Available online at https://asric.africa/health-sciences
ASRIC Journal on Health Sciences Vol.4(1)(2024) 113-121

Spatial Distribution and Determinants of Caesarean Section Delivery in Ethiopia: a Spatial and Multilevel Analysis EDHS 2019

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Received 30 April 2024; revised 06 July 2024; accepted September 2024

Abstract

Introduction: Assessing the spatial distribution of caesarean section (CS) is important in developing an effective intervention. However, there is no spatial analysis of the distribution of CS in Ethiopia. Therefore, this study aims to investigate the spatial distribution and the determinants of CS delivery in Ethiopia. **Methods:** The Bernoulli model was applied using SaTScan V.9.6. Geospatial patterns and prediction of CS delivery in unsampled areas were mapped using ArcGISV.10.8. A multilevel regression model was fitted. The adjusted odds ratio was reported by 95% CI and a p-value<0.05 was declared a statistically significant factor. **Result:** In Ethiopia, the prevalence of CS delivery was 5.44 %(95% CI: 4.9-6). Spatial clustering CS was observed in Addis Ababa and Dire Dawa. In the multilevel analysis, rural settlement (AOR=1.98; 95% CI: 1.02 to 3.86), the primary (AOR= 2.41; 95% CI: 1.67 to 3.47), the secondary (AOR= 3.61; 95% CI: 2.19 to 5.94) and higher education (AOR= 3.80, 95% CI: 2.11 to 6.85), rich wealth status (AOR=1.66, 95% CI: 1.06-2.59), and twin birth (AOR= 7.32; 95% CI: 4.13-12.99) were significantly associated with CS. **Conclusion and recommendation:** Significant spatial variation had seen in Ethiopia. Therefore, reducing the unnecessary use of CS delivery should be improved in the hotspot areas.

Keywords: Caesarean section, spatial analysis, Multilevel, Ethiopia

Introduction

A caesarean section(CS) is the surgical procedure in which one or more babies are delivered through an incision in the mother's abdomen, often performed because vaginal delivery would put the baby or mother at risk(Rudey, do Carmo Leal, & Rego, 2020). It is an important life-saving intervention that can reduce the mortality and morbidity of newborns and mothers(Elnakib, Abdel-Tawab, Orbay, & Hassanein, 2019). The dramatic increase in CS levels worldwide has raised concerns that the procedure may be overused or used for inappropriate indications (Chen & Tan, 2019).

According to new research released by the World Health Organization (WHO), surgical use continues to grow worldwide, accounting for more than 1 in 5 (21%) of all childbirths(Organization, 2021b). The prevalence of surgical delivery with abdominal incision was 35.6% in China(Yan et al., 2020), 34% in Australia(Fox, Callander, Lindsay, & Topp, 2019), 51.2% in Turkey(Eyi & Mollamahmutoglu, 2021), 72% in Iran(Amini, Mohammadi, Omani-Samani, Almasi-Hashiani, & Maroufizadeh, 2018), 19% in India(Roy, Paul, Chouhan, Rahaman, & Kapasia, 2021), 43.7% in Brazil(Coelho et al., 2021), 13% in Kenya(Ochieng Arunda, Agardh, & Asamoah, 2020), 9.9% in Uganda(Atuheire et al., 2019), 2.1% in Nigeria(Adewuyi, Auta, Khanal, Tapshak, & Zhao, 2019), and 6% in Tanzania(Cavallaro et al., 2018). Women who undergo CS delivery face the risks of surgery and increase risk of complications in future pregnancies such as infection, postpartum hemorrhage, reactions to anesthesia, blood clots, and surgical injury(Ahmeidat, Kotts, McLernon, & Black, 2021).

In Ethiopia, the demographic and health survey (EDHS) 2016 reported, the prevalence of caesarean section was 1.9%(Yisma, Smithers, Lynch, & Mol, 2019) with significant regional variations. Understanding the spatial distributions of caesarean sections in Ethiopia is essential to designing health care programs, which absorb the rising need for caesarean sections. Residence, educational status, prior caesarean delivery, complicated pregnancy, abnormal placenta, obstructed labor, fetal distress, large fetus, and cephalopelvic disproportion (CPD) imbalance have been identified as important factors related to surgical delivery (Arikan et al., 2021; Waniala et al., 2020). CS delivery rates vary widely across the country(Organization, 2021a). Therefore, the identification of high-risk CS delivery sites using geospatial analysis is essential to detect targeted public health interventions that increase access to health care that sucks mothers in need of childbirth and reduce unnecessary caesarean delivery. However, data on the spatial distribution and determinants of caesarean section was a lack in Ethiopia. Thus, this study aimed to investigate the spatial distribution and determinants of caesarean delivery in Ethiopia.

Materials and Methods

Study design and setting: A secondary EDHS data of 2019 analysis was conducted to investigate the spatial distribution and determinants of CS delivery in Ethiopia. Ethiopia has an area of about 1.1 million km^2 with a range of 125 meters below sea level at Danakil depression to 4620 above sea level at Ras Dashen Mountain(Billi, Golla, & Tefferra, 2015). Ethiopia uses a three-tier health system, namely primary care consisting of health posts, health centers, and primary hospitals; secondary care includes general hospitals and higher care consists of comprehensive specialized hospitals where CS delivery and health services are provided.

Source of Data and Data Collection Process

Data for this study were obtained from the EDHS 2019 after permission was granted in an online application explaining the purpose of this our study. It is nationwide data. This study was the second of its kind in the country, designed to provide estimates at national, regional, and local levels. During the data collection, there were no conflicts across the country.

EDHS used two-stage stratified probability sampling. In the first phase or stage, a total of 305 enumeration areas (EAs) were selected using samples that were subdivided into urban and rural areas. In the second phase, households were selected using probability sampling from each cluster. In this analysis, a total of 5527 mothers aged 15-49 in weight was extracted or taken from the women's (IR) data set, with a history of birth five years before the study. The geospatial data was also obtained from the EDHS 2019. For spatial analysis, we used the Kriging interpolation method to predict CS in unsampled areas as it improved the predictive rate by taking into account the effect of distance reduction (distance to weight). Extrapolation or addition may tend to be biased because it predicts beyond the distance limit, while in our study interpolation was used to predict CS in unsampled areas.

The Population of the Study

The source population of this study was all women of childbearing age, who had a history of birth within 5 years prior to the survey in Ethiopia. Whereas, the study population was women of childbearing age with a history of birth five years before the survey in selected enumeration areas (clusters). Women with incomplete birth histories were not included in the analysis.

Study Variables

Outcome Variable

The outcome variable for this study was caesarean section delivery (Yes/No). The EDHS survey has a question for mothers who have a birth history about whether they experienced caesarean section or not. If they say Yes to this question we coded it as "1" which means they experienced caesarean section and we coded it as"0" if they say No to the question that means they didn't experience CS.

Independent Variables

In this study, we used two-level factors due to the nature of EDHS data sequencing. Level 1 contained individual, social, economic, and pregnancy factors such as age, marital status, education status, religion, wealth status, and twin pregnancies. The community-level factors are the place of delivery, the region, the place of residence, and the gender of the child.

Data Management and Analysis

After cleaning, the data were evaluated using sample weight, statistical analysis; the main sampling unit, strata, and sampling design was considered for retrieval representative representation and obtaining reliable mathematical estimates. To obtain a statistical representation of Ethiopia, the distribution of women in the sample needs to be measured or weighted (statistically adjusted) to match the actual distribution in Ethiopia, using sampling weight (v005). Descriptive statistics were performed and summarized using tables and texts. In order to determine the variables that would include a multivariable model, a bivariate analysis between each descriptive variable and the outcome variable was done.

The descriptive variables most closely related to the outcome variable at a P value of less than 0.2% were included in the multivariable logistic regression model to identify independent determinants of the caesarean section. Odds ratios (OR) were calculated to determine the strength of associations between independent variables and the outcome variable at a 95% confidence interval (CI).

Sample weights were used to compensate for the unequal probability of choice between the categories or strata, which have been defined geographically without responses. A detailed description of the weighting procedure can be found in the EDHS method report(Casebolt, 2021).

Spatial Analysis

For the spatial analysis, data was managed using STATA 14 and Microsoft Excel 16 version; mapping was performed using ArcGIS version 10.8, and SaTScan 9.6 software.

Spatial Autocorrelation Analysis

Spatial autocorrelation (Global Moran's I) was performed to assess whether there was a significant spatial clustering of caesarean sections in Ethiopia. Moran's I statistics measure whether CS patterns are dispersed, clustered, or randomly distributed in the study area(Radersma & Sheldon, 2015) by taking the whole set of data set and producing a single output value(−1 to +1). Moran's I values close to −1 indicate spatial distribution of caesarean section was dispersed, while Moran's I values close to +1 indicate spatial distribution of CS was clustered, and an I value of 0 means caesarean section was randomly distributed. Moran's I ($p<0.05$) statistically significant leads to the rejection of the null hypothesis (CS is randomly distributed) and indicates the presence of significant spatial autocorrelation/spatial dependence.

Hotspot Analysis of Caesarean Section

The Hotspot analysis (Getis-Gi*) was employed to identify the spatial clustering of caesarean sections in Ethiopia (Hu et al., 2019). Spatial scan statistical analysis (SaTScan) using the Bernoulli model was used to assess the availability of statistically significant spatial clusters for caesarean section (Lee, Moon, & Jung, 2021). The SaTScan statistics use a round/circular scanning window that runs across the study area. Women who underwent caesarean section were considered as cases and those who gave birth without CS as controls to fit the Bernoulli model. Geographical coordinates' data were also fitted along with the cases and controls. The default spatial cluster size of <50% of the population was used as the maximum limit, allowing to detection of both small and large clusters. Ignored clusters/groups were that contain more than the upper limit. Likelihood ratio (LR) test statistics, relative risk, and p-

values were used to determine whether the number of observed caesarean sections within the potential cluster was significantly higher than expected or not.

Spatial Interpolation

Spatial interpolation method was used to predict caesarean sections in unsampled areas. There are various ways of determining geostatistical interpolation methods. Among the various methods of deterministic and geostatistical interpolation, conventional Kriging and empirical Bayesian Kriging are considered the best methods as they incorporate spatial autocorrelation and statistically optimize the weight(Geography, 2019). In this study, the ordinary Kriging interpolation method was used to estimate caesarean sections in unobserved areas of Ethiopia.

Determinants of Caesarean Section

In the EDHS data, women are expected to be built within the cluster, and women within the same cluster were more similar than women across the country. It violates standard regression model assumptions, which are independent of observation and equal variability in all cluster speculations. This means the need to use an improved model due to the difference between clusters. For this reason, a multilevel logistic regression model was fitted to measure the association between individual-level and community-level variables and the chance or LR of caesarean section. Deviance (-2 log-likelihood) was used in model comparison as models were developed. To measure the difference between cluster groups, the LR test and intra-cluster correlation coefficient (ICC) were computed. The ICC measures the level of heterogeneity of caesarean sections between clusters (a fraction of the total amount observed in caesarean sections caused by differences between clusters). Multilevel random intercept logistic regression was used to analyze caesarean section-related factors at two levels to take into account the sequence of data, at the individual and the community level. In order to analyze multilevel logistic regression, four models were developed. The first model (a multilevel random intercept logistic regression model without covariates) was the null model without any descriptive variables, in order to determine the degree of cluster variability in the caesarean sections. A second model (a multi-level model) level1 variables, and adjusted for individual-level variables. The multi-level model with level 2 variables was the third model and adjusted to the community level variables; the model fitted in the individual and community level variables was the fourth model. The latter model was the best-fitted model as it had a very low deviation value. The variables with a p-value ≤ 0.2 in the bivariable analysis of both individual-level and community-level factors were fitted in the multivariable model. Adjusted OR (AOR) with 95% CI and $p<0.05$ in the multivariable model were used to express significantly associated factors of caesarean section.

Ethical Approval

The study is based on the second analysis of EDHS-2019 data. The authors requested the Measure DHS through outlining the objectives of this analysis and access was provided for the use of the website data (http://dhsprogram.com), so ethics authorization was not required.

Results

Socio-Demographic and Economic Characteristics of Participants

A total of 5527 weighted women who gave birth during the 5 years prior to the survey were included in the analysis. Nearly one-third of study participants (31.8%) were aged 25-29 years and slightly higher than half (53.6%) of the mothers had informal education. About 75.3% of study participants were rural dwellers. The majority (94.5%) of mothers were married, and 38.0% of the Muslim population followed by the Orthodox 33.7% (Table1).

Pregnancy and Health Service-Related Characteristics of the Participants

About half (50.1%) of the mothers gave birth at home. Of mothers, 5380(97.4%) gave single baby and 51.4% of the children were males (Table 2). In Ethiopia, the overall prevalence of caesarean section was 5.44% (95% CI: 4.9-6.1). A high prevalence of CS delivery was observed in Addis Ababa and Dire Dawa (Figure 1).

Spatial Analysis

Spatial Autocorrelation

The global autocorrelation analysis revealed that caesarean section varied significantly across the country, with a Global Moran's I value of 0.75, p<0.01) (Figure 2).

Hotspot Analysis of Caesarean Section

In analyzing the Hotspot analysis (Getis-Ord Gi*) mapping, significant clustering of caesarean sections was found in Central Addis Ababa and Eastern Dire Dawa of Ethiopia. Whereas, spatial dispersion of caesarean section delivery was observed in Gambella, Western Oromia, Southern Benishangul, Eastern Amhara, and in the eastern parts of SNNPR (Figure 3).

In a statistical analysis of special scan, a total of 58 significant clusters were identified, 27 of which were primary (likely clusters), 13secondary, 16 tertiary, and 2 quaternary clusters. The main spatial window of the cluster was located in Addis Ababa at 8.651588 N, 39.118340E location, with an area of 65.24 km, the relative risk of 4.89, and LLR of 60.6, at p<0.001) (Table 3). It confirms that mothers within the spatial window were 4.89 times more likely to have caesarean section than mothers outside the window. The second and tertiary SaTScan window was located at Dire Dawa at 8.651588 N, 39.118340 E with 65.24 km and 9.585229 N, 41.849280 E with 3.57 km radius respectively. Women in the secondary (p value<0.001) and tertiary (p value=0.0029) windows were 4.94 and 2.55 times more at high risk to have caesarean section than mothers outside the window respectively (Figure 4 and Table 3).

Spatial Interpolation of Caesarean Section

The predicted high prevalence of caesarean section was seen in Addis Ababa, Dire Dawa, Northern Amhara, and Northern parts of SNNPR. Whereas, predicted low prevalence of caesarean section was observed in eastern (Somali region) and western (Gambela region) parts of Ethiopia (Figure 5).

Factors of Caesarean Section

The ICC and LLR tests were tested, and the multi-level model became the best-fitted data model. Thus, a multilevel logistic regression model was used to get the unbiased inference. The deviation was used to compare the model and the final model was a well-fitted model with a very low deviation value. The ICC value was 44% in the empty/null model; indicating that 44% of the total caesarean section variability was due to between-cluster or EA difference, with the remaining 56% due to individual difference. In a multivariable multilevel model, educational status, residence, wealth status, and gave twins child were closely associated with caesarean section. At the community level (level 2), one variable was associated with caesarean section. The chance of having caesarean section among mothers living in urban areas was 1.98 times (AOR=1.98; 95% CI: 1.02-3.86) more than mothers living in rural areas. At the individual level, three variables were significantly associated with caesarean section. Women's educational level was significantly associated with caesarean section. The chance of having caesarean section among women who received primary, secondary, and higher education were 2.41 times (AOR= 2.41; 95% CI: 2.41, CI 1.67 to 3.47), secondary 3.61 times (AOR= 3.61; 95% CI: 2.19-5.94), and higher education was 3.80 times (AOR= 3.80; 95% CI: 2.11-6.85) higher than women without formal education. Also, mothers who were rich in economic status were 1.66 times (AOR=1.66; 95% CI: 1.06-2.59) had a higher chance of experiencing caesarean section compared with their counterparts. Gave the twin child was one of the predictors for caesarean section. Women who gave birth to twins who were 7.32 times (AOR= 7.32; 95% CI: 4.13-12.99) had a higher chance of having caesarean section compared to women who gave birth to one (Table 4).

Discussion

The prevalence of caesarean section in Ethiopia was 5.44% (95% CI: 4.9-6.1), with significant spatial heterogeneity. The spatial distribution of caesarean sections varied greatly across the country. SaTScan analysis found the total number of spatial windows of four statistically significant areas with high caesarean section rates. The significant caesarean section hot spot sites have been identified in Addis Ababa, and Dire Dawa. A possible explanation could be because these areas are more civilized compared to the Oromia, Amhara, SNNPR, Pastoralist area regions, and one of them is the rise in obesity in the urban areas. In pastoralist areas such as Afar, Benishangul gumuz, and Somalia regions people do not have permanent settlements. Therefore, may be affected by their livelihoods compared to

agricultural and urban people. In addition, the rests of the regions are rural and therefore have poor network health networks, which can reduce the risk of obesity. Evidence has shown, The evidence showed, the occurrence of CS among obese women is higher by 2.05 compared with normal weight women(Endalifer, Diress, Almaw, & Endalifer, 2021).

In multi-level analyzes, different individual and social factors were strongly associated with the caesarean section. Among the variables at the community level, studies have shown that the chance of having caesarean section was higher for women living in urban areas, and this was in line with findings from previous studies in Vietnam(de Loenzien, Schantz, Luu, & Dumont, 2019), and Nepal(Khanal, Karkee, Lee, & Binns, 2016). This may be due to disparity in mothers' awareness, as well as mothers' choice of caesarean section because women residing in urban areas are more knowledgeable about the advantages of CS. A woman's likelihood of having a caesarean delivery depends more on whether she lives in an urban region(Yisma, Mol, Lynch, & Smithers, 2019). Among the individual-level factors, this study identified a higher risk of caesarean section among women who received primary and higher education compared with uneducated women. These findings are comparable with previous studies in Ghana(Manyeh, Amu, Akpakli, Williams, & Gyapong, 2018), and Tanzania(Cavallaro et al., 2018). It may be due to the fact that education can improve the behavior of those seeking health care, such as timely decisions to provide better care for their health and that of their fetus. Education enhances women's ability to make decisions about their health care and there is the belief that many highly educated women prefer caesarean section delivery(Afiaz, Arusha, Ananna, Kabir, & Biswas, 2021). The chances of having a caesarean section were high for women with a wealth of economic status. Similar findings were reported in Nigeria(Ushie, Udoh, & Ajayi, 2019), Ghana(Diema Konlan, Baku, Japiong, Dodam Konlan, & Amoah, 2019), and Addis Ababa Ethiopia (Bayou, Mashalla, & Thupayagale-Tshweneagae, 2016). There has been a high concentration of caesarean section delivery among women in high-income areas because families with high socioeconomic status could easily access and afford CS costs(Milcent & Zbiri, 2018). The birth of twins is closely related to the increase in caesarean section, and this was in line with previous findings of low-income earners in middle-income countries, Sweden(Jonsson, 2015), and East and Southern Africa(Hanson et al., 2019). Twin pregnancies appear to be an independent risk factor in caesarean section delivery(Loscul, Schmitz, Blanc-Petitjean, Goffinet, & Le Ray, 2019). The planned vaginal birth policy for pregnant women with twins is associated with a 30% to 40% emergency CS delivery(Hofmeyr, Barrett, & Crowther, 2015). The strength of this study was to use spatial analysis and weighted data to ensure representation at national and regional levels. Therefore, it can be generalized to all women who give birth in Ethiopia during the study. In addition, the use of GIS and SaTScan statistical testing has helped to identify similar and hot spot areas in terms of caesarean section statistics and will help design effective public health systems.

The findings of this study have important policy implications for planned health planning and interventions. Areas of high risk of caesarean sections can be easily identified for effective local intervention. In general, these findings are of great importance to the Minister of health, regional health institutions, and non-governmental organizations in developing interventions to reduce caesarean section in the hotspot areas identified by the study.

Conclusion and Recommendation

Caesarean section had been sharply raised in Ethiopia with significant spatial variation. Spatial clustering of caesarean sections was seen in Addis Ababa and Dire Dawa. Residence, educational status, wealth status, and twin births were important predictors of caesarean section. Therefore, public health interventions targeted to increase the health care access that absorb the mothers in need of caesarean delivery and reduce unnecessary use of caesarean delivery should be improved in the hotspot areas.

Abbreviations: AOR, Adjusted Odds ratio; ArcGISV, Aeronautical Reconnaissance Coverage Geographic Information System; COR, Crude Odds Ratio; CS, Caesarean Section; EDH, Ethiopian Demographic and Health Survey; EAs, Enumeration Areas; ICC, Intra-class Correlation; LR, Likelihood Ratio; LLR, Log-likelihood Ratio; RR, relative risk; SNNPR, Southern Nations, Nationalities and People's Region; SaTScan, Spatial Scan Statistical Analysis.

Declarations

Funding: None

Conflict of interest: No conflict of interest

Authors' contributions: YB, WA, ATG and KAA wrote the main manuscript, conducting the analysis. WZ, YGB, and AWA prepared figures. All authors reviewed the manuscript.

Acknowledgments

We owe the DHS program permission for us to use the 2019 EDHS data for this analysis.

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