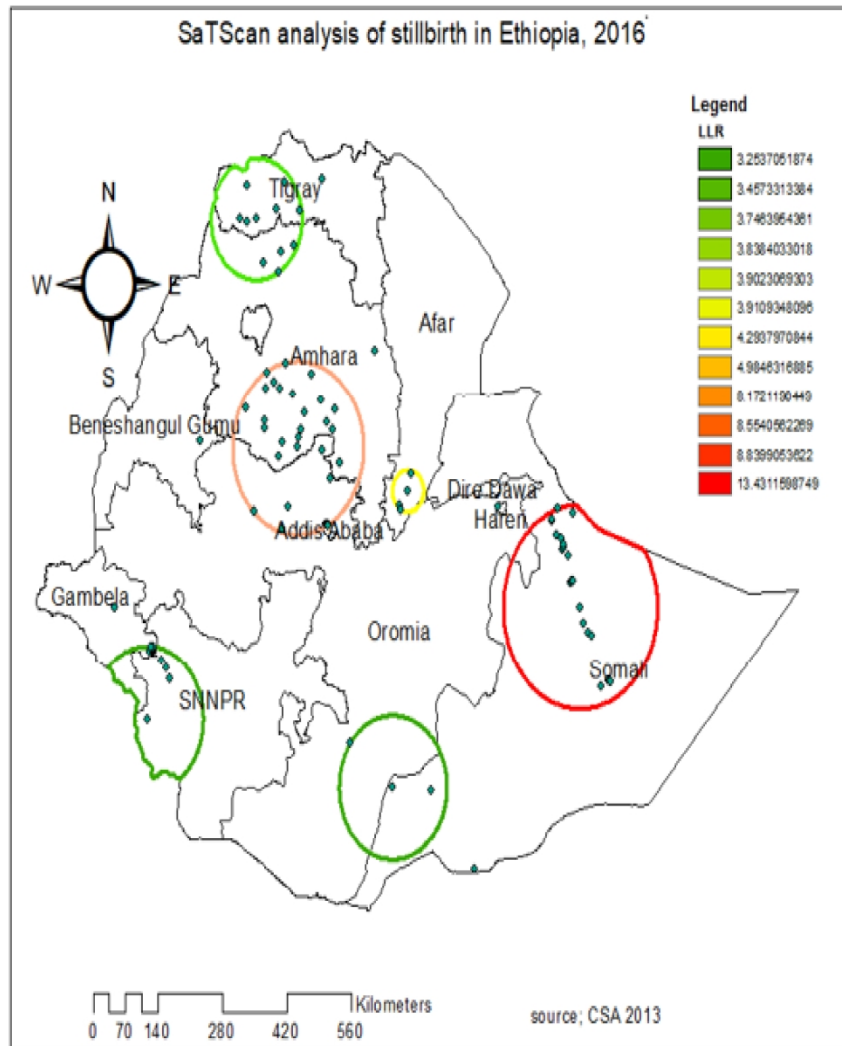


Figure 4: Spatial Scan Statistical analysis of hotspot areas of stillbirth in Ethiopia, 2016 (Source: Central Statistical Agency (CSA), Ethiopia, 2013)

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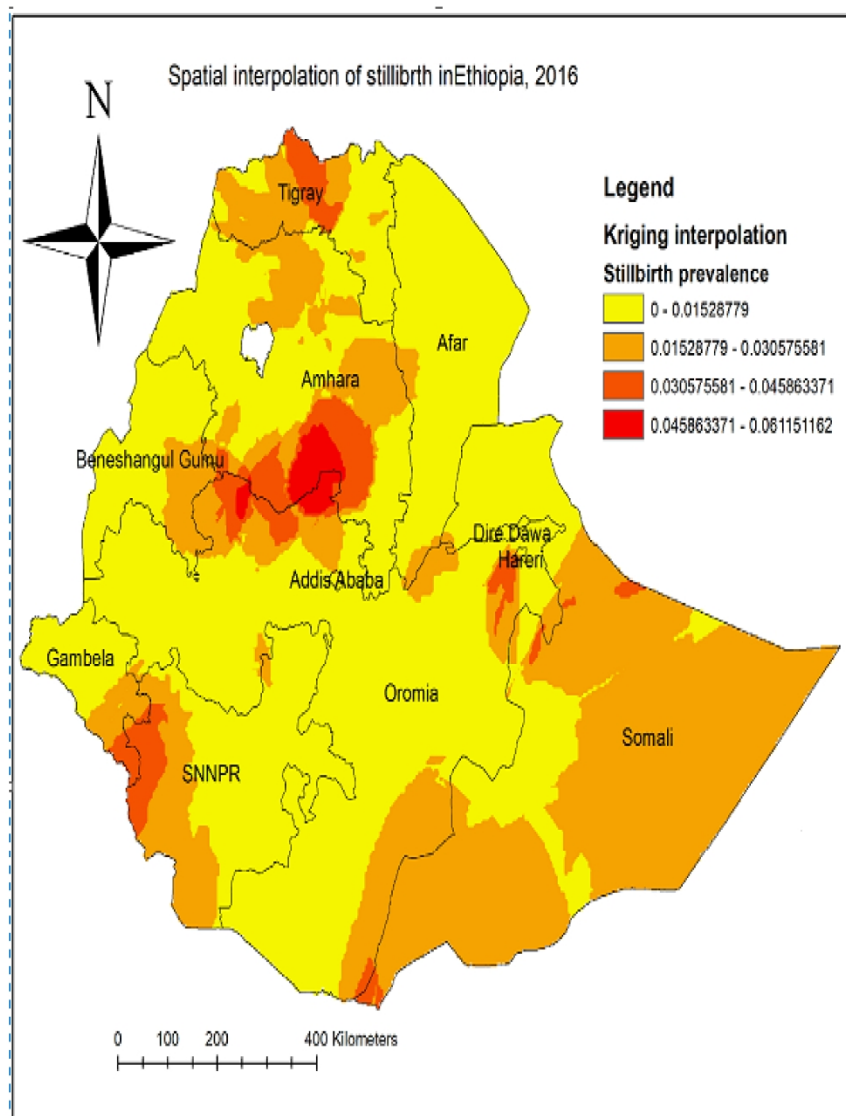


Figure 5: Kriging Interpolation of stillbirth in Ethiopia, 2016 (Source: Central Statistical Agency (CSA), Ethiopia, 2013)

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## STROBE Statement—checklist of items that should be included in reports of observational studies

	Item No.	Recommendation	Page No.
<b>Title and abstract</b>	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&3
<b>Introduction</b>			
Background/rationale	2	Explain the scientific background and rationale for the investigation being reported	4, 5 & 6
Objectives	3	State specific objectives, including any pre-specified hypotheses	6
<b>Methods</b>			
Study design	4	Present key elements of study design early in the paper	6
Setting	5	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection	6, 7 & 8
Participants	6	(a) <i>Cohort study</i> —Give the eligibility criteria, and the sources and methods of selection of participants. Describe methods of follow-up	N/A
		<i>Case-control study</i> —Give the eligibility criteria, and the sources and methods of case ascertainment and control selection. Give the rationale for the choice of cases and controls	N/A
		<i>Cross-sectional study</i> —Give the eligibility criteria, and the sources and methods of selection of participants	6 & 7
		(b) <i>Cohort study</i> —For matched studies, give matching criteria and number of exposed and unexposed	N/A
		<i>Case-control study</i> —For matched studies, give matching criteria and the number of controls per case	N/A
Variables	7	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable	7 & 8
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	7&8
Bias	9	Describe any efforts to address potential sources of bias	8 & 9
Study size	10	Explain how the study size was arrived at	6&7

Continued on next page

Quantitative variables	11	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why	, 8,9,10 &11
Statistical methods	12	(a) Describe all statistical methods, including those used to control for confounding	8,9,10 &11
		(b) Describe any methods used to examine subgroups and interactions	N/A
		(c) Explain how missing data were addressed	10, 11
		(d) <i>Cohort study</i> —If applicable, explain how loss to follow-up was addressed	N/A
		<i>Case-control study</i> —If applicable, explain how matching of cases and controls was addressed	N/A
		<i>Cross-sectional study</i> —If applicable, describe analytical methods taking account of sampling strategy	8,9 &10
		(e) Describe any sensitivity analyses	N/A
<b>Results</b>			
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	N/A
		(b) Give reasons for non-participation at each stage	N/A
		(c) Consider use of a flow diagram	N/A
Descriptive data	14*	(a) Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders	14
		(b) Indicate number of participants with missing data for each variable of interest	15
		(c) <i>Cohort study</i> —Summarise follow-up time (eg, average and total amount)	N/A
Outcome data	15*	<i>Cohort study</i> —Report numbers of outcome events or summary measures over time	N/A
		<i>Case-control study</i> —Report numbers in each exposure category, or summary measures of exposure	N/A
		<i>Cross-sectional study</i> —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	16 & 17
		(b) Report category boundaries when continuous variables were categorized	14
		(c) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period	N/A

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Other analyses	17	Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses	N/A
<b>Discussion</b>			
Key results	18	Summarise key results with reference to study objectives	22
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	21
Interpretation	20	Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence	18, 19, 20, 21& 22
Generalisability	21	Discuss the generalisability (external validity) of the study results	21
<b>Other information</b>			
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	23

\* cross-sectional studies.