

Geographical Accessibility to District Hospitals/Medical Laboratories for Comprehensive Antenatal Point-of-Care Diagnostic Services in the Upper East Region, Ghana

Desmond Kuupiel^{a,d,*}, Kwame Manu Adu^b, Vitalis Bawontuo^{c,d}, Tivani P. Mashamba-Thompson^a

^a Discipline of Public Health Medicine, School of Nursing and Public Health, University of KwaZulu-Natal, Durban, South Africa

^b Adu Manu Kwame Consultancy, Accra, Ghana

^c Faculty of Health and Allied Sciences, Catholic University College of Ghana, Fiapre, Sunyani, Ghana

^d Research for Sustainable Development Consult, Sunyani, Ghana

ARTICLE INFO

Article history:

Received 13 August 2018

Received in revised form 24 June 2019

Accepted 25 June 2019

Available online 3 July 2019

ABSTRACT

Background: Access to referral healthcare facilities from primary healthcare (PHC) clinics for diagnostic services is critical for improving maternal health outcomes. We described the geographical distribution and accessibility to district hospitals/medical laboratories for comprehensive antenatal point-of-care (POC) diagnostic services in the Upper East region (UER), Ghana.

Methods: We assembled detailed spatial data on 100 participated PHC clinics in our previous survey, their nearest referral district hospitals/medical laboratories, and landscape features influencing journeys in the UER. These were used in a geospatial model to estimate actual distance and travel time from a PHC facility to the nearest referral health facility for antenatal POC diagnostic services. Spatial distribution of the facilities was determined using spatial auto-correlation tool run in ArcMap 10.4.1. We employed Stata V14 for all other analysis.

Findings: Of the 100 PHC clinics included in the analysis, only 15% were located less than 10 km to their nearest referral health facilities. The mean distance \pm standard deviation from a PHC clinic to the nearest referral district hospital/medical laboratory for comprehensive antenatal POC diagnostic services was 7.0 km \pm 4.9. Whilst the mean travel time using a motorized tricycle speed of 20 km/h to the nearest referral health facility for comprehensive antenatal POC diagnostic was 14.0 min \pm 8.8. The spatial auto-correlation results for the PHC clinics suggested that the PHC clinics were spatially distributed at random rather than clustered (MI = 0.01, z-score = 0.33, p = 0.74). Whereas the spatial distribution of the referral health facilities suggested that the hospitals or medical laboratories were spatially dispersed (MI = -0.69 z-score = -2.05, p = 0.04).

Interpretation: Although there is moderate geographical accessibility to district hospitals/medical laboratories for comprehensive antenatal diagnostic services in the UER, targeted improvement of POC diagnostic services in PHC clinics is recommended for improved maternal healthcare.

Funding: University of KwaZulu-Natal, College of Health Sciences Research Scholarship.

© 2019 Published by Elsevier Ltd. This is an open access article under the CC BY-NC-ND license (<http://creativecommons.org/licenses/by-nc-nd/4.0/>).

1. Introduction

It is estimated that over 285,000 women still die annually due to pregnancy in Low- and Middle-income countries (LMICs), the highest number globally [1]. Antenatal care (ANC) is one vital component in the package of services aimed at advancing maternal and newborn health [2]. ANC services include promotion of health, health education, screening, diagnosis, disease prevention, and management [3]. ANC,

skilled delivery as well as emergency obstetric care are essential services not only to facilitate positive pregnancy experience, but also to decrease maternal mortality [3,4]. Access to diagnostic services as part of ANC enables screening and testing at the point-of-care (POC) for both preventive and clinical decisions [5,6]. Nonetheless, access to diagnostic services may be a challenge for expectant mothers in most rural and resource-limited settings. The results of a survey prior to this study, demonstrated poor availability (less than 5 tests) of pregnancy-related POC diagnostic tests for maternal healthcare in Upper East Region's (UER) primary healthcare (PHC) clinics in Ghana [7] mostly due to poor supply chain management [8]. Disparities in the quality of ANC exist between pregnant women seeking ANC in rural health facilities and in urban health facilities, owing to lack of laboratory facilities in

* Corresponding author at: 2nd Floor George Campbell Building, Department of Public Health Medicine, University of KwaZulu-Natal, Howard College Campus, Durban 4001, South Africa.

E-mail address: KuupielD@ukzn.ac.za (D. Kuupiel).

Research in context

Evidence before This Study

The Ghanaian government has prioritized maternal healthcare in her quest to reduce maternal mortality to less than 70 per 100,000 live births stipulated by the United Nations Sustainable Development Goal (SDG) 3.1. Antenatal care (ANC) is one of the key safe motherhood strategies targeted to help achieve this goal. ANC provides an opportunity for expectant mothers to be screened, diagnosed and linked to care or prevention. In 2012, a study was conducted to assess the geographical access to care at the time of birth in Ghana, but it did not include ANC. A survey of PHC clinics in the UER conducted prior to this current study, demonstrated poor availability of pregnancy-related POC tests for maternal healthcare in PHC clinics. Our search strategy (Supplementary file 1) prior to the conduct of this research also yielded zero result hence, informing this current study.

Added Value of This Study

This study showed evidence of moderate geographical accessibility to referral health facilities from PHC clinics for comprehensive ANC diagnostic services in the UER. It also revealed the spatial distribution of the PHC clinics, and the referral health facilities. This study further demonstrated the proximity and travel time from PHC clinics to referral health facilities. We have additionally provided evidence to facilitate targeted implementation of POC diagnostic services in Ghana's PHC clinics. Moreover, we have provided baseline information for future studies aiming to assess geographical accessibility of ANC diagnostic services in Ghana. Finally, this study adds to the body knowledge on ANC.

Implications of All the Available Evidence

Mothers with infections such as Human Immuno-deficiency Virus (HIV), hepatitis B, syphilis, and other medical conditions potentially detrimental to the health of both mother and unborn baby, may go unnoticed/untreated/overlooked. Expectant mothers in the UER may have to walk for hours or pay exorbitant transport fares to reach a referral health facility for diagnostic services. This may lead to a reduction in the number of pregnant women who access quality ANC. Additionally, expectant mothers with conditions such as hypertension disorders of pregnancy and low hemoglobin levels may be detected late, and this could potentially result in adverse pregnancy outcomes

in traveling from a PHC clinic to the entrance of a referral health facility for ANC POC diagnostic services. Geographical accessibility to healthcare facilities can potentially present a barrier to utilization of ANC diagnostic services [15,16,17]. People such as pregnant women may have a tendency to either limit or utilize essential healthcare services such as ANC closer to them [18]. It is a policy for expectant mothers in Ghana to be screened and tested for the following: hemoglobin, HIV, sickling, Glucose-6-phosphate dehydrogenase, syphilis, blood type (Rhesus factor), screening for malaria, sexually transmitted infections, blood pressure, urine and stool for routine examinations, as well as ultrasound scans, depending on the stage of the pregnancy at the first ANC visit [19].

The United Nations Development Program identified geographical access by mothers, families and communities to health facilities as one of the key barriers to critical health services [20]. Geographic location of a referral health facility (district hospital/medical laboratory) can have an effect on accessibility to health services [21]. Geographical access is particularly vital where health service provision is sparse, with weak transportation systems, and where the population is predominantly rural [21]. To the best of our knowledge, no study has assessed the geographical accessibility to ANC diagnostic services in Ghana. This study therefore aimed to describe the geographical distribution and accessibility to the nearest district hospital/medical laboratory for comprehensive ANC POC diagnostic services from a PHC clinic in the UER, Ghana. We anticipate that the results of this study will inform policy decisions of the Government of Ghana to improve access to POC diagnostic services in rural PHC clinics in line with the World Health Organization (WHO) recommendations [22].

2. Methods

2.1. Data Sources

We developed models and algorithms for measuring geographical accessibility of POC diagnostic services from rural clinics to referral health facilities. This current study is a follow-up to a prior cross-sectional survey of 100 randomly selected PHC clinics in the UER which assessed the accessibility to pregnancy-related POC diagnostic tests in UER's PHC clinics, Ghana [7]. The sampling strategy used for the selection of the participated PHC clinics in this study its rationale is described and in published elsewhere [7]. We collected data on the nearest referral facilities, transportation options, duration of obtaining test results from expectant mothers, and electronic options for communicating test results using a survey tool (Supplementary file 2). We also obtained the geo-located data on PHC clinics and their referral facilities for comprehensive ANC POC diagnostic services from the Upper East Regional Health Directorate. Thereafter, we applied the world geodetic system (WGS) Zone 30 degrees' North coordinate system to all spatial data to allow for results of spatial processes in a preferred unit of meters. Landscape or topographic data included roads, rivers and a digital elevation model (DEM) of the rivers and high points/elevation. We then calibrated high points in the districts as barriers. Based on information gathered on the most commonly used public transport option from PHC clinics to the referral facilities in the region, we estimated travel time via road, paths and tracks using a motorized tricycle popularly known as "Motor king" or "Mahama can do". The estimation involved recalibrating travel time per pixel (10 m by 10 m grid) for both roads and paths. This ultimately helped to estimate travel distance and time from rural clinics to referral facilities for all the districts in the region.

2.2. Geo-database of Referral Health Facilities

Geo-located data on referral facilities, which also included attribute data on the type of diagnostic tests offered at the referral facility, were extracted from the survey prior to this study [7]. We geo-referenced all data that lacked a coordinate system and loaded it in Google Earth

most lower level health facilities [9]. It is estimated that 49% of Ghanaian mothers receiving ANC services from lower level health facilities in rural communities are more likely to receive poor quality care compared to 29% receiving care from higher level facilities in the urban areas [9]. It is also reported that Ghana's maternal mortality rate remains much higher than global averages [10]. Major causes of negative pregnancy outcomes in Ghana are: Hypertensive diseases of pregnancy, anemia, malaria, sickling, HIV/AIDS and syphilis, which are preventable, if diagnosed and managed/treated early [11,12].

Poor geographical accessibility to referral healthcare facilities such as district hospitals/medical laboratories from a PHC clinic may contribute to pregnant women failing to get required tests done. Many definitions of accessibility and the dimensions of measurement exist in the literature [13,14]. In this study, accessibility refers to the distance to the nearest referral health facility for a comprehensive ANC POC diagnostic service from a PHC clinic. Travel time in this study is defined as the approximated period a referred pregnant woman is likely to spend

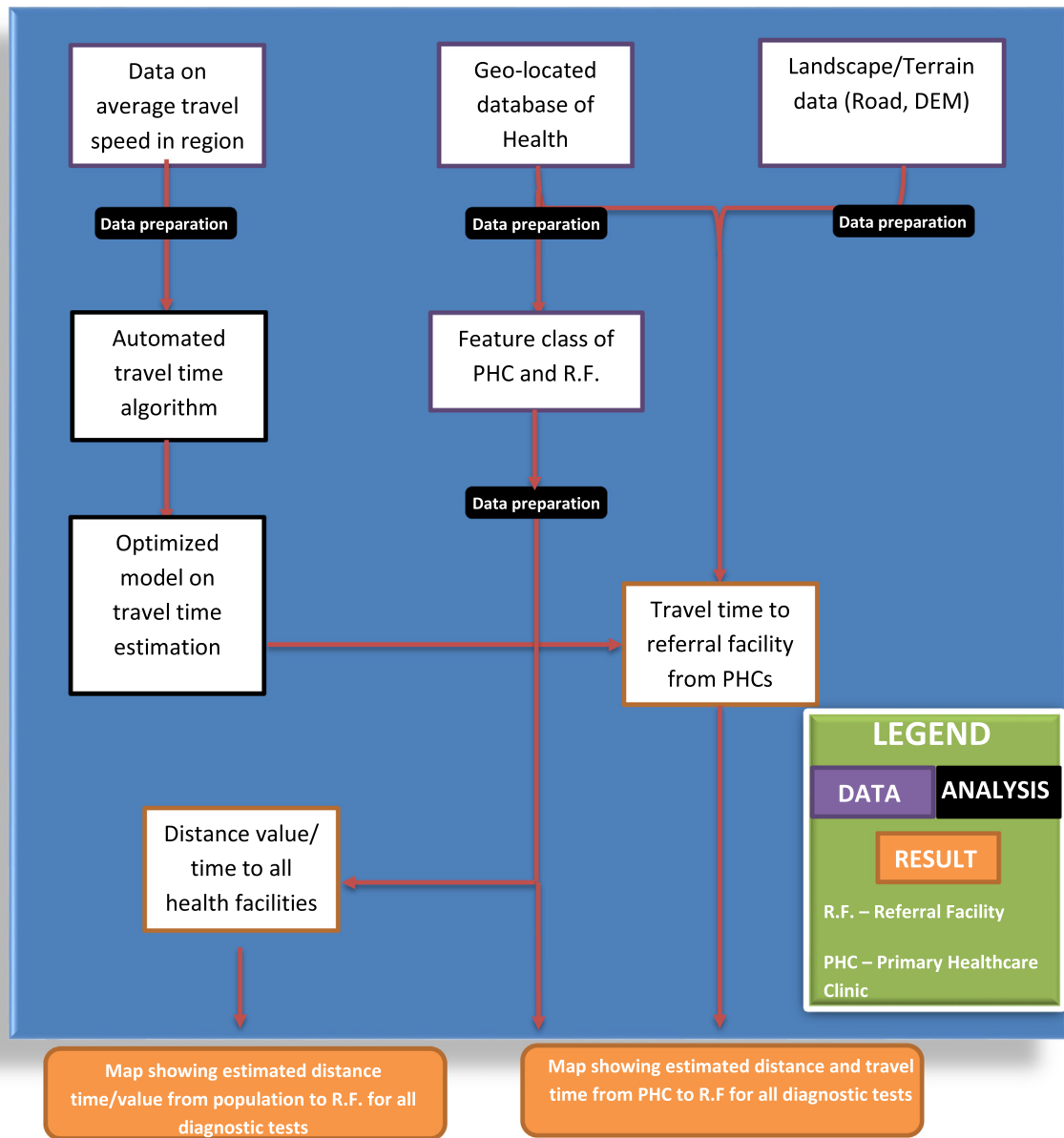


Fig. 1. Process flow diagram for the procedures undertaken to arrive at distance and travel time.

to determine their positions. This enabled us to identify PHC clinics that fell outside the boundary of their districts and the region. The data was reconciled and imported to ArcGIS 10.4 in the point shape file format.

2.3. Landscape/Topographical Data

We captured data on digitized and geo-referenced road networks and paths as well as features such as rivers and lakes. We obtained the DEM of the region, which assisted in identifying natural barriers such as hills and valleys as well as undulating land that would inform the decision on estimating travel distance and time. All the above data was obtained from Adu Manu Kwame (AMK) Consultancy. We juxtaposed these data with the data obtained from the University of Ghana Remote Sensing and Geographic Information Systems laboratory to validate accuracy. Following this, we reclassified DEM into highlands (more than 200 m high) and flatlands (between 119 m and 200 m high). This was determined by the DEM data which showed that the highest point in the region was about 470 m, while the lowest point was identified as 119 m.

Table 1

Recommended diagnostic tests/investigations during pregnancy in Ghana and the number of PHC clinics test/investigation is available in the UER (N = 100).

Recommended diagnostic tests/investigations during pregnancy	Number of PHC clinics diagnostic testing/investigation is available
Hemoglobin	24
Blood glucose	10
HIV	93
Syphilis	24
Hepatitis B	21
Hepatitis C	6
Sickling test for sickle cell status	9
Blood type	4
G6PD	0
Malaria	96
Tuberculosis	3
Urine pregnancy	90
Urinary tract infections	13
Urine proteinuria	19
Hypertension (blood pressure device)	89
Ultrasound scan	1

2.4. Developing a Model for Estimating Cost Distance and Travel Time

A model for estimating cost was accomplished using a sequence of algorithms with the final output resulting from the cost distance tool in ArcGIS 10.4. Cost distance calculates the shortest time to a source based on a cost dataset. To realize this, we designed a cost surface algorithm with the following parameters: a grid cell with the size of 10 m was assigned to the spatial features and values were then assigned to the predetermined grids. We assigned roads low values because traveling on roads is faster than travel via paths or impediments. Assigning of values to spatial features was done via the map algebra tool and, since cost distance requires the cost surface dataset and the source, the calibrated spatial dataset served as the cost surface dataset and referral facilities served as the source for calculating the cost distance. The output is a map showing the shortest travel time (cell by cell) from any point in the map to referral facilities in the region. Algorithms which allowed for carrying out conversion of data from vector to raster, map algebra (cost

surface models) and cost distance were developed using Python 2.7. All the algorithms were consolidated into a single algorithm. Based on the earlier information on transportation options for longer distances (motorized tricycle), we pegged the travel speed at 20 km/h. This served as a guide for determining travel time from each PHC clinic to the referral facility. Fig. 1 shows the flow diagram for the procedures undertaken to arrive at the results of this study.

2.5. Outcome Measures

The primary outcome of this study was: geographical accessibility to the nearest referral district hospital/medical laboratory for comprehensive ANC POC diagnostic services in the UER of Ghana. Geographical accessibility was measured as: ≤ 5 km = high geographical accessibility; < 5 km to 10 km was considered as moderate geographical accessibility, and > 10 km was considered to low geographical accessibility.

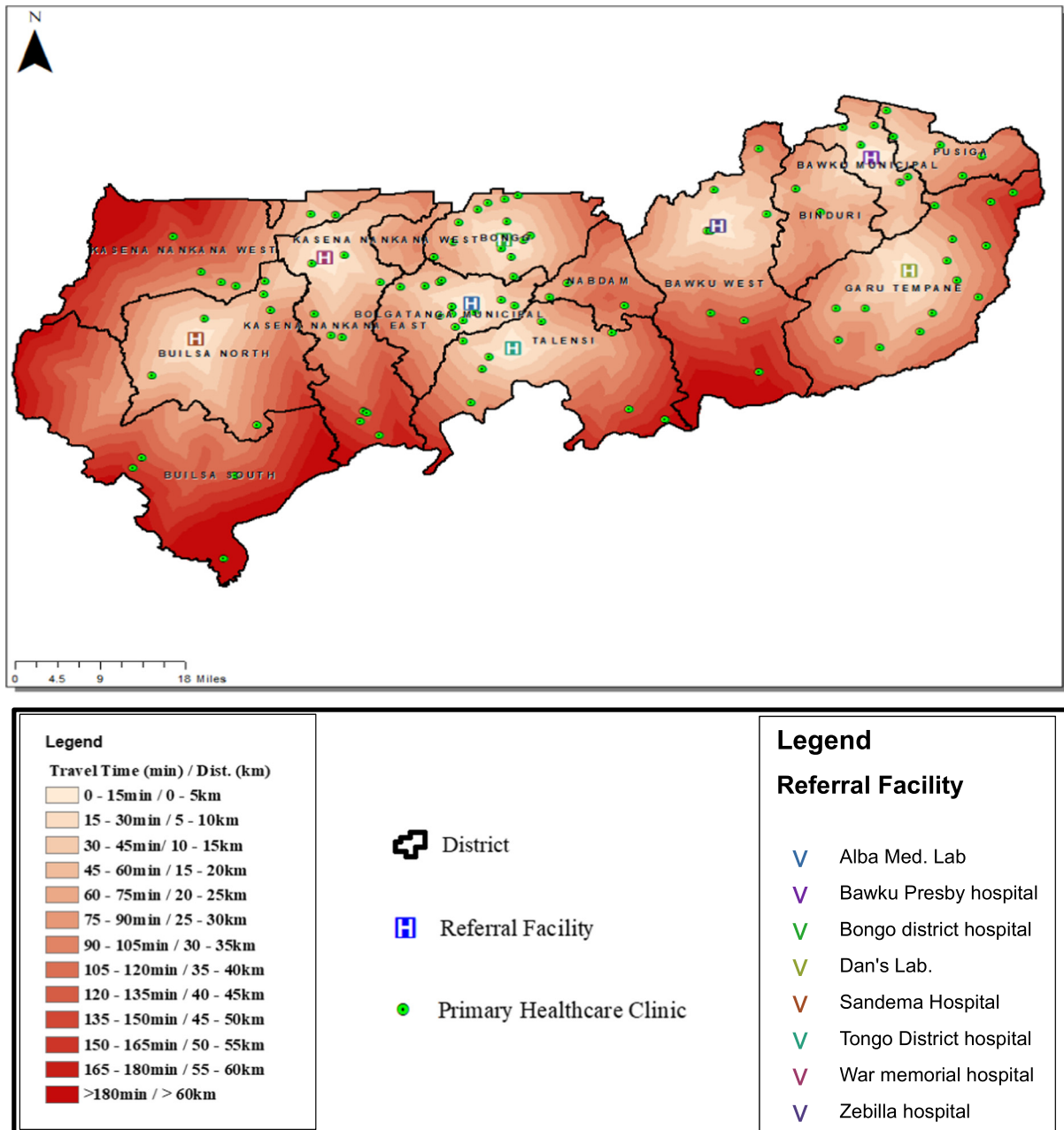


Fig. 2. Map showing distance of referral health facilities from primary healthcare clinics in the Upper East Region of Ghana.

2.6. Statistical Analysis

To determine the spatial distribution/measure how close the PHC clinics and their nearest referral district hospital/medical laboratory for a diagnostic test were, a spatial autocorrelation tool or Moran's Index (MI) [23] was run in ArcMap 10.4.1. MI, Z-scores, and p-values for both PHC clinics and the referral facilities were reported. MI value greater than zero ($MI > 0$) was interpreted as spatially clustered, and MI value less than zero ($MI < 0$) was considered as spatially dispersed and null MI score or equivalent to zero (< 0.5), was classified as spatially random or no spatial auto-correlation. MI value of 0, or very close to 0, was considered as spatial random distribution. Estimated distances and travel times were processed in Microsoft Excel and imported into Stata statistical software, version 14, for analyses. Means, standard deviations (SD), and 95% confidence interval (CI) were generated for distance and travel time.

2.7. Role of the Funding Source

This study was funded by the University of KwaZulu-Natal, College of Health Sciences Research Scholarship. Funders played no role in data collection, analysis, and preparation of the manuscript.

3. Results

3.1. Characteristics of the Primary Healthcare Clinics

Of the 959 health professionals that were recorded in all 100 PHC clinics, majority (30%) were Nurse Assistants (Preventive) and the minority (2.4%) were Dispensary Technicians/Assistants. Also, of the total 959 health professional recorded in all 100 PHC clinics, midwives were 124 (12.9%). The mean antenatal clinic attendance was 65 ± 67 pregnant women per month. Mean test results turnaround time from referred expectant mothers to the PHC clinic staff was estimated at 15.4 ± 3.4 days. Electronic option of communicating test results from a referral health facility to the PHC clinic staff was not available. The most commonly used public transport from the PHC clinics to the referral health facility for diagnostic testing in the region is a motorized tricycle. Table 1 shows the recommended diagnostic tests/investigations during pregnancy in Ghana and the number of PHC clinics test/investigation is available in the UER.

3.2. Spatial Distribution of PHC Clinics and Their Nearest Referral Health Facilities

We performed a spatial autocorrelation to determine the spatial distribution/measure the closeness of the PHC clinics and their nearest referral health facilities for comprehensive ANC POC diagnostic services in the region. The results of the PHC clinics showed positive spatial autocorrelation ($MI = 0.01$, z-score = 0.33, $p = 0.74$). However, the MI score suggested the PHC clinics were spatially distributed at random rather than clustered. On the other hand, the results of the referral health facilities showed negative spatial auto-correlation ($MI = -0.69$ z-score = -2.05 , $p = 0.04$). Hence, suggested the district hospitals or medical laboratories used by the participated PHC clinics as referral health facilities in the UER were spatially dispersed. Supplementary files 3 and 4 shows the output of the analysis.

3.3. Geographical Accessibility to Referral Health Facilities

Fig. 2 is a map visualizing the results of the cost distance algorithm which is an estimation of distance values from 100 PHC clinics locations to their referral health facilities for comprehensive antenatal diagnostic services in the UER. The maps provide visual prominent indications of the degree of variation in levels of geographical accessibility in relation to distance in the region. In all, eight [8] referral facilities were utilized

by all sampled clinics in the region for “one-stop” ANC POC diagnostic services for tests not available at the PHC clinics. Of the eight referral facilities, five (62.5%) were owned by Ghana Health Service (GHS), two (25%) were privately owned, and one (12.5%) owned by a church registered with the Christian Health Association of Ghana.

Of the 100 selected PHC clinics involved in this study, only 15% were located less than 10 km to their nearest referral facilities. Majority (66%) of the PHC clinics were located from 15 to 40 km away from the nearest referral hospital/medical laboratory. Another 16% of the PHC clinics were located more than 45 km to their nearest referral health facilities for all diagnostic services in the region, as shown on Table 2 below.

The mean distance \pm SD from a PHC clinic to the nearest referral health facility for comprehensive ANC POC diagnostic services in UER was $7.0 \text{ km} \pm 4.9$. Whilst the mean travel time \pm SD using a motorized tricycle speed of 20 km/h to the nearest referral facility for comprehensive ANC POC diagnostic services in the UER was $14.0 \text{ min} \pm 8.8$. The longest mean distance and travel time from PHC clinics to the nearest referral health facility for comprehensive antenatal diagnostic services was recorded in the Binduri district that is, $12.3 \text{ km} \pm 0.5$ and $24.5 \text{ min} \pm 1.1$ respectively. Whereas, PHC Clinics in the Bolgatanga Municipal recorded the shortest mean distance and travel time to the nearest referral health facility for comprehensive antenatal diagnostic services in the region that is, $2.7 \text{ km} \pm 2.0$ and $5.4 \text{ min} \pm 3.9$ respectively, as illustrated in Table 3.

4. Discussion

This study described the geographical accessibility of district hospitals/medical laboratories for comprehensive antenatal POC diagnostic services in the UER, Ghana. The study results showed that a substantial proportion of the PHC clinics (85%) were located at a distance greater than 10 km to the nearest referral hospital/medical laboratory. Whilst the PHC clinics were spatially at random, their referral health facilities were spatially dispersed. The analysis of the districts also revealed considerable disparities regarding geographical access to antenatal POC diagnostic services. Whilst PHC clinics in the Bolgatanga Municipal were much nearer to the referral facility, besides the regional hospital, closely followed by Bawku Municipal and Bongo district, the same could not be said about the remaining districts, especially Builsa South district.

Similar to our study findings, poor geographical accessibility was revealed by a study aimed at auditing geographic access to care at birth in Ghana [21]. Patients in these rural areas must walk for hours or pay exorbitant transport fares to reach a referral facility [21,24]. Consequently, in this study, delay was shown in test results turnaround time from patients to PHC clinic staff for linkage to care, and this can potentially result in adverse maternal health outcomes. Evidence shows that pregnant women tend to limit or use essential healthcare such as ANC

Table 2

Distance and travel time to referral health facilities and proportion of PHC clinics within the graduating distance classifications in the Upper East Region of Ghana.

Distance (km)	Travel time (minutes)	Number of PHC clinics (N = 100)	Cumulative percentage of PHC clinics
0–5	0–15	6	6
5–10	15–30	9	15
10–15	30–45	19	34
15–20	45–60	19	53
20–25	60–75	11	64
25–30	75–90	11	75
30–35	90–105	4	79
35–40	105–120	2	81
40–45	120–135	5	86
45–50	135–150	5	91
50–55	150–165	3	94
55–60	165–180	4	98
>60	>180	2	100

Table 3
Summary of mean (standard deviation) distance and traveling time to the nearest referral health facility for comprehensive antenatal POC diagnostic services in each district.

District	Mean/average distance (km)	Standard deviation	Mean/average traveling time(min)	Standard deviation
Builsa North	6.6	6.7	13.1	13.4
Kassena Nankana West	3.8	3.1	7.6	6.2
Kassena Nankana Municipal	9.4	8.2	18.9	16.3
Bolgatanga Municipal	2.7	2.0	5.4	3.9
Talensi	5.6	3.7	11.2	7.4
Bongo	2.9	2.4	5.7	4.9
Bawku West	12.0	17.0	24.0	21.9
Garu-Tempne	7.9	5.1	15.8	10.3
Bawku Municipal	6.1	1.9	12.2	3.8
Builsa South	6.7	6.9	13.4	13.7
Nabdum	8.3	2.0	16.7	4.0
Binduri	12.3	0.5	24.5	1.1
Pusiga	6.5	3.5	13.1	6.9

services closer to them [20]. The majority of rural populations in Low- and Middle-Income countries are farmers [25]. Therefore, a patient may fail to go for a test or go back for test results when asked to come back the following day or week, especially at certain times of the season [14,26].

In this study, we employed the spatial methodology to identify PHC clinics requiring priority attention due to their proximity to their referral facilities. Spatial accessibility measures have been shown to be important policy tools for managing healthcare provision and reducing health disparities [27]. The methodology employed in this study enabled us to identify disparities in geographical access to referral facilities from PHC clinics for comprehensive antenatal diagnostic services in the region. Health sector budgetary allocation of countries like Ghana is poor and it is most often supported by development partners, international organizations, and donors with many competing interests. Therefore, the spatial methodology adopted by this study has the strength to inform policy makers to provide targeted POC diagnostic services for rural populations, especially pregnant women.

Despite the above-mentioned strengths of the study, the following limitations should be noted. Access to a referral health facility from a PHC clinic for ANC diagnostic services may also be determined by a complex interplay of a diverse set of factors such as the health system (supply chain management, availability, quality, and cost) and population (education, wealth, and culturally mediated perceptions) [28,29,30,31]. Although, we assembled a comprehensive set of data describing the landscape, it is possible that we may not have captured all the local details such as the population of women at reproductive age, which in some cases may be relevant. In addition, using an assumed motorized tricycle speed (most common form of transport) of 20 km/h to calibrate travel time may not be applicable always. Traveling time can be affected by seasonal changes, traffic and other essential factors. Other transportation options to referral facilities may be utilized by some mothers, such as walking, use of a motorcycle, bicycle or a car. Nonetheless, this study provided very useful information to help the planning and improvement of geographical access to POC testing for rural populations.

Based on the findings of this study, we recommend an improvement of existing POC diagnostics and the adoption of new POC tests for rural clinics in line with the WHO List of Essential Diagnostics [22]. Although the Government of Ghana is making efforts to build more district hospitals, we recommend improvement of POC diagnostic services in existing PHC clinics in the country to facilitate attainment of universal health coverage.

5. Conclusion

This study findings demonstrates that there is moderate geographical accessibility to district hospitals/medical laboratories for comprehensive antenatal diagnostic services in UER, Ghana. This study has provided evidence-based information to help with

planning and improving POC testing, targeting primarily PHC clinics in the UER with poor access to the nearest district hospital or medical laboratory accredited by the National Health Insurance Authority. Although the findings of this study may be useful to similar settings and may also guide future studies, the finding cannot be generalized. Hence, we recommend a replication of this study in the other fifteen regions in Ghana as well as other LMICs with settings like UER to facilitate the achievement of SDG 3, which seeks to ensure healthy lives and well-being for all at all ages. In addition, a systematic review and meta-analysis to demonstrate the impact of geographical accessibility of POC testing on maternal health outcomes would also be useful.

Abbreviations

ANC	Antenatal care
PHC	Primary Healthcare
POC	Point-of-Care
SDGs	Sustainable Development Goals
UER	Upper East Region
WHO	World Health Organization

Supplementary data to this article can be found online at <https://doi.org/10.1016/j.eclinm.2019.06.015>.

Contributors

DK conceptualized the study and developed the analytical strategy. DK collected and processed the data, performed statistical analysis, interpreted the results, and wrote the first draft of the study. KMA contributed to the spatial analysis and interpretation of the results. TPM-T and VB contributed to the analytical strategy, to the interpretation of the results, and did critical revisions. DK wrote the final draft and it was approved by all authors.

Declaration of Competing Interest

None declared.

Acknowledgements

We are thankful to the University of KwaZulu-Natal for providing us with essential research resources during this study. The authors would like to thank the authorities of the Upper East Regional Health Directorate, the District Health Management Teams, and all the rural PHC managers for granting us permission to conduct this study. We also thank the University of KwaZulu-Natal, College of Health Sciences for providing funding for the conduct of this study. Finally, we would like to thank the staff of the Department of Public Health Medicine, University of KwaZulu-Natal for their support in diverse ways.

Ethics Approval and Consent to Participate

This study was approved by the Navrongo Health Research Centre Institutional Review Board/Ghana Health Service (approval number: NHR CIRB291) and the University of KwaZulu-Natal Biomedical Research Ethics Committee (approval number: BE565/17). Permission was obtained from the Upper East Regional Health Directorate prior to conducting the study.

Consent to publish

Not applicable.

Data Availability

Data for this study are the property of the University of KwaZulu-Natal and can be made available publicly. All interested persons can access the dataset from the senior author, Desmond Kuupiel, via this email address: desmondkuupiel98@hotmail.com or the University of KwaZulu-Natal Biomedical Research Ethics Committee (BREC) using the following contacts: The Chairperson Biomedical Research Ethics Administration Research Office, Westville Campus, Govan Mbeki Building, University of KwaZulu-Natal P/Bag X54001, Durban, 4000 KwaZulu-Natal, South Africa, Tel.: +27 31,260 4769, Fax: +27 31,260 4609 Email: BREC@ukzn.ac.za.

References

- World Health Organization. World health statistics 2016: Monitoring health for the SDGs sustainable development goals. World Health Organization; 2016.
- Villar J, Ba'aqeel H, Piaggio G, Lumbiganon P, Belizán JM, Farnot U, et al. WHO antenatal care randomised trial for the evaluation of a new model of routine antenatal care. *The Lancet* 2001;357(9268):1551–64.
- World Health Organisation. WHO recommendations on antenatal care for a positive pregnancy experience Geneva. Available from WHO Press <http://www.who.int/nutrition/publications/guidelines/antenatalcare-pregnancy-positive-experience/en/>; 2016.
- Bloom SS, Lippeveld T, Wypij D. Does antenatal care make a difference to safe delivery? A study in urban Uttar Pradesh, India. *Health Policy Plan* 1999;14(1):38–48.
- Pai NP, Vadnais C, Denkinger C, Engel N, Pai M. Point-of-care testing for infectious diseases: diversity, complexity, and barriers in low-and middle-income countries. *PLoS Med* 2012;9.
- Tucker JD, Bien CH, Peeling RW. Point-of-care testing for sexually transmitted infections: recent advances and implications for disease control. *Curr Opin Infect Dis* 2013;26(1):73.
- Kuupiel D, Tlou B, Bawontuo V, Mashamba-Thompson TP. Accessibility of pregnancy-related point-of-care diagnostic tests for maternal healthcare in rural primary healthcare facilities in Northern Ghana: a cross-sectional survey. *Heliyon* 2019;5(2):e01236.
- Kuupiel D, Tlou B, Bawontuo V, Drain PK, Mashamba-Thompson TP. Poor supply chain management and stock-outs of point-of-care diagnostic tests in Upper East Region's primary healthcare clinics, Ghana, vol. 14(2); 2019; e0211498.
- Afulani PA. Determinants of stillbirths in Ghana: does quality of antenatal care matter? *BMC Pregnancy Childbirth* 2016;16(1):132.
- Ameyaw EK, Kofinti RE, Appiah F. National health insurance subscription and maternal healthcare utilisation across mothers' wealth status in Ghana. *Health Econ Rev* 2017;7(1):16.
- Der EM, Moyer C, Gyasi RK, Akosa AB, Tettey Y, Akakpo PK, et al. Pregnancy related causes of deaths in Ghana: a 5-year retrospective study. *Ghana Med J* 2013;47(4):158–63.
- Lee QY, Odoi AT, OPARE-ADDO H, Dassah ET. Maternal mortality in Ghana: a hospital-based review. *Acta Obstet Gynecol Scand* 2012;91(1):87–92.
- Penchansky R, Thomas JW. The concept of access: definition and relationship to consumer satisfaction. *Med Care* 1981;19:127–40.
- MacKinney A, Coburn A, Lundblad J, McBride T, Mueller K, Watson S. Access to rural health care—a literature review and new synthesis. Policy report Rupri. Rural Policy Research Institute; 2014.
- Ferguson WJ, Kemp K, Kost G. Using a geographic information system to enhance patient access to point-of-care diagnostics in a limited-resource setting. *Int J Health Geogr* 2016;15:10.
- Carr-Hill RA, Rice N, Roland M. Socioeconomic determinants of rates of consultation in general practice based on fourth national morbidity survey of general practices. *Bmj* 1996;312(7037):1008–12.
- Kuupiel D, Bawontuo V, Mashamba-Thompson TP. Improving the accessibility and efficiency of point-of-care diagnostics Services in low-and Middle-Income Countries: lean and agile supply chain management. *Diagnostics* 2017;7(4):58.
- Brondeel R, Weill A, Thomas F, Chaix B. Use of healthcare services in the residence and workplace neighbourhood: the effect of spatial accessibility to healthcare services. *Health Place* 2014;30:127–33.
- Ministry of Health, Ghana Health Service. Maternal health record book. In: Reproduction and Child health, editor, Republic of Ghana, Ghana Health Service. A guide for maternal and newborn care part one: Maternal care.
- United Nations Development Program Ghana. Improve maternal health MDG 5. Available from: <http://www.gh.undp.org/content/ghana/en/home/post-2015/mdgoverview/overview/mdg5.html>; 2015.
- Gething PW, Johnson FA, Frempong-Ainguah F, Nyarko P, Baschieri A, Aboagye P, et al. Geographical access to care at birth in Ghana: a barrier to safe motherhood. *BMC Public Health* 2012;12(1):991.
- World Health Organization. World Health Organization model list of essential in vitro diagnostics. . 1st ed., vol. 2018 Geneva: World Health Organization; 2018; 2018.
- Global Moran's I. How spatial autocorrelation (global Moran's I) works. [cited 2018 17/07/2018]. Available from: <http://pro.arcgis.com/en/pro-app/tool-reference/spatial-statistics/h-how-spatial-autocorrelation-moran-s-i-spatial-st.htm>.
- Addai I. Determinants of use of maternal-child health services in rural Ghana. *J Biosoc Sci* 2000;32(1):1–15.
- Wiggins S, Marfo K, Anchirirah V. Protecting the forest or the people? Environmental policies and livelihoods in the forest margins of Southern Ghana. *World Dev* 2004;32(11):1939–55.
- Kuupiel D, Adu KM, Apiribu F, Bawontuo V, Adogboba DA, Ali KT, et al. Geographic accessibility to public health facilities providing tuberculosis testing services at point-of-care in the upper east region, Ghana. *BMC Public Health* 2019;19(1):718.
- Langford M, Higgs G. Measuring potential access to primary healthcare services: the influence of alternative spatial representations of population. *The Professional Geographer* 2006;58(3):294–306.
- Filippi V, Ronsmans C, Campbell OM, Graham WJ, Mills A, Borghi J, et al. Maternal health in poor countries: the broader context and a call for action. *The Lancet* 2006;368(9546):1535–41.
- Campbell OM, Graham WJ. Group LMSSs. Strategies for reducing maternal mortality: getting on with what works. *The Lancet* 2006;368(9543):1284–99.
- Kuupiel D, Bawontuo V, Donkoh A, Drain PK, Mashamba-Thompson TP. Empirical framework for point-of-care diagnostics supply chain management for accessibility and sustainability of diagnostic services in Ghana's primary health care clinics. *Point of Care* 2019;18(2):72–5.
- Katoba J, Kuupiel D, Mashamba-Thompson TP. Toward improving accessibility of point-of-care diagnostic services for maternal and child health in low- and middle-income countries. *Point Care* 2019;18(1):17–25.