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Exploring Geographical Variation in Iron Supplementation among Ethiopian Women Aged 15 to 49 who have had a Child in the Last Five Years: A Spatial Analysis of the Ethiopian Demographic and Health Survey 2016-2019

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Abstract

Background: Anemia among women of childbearing age is a major public health issue worldwide, especially in low- and middle-income nations. The most prevalent type of anemia in the world is nutritional anemia, which is caused by a lack of iron, folate and vitamin B12. Iron deficiency anemia is the most frequent cause of anemia, accounting for more than half of all cases. Investigating regional variations in iron supplementation among women is necessary for designing and assessing successful intervention strategies. As a result, from 2016 to 2019, this study aimed to investigate the regional variance in iron supplementation among Ethiopian women aged 15 to 49 who had a child in the previous five years.

Methods: The 2016 and 2019 Ethiopian Demographic and Health Surveys were used. Researchers employed spatial autocorrelation analysis, hotspot analysis, spatial interpolation, and spatial scan statistics to identify geographical risk areas for iron supplementation coverage. Using ArcGIS V.10.3 and SaTScan V.10.0 statistical software, the spatial pattern and major hotspot areas for iron supplementation among women were explored.

Results: At the regional level in Ethiopia, iron supplementation coverage was regionally clustered. (Global Morans = -0.517864 (p = 0.033744)). In Ethiopia, the solely SaTScan spatial analysis showed seven significant clusters. The SaTScan cluster with the lowest iron supplementation coverage was shown to be the most likely cluster in Oromia (LLR = 164.51, p < 0.01) and Somalia (LLR = 12.01, p < 0.01). In 2016 and The SaTScan cluster with the lowest iron supplementation coverage was shown to be the most likely. in Somalia (LLR = 82.34, p < 0.01), Oromia (LLR = 14.10, p < 0.01).and SNNPRS (LLR4.81, p < 0.01) in 2019.

Three notable clusters were detected using the Space-Time SaTScan analysis.

The SaTScan cluster with the lowest iron supplementation coverage was shown to be the most likely. in Oromia (LLR = 162.13, p < 0.01) and SNNPRS (LLR 3.24, p < 0.01) during the period from 2016/6/27-2017/6/28.

Conclusion: Women in the Harar, Dire Dawa, Gambella, Somalia Oromia, and Southern Nation Nationalities and Peoples Regions had a low likelihood of receiving iron supplements.

As a result, these locations should be considered when designing effective Antenatal care programs to increase iron supplementation among women in order to reduce the burden of anemia and its repercussions among pregnant women in Ethiopia.

Keywords: *Iron Supplementation;* Spatial Analysis

Introduction

Anemia among women of childbearing age is a major public health issue worldwide, especially in low- and middle-income nations [1,2]. Though anemia is prevalent among pregnant women, it affects women of all age groups [1,3]. In 2019, anemia prevalence was 29.9% in women of reproductive age, and 36.5% in non-pregnant women of reproductive age globally [1].

The most prevalent type of anemia in the world is nutritional anemia, which is caused by a lack of iron, folate, and vitamin B12. Iron deficiency anemia is the most frequent cause of anemia, accounting for more than half of all cases [3,4]. The recommended iron supplementation for pregnant women is 20 mg per day, which is more than the requirement for non-pregnant women [5].

The World Health Organization (WHO) recommends that all pregnant women, regardless of their hemoglobin level, receive iron supplementation [6]. The difficulties of mother and child health can be avoided if the correct dosage is taken on time [7,8]. Anemia is a serious public health problem in Ethiopia, according to WHO guidelines [3].

Anemia has a number of negative health consequences in reproductive women, including increased susceptibility to infection, decreased productivity due to lower work capacity, cognitive impairment, stillbirth/miscarriage, and maternal death [9].

Advanced maternal age [10,11], parity [11], knowledge of anemia and diagnosis of anemia [11,12] and usage of other food supplements [13] are all linked to iron supplementation in pregnant women. In Ethiopia, iron supplementation coverage among pregnant women is inadequate, falling short of WHO recommendations [6]. Furthermore, it differs from one place to the next.

Iron supplementation during pregnancy, maternal education, household economic status, sex of household head, maternal age, antenatal care visit, cesarean delivery, history of a terminated pregnancy, maternal occupation, religion, marital status, maternal body mass index (BMI, source of drinking water, parity, place of delivery, current modern contraceptive use, duration of breastfeeding and number of births are the factors associated with anemia during pregnancy [14,15].

According to WHO estimates, anemia among women of reproductive age remains high in both developed and developing countries [3]. In impoverished nations like Ethiopia, the severity of the problem is widespread and linked to a variety of factors affecting the people.

Despite the problem's broader extent, there hasn't been enough research done utilizing spatial analysis to understand how the problem varies between clusters. Designing and evaluating effective intervention programs necessitates investigating regional variations in iron supplementation among women. As a result, the goal of this study was to look at the regional variance in iron supplementation among Ethiopian women aged 15 to 49 who had a child in the previous five years from 2016 to 2019.

Methods

Study design, setting, and period

The Ethiopian Demographic and Health Survey (EDHS) was held on June 27, 2016, and the smaller Ethiopian Demographic and Health Survey (EDHS) was conducted on June 28, 2019.

Ethiopia has nine regional states (Tigray, Amhara, Afar, Oromia, Benishangul-Gumuz, Gambela, Harari, Somalia, and Southern Nations, Nationalities, and People's Region (SNNPR)) and two administrative centres (Addis Ababa and Dire Dawa). Ethiopia is primarily a farming country, with agriculture accounting for 43% of GDP. Amhara, Oromia, and SNNPR are the three regional states that make up the country's population [16].

Ethiopia is Africa's second most populous country and the world's 13^{th} most populous country. Primary (hospitals, health centers, health posts, primary clinics, and medium clinics), secondary (general hospitals, speciality clinics, and specialty centers), and tertiary (hospitals, specialty clinics, and specialty centers) health care are currently available in Ethiopia (specialized hospital). The number of hospitals varies by region, owing to differences in population size.

There are 30 hospitals in Oromia, the most populous region. SNNPR and Amhara, the next two most populated areas, each have ninety and twenty hospitals, while Tigray, the fourth most populous region, has sixty hospitals. There is only one hospital in Gambela, but Benishangul-Gumuz has two [17].

Sample population and variable measurement

With the 2007 Population and Housing Census (PHC) as the sampling frame, which was selected in two phases, the EDHS used a stratified two-stage cluster sampling technique. Each region was divided into urban and rural divisions to stratify it.

Because the Addis Ababa region is completely urban, there were a total of 21 sampling strata constructed. Using a probability proportional to survey cluster size and independent sample stratum selection in each sampling stratum, 645 survey clusters (202 in the city) were selected in the first step.

Due to the passage of time since the PHC, the second stage involved a full home listing operation in all selected survey clusters prior to the start of field operations, with an average of 28 families being selected methodically.

Finally, there were 18 008 families and 4453 children in the research. A thorough sampling technique is included in the full EDHS 2016 and 2019 report [16]. Iron supplementation was classed as either yes or no.

The percentage of women who take iron supplements was used for additional spatial analysis. A google search yielded the geographical coordinates XY data (latitude and longitude coordinates) for each GBS region. The survey data sets and location data were obtained after justifying the purpose of data access and being declared an authorized user. The survey data sets and location data were accessed through the international Demographic and Health Survey Program website.

Spatial data analysis

The data on coordinates and outcome frequency (weighted) variables with amount of clusters was entered using Excel. ArcGIS V.10.3 was used for the analysis.

Iron supplementation was disseminated, concentrated, or randomly distributed in this study region, according to the spatial autocorrelation by aggregating the whole data set and producing a single output value ranging from 1 to +1, the Global Moran's I spatial statistics were employed to measure spatial autocorrelation.

When Moran's I values are close to 1, it means scattered iron supplementation coverage, whereas Moran's I values near +1 indicate clustered iron supplementation coverage, and an I value of 0 indicates randomly distributed iron supplementation coverage.

The presence of spatial autocorrelation is revealed by a statistically significant Global Moran's I (p0.05), which rejects the null hypothesis (iron supplementation coverage is randomly distributed).

Hotspot analysis (Getis-Ord Gi* statistics)

Depending on the study setting, the degree of spatial autocorrelation varies.

The Getis-Ord Gi* statistics and the GiBin statistic were used to calculate the variance for each location. To establish the statistical significance of clustering, the z-score (CI) and p-value were determined [18]. In Ethiopian women aged 15 to 49, statistical output with a high GiBin* indicates a 'hotspot,' or varied geographical locations with low iron supplementation coverage, whereas a low Gi* indicates a 'cold spot,' or sites with high iron supplementation coverage [19-21].

Spatial interpolation

In both deterministic and probabilistic approaches, interpolation algorithms anticipate iron supplementation coverage in unseen areas based on known data. The most often utilized probabilistic types of interpolation methods for prediction are ordinary kriging, universal kriging, and empirical Bayesian kriging.

Based on this information, we conducted and compared the three processes using residuals and root mean square error. Because it has the lowest residuals and root mean square error value depending on the parameters, we chose ordinary kriging as the interpolation approach for this investigation.

Kriging spatial interpolation is a technique that predicts the proportion of iron supplementation coverage among women aged 15 to 49 in unsampled areas of the country using observable measures [22].

Finally, the ordinary kriging spatial interpolation approach was utilized to forecast iron supplementation coverage among women aged 15 to 49 years in unobserved areas of Ethiopia since it comprises spatial autocorrelation and statistically optimizes the weight [23].

Statistical analysis of a spatial scan

The statistical methodology used in the spatial scan is often suggested because it accurately detects local clusters and has greater power than other spatial statistical methods [24]. Spatial scan statistical analysis was utilized to hunt for statistically significant geographical hotspots using Kulldorff's SaTScan V.10.0 software (clusters with low iron supplementation coverage) [25].

Cases were women who used iron supplements, whereas controls were women who did not take iron supplements and were placed in the Bernoulli model. A Bernoulli distribution was used to disperse the number of cases in each location, and the model required data on cases, controls, and geographic coordinates.

The default maximum spatial cluster size of 50% of the population was used as an upper limit, allowing for the discovery of small and large clusters while clusters larger than the maximum limit were ignored.

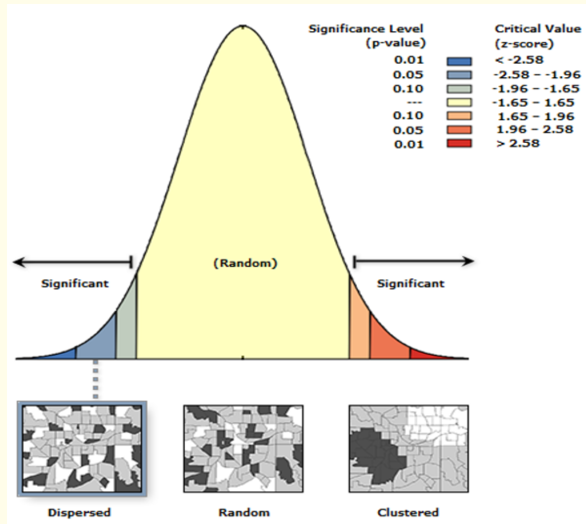
According to the null hypothesis, the scanning window and the rest of the country have the same level of danger. Places with a high log-likelihood ratio (LLR) and p0.05 were deemed high risk when compared to areas outside the window.

The LLR, relative risk, and p-value were used to identify important and most likely clusters. Using ArcGIS V.10.3, the most likely clusters' location has been determined.

The primary and secondary clusters are located, given p values, and sorted based on the probability ratio test they conducted and There were 999 Monte Carlo simulations in total.

Result

With a Moran's index of -0.517864 (p = 0.033744), the regional distribution of Iron supplementation coverage among women aged 15 - 49 years was shown to be clustered (non-random) in Ethiopia (Figure 1).

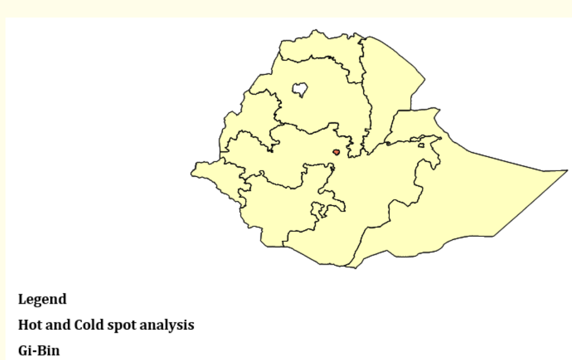


Global Moran's I Summary	
Moran's Index:	-0.517864
Expected Index:	-0.100000
Variance:	0.038737
z-score:	-2.123115
p-value:	0.033744

Figure 1: *Spatial autocorrelation analysis of iron supplementation coverage among women 15 - 49 years age, EDHS2016-2019.*

Iron supplementation in women aged 15 - 49 years identified as a hotspot

Significant (p0.001) clusters of high iron supplementation (non-risk areas) are indicated by the dark red hue, whereas significant (p0.001) clusters of poor iron supplementation are indicated by the green tint (risky areas). From 2016 to 2019, Addis Ababa was classified as having high iron supplementation (hotspot areas) (Figure 2).



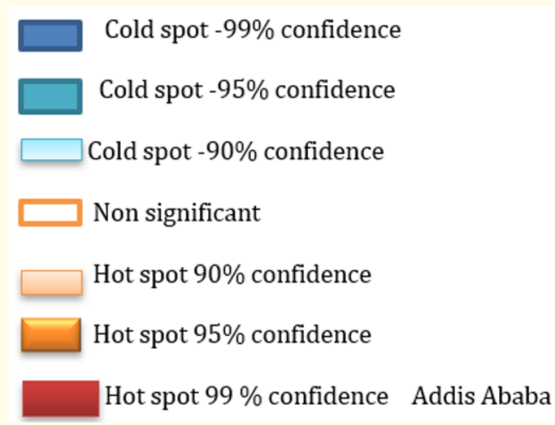


Figure 2: *Hotspot analysis of iron supplementation coverage among women 15-49 years age, 2016 and 2019 Ethiopian Demographic and Health Survey. CSA, Central Statistics Agency.*

Interpolation of iron supplementation coverage among women aged 15 - 49 years

Harar, Dire Dawa, and Gambella were identified as the locations with the lowest iron supplementation coverage. However, iron supplementation coverage was determined to be low-risk in Amhara and Oromia (Figure 3).

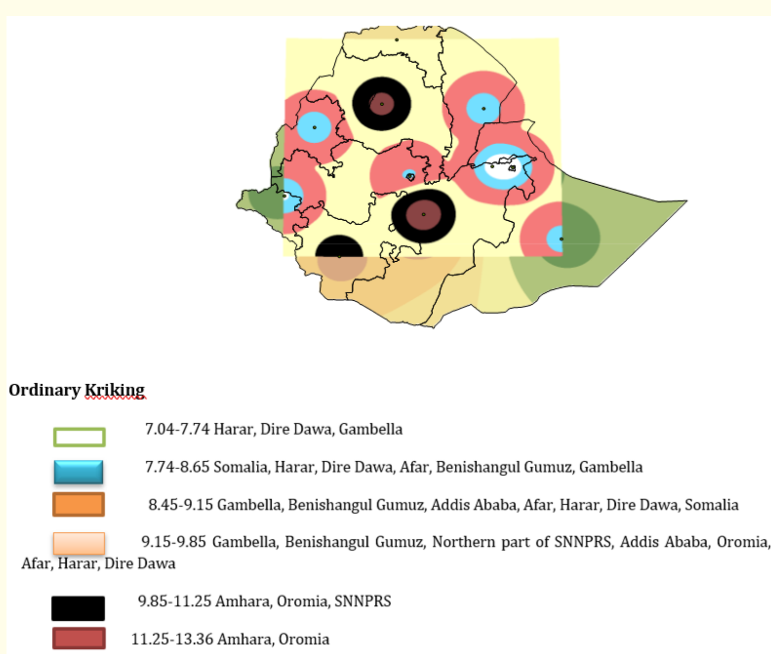


Figure 3: *Spatial interpolation of iron supplementation coverage among women 15 - 49 years age, 2016 and 2019 Ethiopian Demographic and Health Survey. CSA, Central Statistics Agency.*

Spatial SaTScan analysis of iron supplementation coverage (Bernoulli-based model)

To determine the most likely clusters, spatial scan statistics were performed using SaTScan V.10.0, and a total of 7 significant clusters were discovered. One cluster was a primary (most likely) cluster, whereas the other six were subsidiary clusters.

The spatial window of the core cluster was found in Tigray, Afar, Amhara, Benishangul Gumuz, Addis Ababa, Hrara, and Dire Dawa, and was centered at 14.032334 N, 38.316573 E in geographical position, with a radius of 673.06 km, and was identified as cluster that is most likely with greatest LLR at p0.001. It was discovered that women who lived within the spatial frame of reference received 1.76 times more iron supplementation than women who lived outside the window. Women within the Secondary Cluster 1 Oromia had 0.59 times lower iron supplementation coverage than women outside the window.

Women within the Secondary Cluster 5 Somalia had 0.65 times lower iron supplementation coverage than women of other regions The other secondary clusters are described in detail in table 1 and figure 4.

Cluster Type	Coordinates /Radius	N	Cluster Regions	Observed Case	Expected Case	RR	LLR	P-value
Most likely Cluster	14.032334 N,38.316573 E/673.06 km	7	Tigray, Afar, Amhara, Benishangul Gumuz, Addis Ababa, Hrara, and Dire Dawa	1511	1080.21	1.76	223.452644	0.001
Secondary Cluster 1	7.592062N,39.225225E/0 km	1	Oromia	935	1315.67	0.59	164.518632	0.001
Secondary Cluster 2	14.032334 N, 38.316573 E/0km	1	Tigray	415	225.80	1.96	148.826617	0.001
Secondary Cluster 3	11.485999 N,41.245999 E/373.28km	4	Afar, Amhara,Harar, Dire Dawa	931	737.10	1.37	56.658614	0.001
Secondary Cluster 4	9.005401 N,38.763611E/0km	1	Addis ababa	126	83.25	1.53	19.164172	0.001
Secondary Cluster 5	6.661229N,43.790845E/0KM	1	Somalia	75	113.11	0.65	12.019462	0.001
Secondary Cluster 6	8.247190N,34.591597 E/301.06 km	2	Gambela, Benishan-gul Gumuz	48	42.89	1.12	0.527961	0.990

Table 1: *In Ethiopia, a SaTScan analysis of iron supplementation among women aged 15 to 49 years old with a child born in the previous five years was conducted in 2016.*

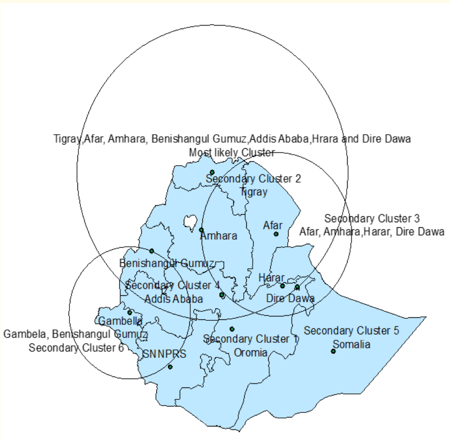


Figure 4: *Spatial SaTScan analysis iron supplementation coverage among women 15- 49 years ago, 2016 Ethiopian Demographic and Health Survey. CSA, Central Statistics Agency; LLR, log-likelihood ratio; SNNPR, Southern Nations, Nationalities, and People's Region.*

Spatial SaTScan statistics of supplementation with iron coverage (Model based on Bernoulli)

Statistics on the spatial scan were compiled. using SaTScan V.10.0 to figure out which clusters are the most likely, and a total of 7 clusters of significance, were identified. From the identified clusters, 1 was a primary (most likely) cluster and 6 clusters that were secondary.

The spatial window for the primary cluster was in Amhara, Benishangul Gumuz, Addis Ababa and Tigray regions and was centered at 11.663240N, 37.821903E with 312.78 km radius (LLR 107.777690, p < 0.001).

It showed that women within the spatial window for the primary cluster had 1.46 times higher iron supplementation coverage than women outside the window. Women within the Secondary Cluster 1 Somalia had 0.30 times lower iron supplementation coverage than other regions and women within the Secondary Cluster 4 Oromia had 0.87 times lower iron supplementation coverage than women outside the window.

Women within the Secondary Cluster 6 SNNPRS had 0.90 times lower iron supplementation coverage than other regions.

The other secondary clusters are described in detail in table 2 and figure 5.

Cluster Type	Coordinates /Radius	N	Cluster Regions	Observed Case	Expected Case	RR	LLR	P-value
Most likely Cluster	11.663240N,37.821903E/312.78 km	4	Amhara, Benishangul Gumuz, Addis Ababa, Tigray	988	780.13	1.46	107.777690	0.001
Secondary Cluster 1	6.661229N,43.790845E/0km	1	Somalia	41	130.82	0.30	82.346611	0.001
Secondary Cluster 2	11.663240N,37.821903E/0km	1	Amhara	624	503.49	1.33	47.934549	0.001
Secondary Cluster 3	14.032334N,38.316573E/0km	1	Tigray	242	172.23	1.45	42.947710	0.001
Secondary Cluster 4	7.592062N,39.225225E/0km	1	Oromia	832	911.55	0.87	14.106787	0.001
Secondary Cluster 5	9.005401N,38.763611E/0KM	1	Addis Ababa	93	76.21	1.23	5.024154	0.034
Secondary Cluster 6	6.033103N,36.433828E/0KM	1	SNNPRS	434	472.28	0.90	4.810161	0.045

Table 2: *SaTScan analysis of iron supplementation among women age 15-49 years with a child born in last 5 years in Ethiopia, 2019.*

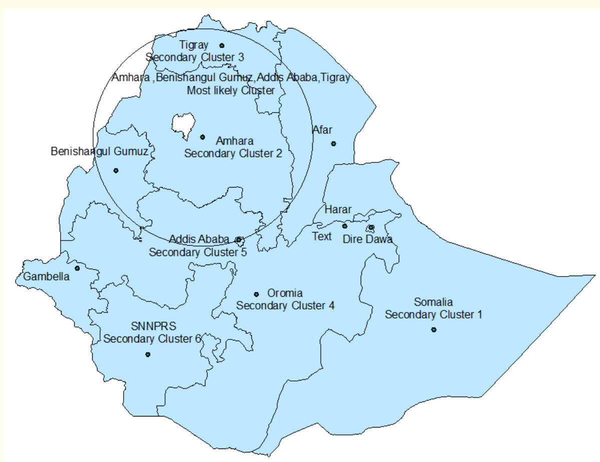


Figure 5: *Spatial SaTScan analysis iron supplementation coverage among women 15 - 49 years ago, 2019 Ethiopian Demographic and Health Survey. CSA, Central Statistics Agency.*

The most likely spatiotemporal cluster location include Tigray, Amhara, Afar, Benishangul Gumuz, Harar, Dire Dawa, and Addis Ababa (Figure 6) and the high-iron supplementation coverage period was from 2016/6/27-2017/6/28 (LLR = 323.372117, *P* = 0.001).

Figure 6: *Space-Time SaTScan analysis iron supplementation coverage among women 15 - 49 years ago, 2016 - 2019 Ethiopian Demographic and Health Survey. CSA, Central Statistics Agency.*

The area's center was Tigray, which was located at 14.032334 N and 38.316573E, with a radius of 673.06 km (Figure 4). During the period 2016/6/27-2017/6/28, a total of 2548 women who had taken iron supplementation were recorded in this location, with an RR of 1.63 (Table 3).

Cluster Type	Cluster Time Frame	Coordinates /Radius	N	Cluster Countries	Observed Case	Expected Case	RR	LLR	P-value
Most likely Cluster	2016/6/27-2017/6/28	14.032334 N,38.316573E /673.06 km	7	Tigray, Amhara, Afar, Benishangul Gumuz, Harar, Dire Dawa, Addis Ababa	2548	1903.76	1.63	323.372117	0.001
Secondary Cluster 1	2016/6/27-2017/6/28	7.592062 N,39.225225 E /0 km	1	Oromia	1767	2239.03	0.69	162.135922	0.001
Secondary Cluster 2	2016/6/27-2017/6/28	6.033103N,36.433828 E /0 km	1	SNNPRS	1095	1150.35	0.94	3.244717	0.185

Table 3: *Space Tiem SaTScan analysis of iron supplementation among women age 15 - 49 years with a child born in last 5 years in Ethiopia, 2016/6/27-2019/6/28.*

During the period from 2016/6/27-2017/6/28, women within the Secondary Cluster 1 Oromia had 0.69 times lower iron supplementation coverage than other regions.

Discussion

The results of this study revealed that iron supplementation coverage among women aged 15 to 49 years in the country was non-random (clustered). A clustering trend in iron supplementation coverage across the country was revealed in the global autocorrelation study (Global Moran's I = -0.517864 (p = 0.033744). This suggests that in specific places, almost identical iron supplementation coverage was aggregated. Addis Ababa (p0.01) was found as the hotspot cluster of high iron supplementation coverage.

One probable explanation is that women in Addis Ababa have a greater understanding of the significance of iron supplementation than mothers in other regions, as well as a higher rate of antenatal care follow-up. As a result, the majority of women participate in iron supplementation.

According to the iron supplementation coverage map prediction, Harar, Dire Dawa, and Gambella are at danger of low iron supplementation coverage. This is most likely due to the fact that these areas are border zones, with limited access to and utilization of healthcare services. These people may also have a lower educational level and reside far away from healthcare facilities [26]. Another factor that may influence iron supplements coverage is a woman's rural residence [27]. Because the majority of these areas are rural, iron supplementation coverage may be poor.

The purely SaTScan spatial analysis, a total of 7 significant clusters, were identified.

The most likely SaTScan cluster of low iron supplementation coverage was identified in Oromia (LLR = 164.51, p < 0.01) and Somalia (LLR = 12.01, p < 0.01). in 2016 and the most likely SaTScan cluster of low iron supplementation coverage was identified in Somalia (LLR = 82.34, p < 0.01), Oromia (LLR = 14.10, p < 0.01).and SNNPRS (LLR4.81, p < 0.01) in 2019.

The Space Tiem SaTScan analysis, a total of 3 significant clusters, were identified the most likely SaTScan cluster of low iron supplementation coverage was identified in Oromia (LLR = 162.13, p < 0.01).and SNNPRS (LLR 3.24, p < 0.01) During the period from 2016/6/27-2017/6/28 This could be due to discrepancies in health service accessibility and consumption, in addition to sociocultural variations in the community. According to studies, women in Afar and other remote places delivered their babies at home due to a lack of faith in local doctors [28]. Furthermore, because pastoralist women primarily live in the Afar and Somali regions, they do not have access to iron supplements during pregnancy. The data acquired at a given period in time and the retrospective nature of the investigation are both limitations of this study.

Finally, SaTScan software program Ignores oddly formed clusters and only finds circular clusters.

Based on the findings of this study, policymakers and programmers in Ethiopia should provide improved interventions in hotspot areas (poor iron supplementation coverage) and develop various techniques to improve iron supplementation coverage among women aged 15 to 49 years.

Conclusion

Women in the Harar, Dire Dawa, Gambella, Somalia Oromia, and Southern Nation Nationalities and Peoples Regions had a low likelihood of receiving iron supplements.

Iron sulphate is cheap but results in a dark stool and causes cramps. Other supplements are more expensive but have fewer side effects which might increase iron supplementation.

As a result, these locations should be considered when designing effective Antenatal care programs to increase iron supplementation among women in order to reduce the burden of anemia and its repercussions among pregnant women in Ethiopia.

Availability of Data and Materials

The paper includes all data.

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