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Geographic Accessibility of Emergency Neonatal Care Services in Ethiopia

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ABSTRACT

Introduction: Access to emergency neonatal health services has not been explored widely in the Ethiopian context. Accessibility to health services is a function of the distribution and location of services, including distance, travel time, cost and convenience. Measuring the physical accessibility of health services contributes to understanding the performance of health systems, thereby enabling evidence-based health planning and policies. The physical accessibility of Ethiopian health services, particularly emergency neonatal care services, is unknown.

Objective: To analyse the physical accessibility of emergency neonatal care services at the national and sub-national levels in Ethiopia

Methods: We analysed the physical accessibility of emergency neonatal care (EmNeC) services within 30, 60 and 120 minutes of travel time in Ethiopia at a national and sub-national level. We used the 2016 Ethiopian Emergency Obstetric and Neonatal Care (EmONC) survey in addition to several geospatial data sources.

Results: We estimate that 21.4%, 35.9%, and 46.4% of live births in 2016 were within 30, 60, and 120 minutes of travel time of fully EmNeC services, but there was considerable variation across regions. Addis Ababa and the Hareri regional state had full access to EmNeC services within two hours, while the Afar (15.3%) and Somali (16.3%) regional states had the lowest access.

Conclusions: The physical access to emergency neonatal care services in Ethiopia is well below the universal health coverage expectations stated by the United Nations. Increasing the availability of EmNeC to health facilities where routine delivery services currently are taking place would significantly increase physical access. Our results reinforce the need to revise

service allocations across administrative regions and consider improving disadvantaged areas in future health service planning. More emphasis needs to be given to less-developed regions.

Keywords: Access, Geographic, Neonatal, Health Services

Strengths and limitations of this study

- This is the first study to investigate the accessibility of emergency neonatal care services in Ethiopia, estimating the geographic accessibility of health services accounting for land cover, elevation, hydrographic and road network travel barriers, and human resource availability.
- The findings indicated the overall gaps and regional disparities of EmNeC services.
- Our study addressed only geographic accessibility while access could be measured in multidimensional aspects.
- The travel scenario for vehicle transportation relayed on assumptions of the maximum permitted speed in Ethiopia, though various factors may impact the speed.
- The health facilities maximum capacity data were partly with assumptions based on the WHO estimate of births per skilled birth attendants per year due to the lack of standard records in Ethiopia

INTRODUCTION

Access is an essential concept in health policy and health services provision.[1-3] It is an important part of health, enabling the opportunity to obtain healthcare when needed.[4] Access to health services has multiple dimensions, including financial and physical access.[5,6] Factors such as income, media exposure, level of education, and healthcare-seeking behaviours are accessibility factors that facilitate or hinder access to health care. Physical accessibility indicates the relationship between healthcare location and the population seeking access, considering transportation infrastructure, travel time, distance, and cost.[2,3,7]

Health services access and utilisation are strongly associated, as utilisation is an indication of revealed accessibility.[8] Accessibility to health services is a function of the distribution and location of health services, including distance, travel time, travel cost and convenience.[9] Traditional approaches to measuring accessibility typically estimate the availability of health facilities within a certain distance of a given population.[10,11] However, methods to estimate the travel time to services, accounting for travel time across varying terrain and road surfaces, are crucial to understanding the actual accessibility to health services.[12,13]

Accessibility to Emergency Obstetric Care (EmOC) and Emergency Newborn Care (EmNeC) services are important determinants of maternal and neonatal survival.[14] Lack of access to these services hinders facility-based delivery and skilled care provider follow-up.[15,16] The WHO handbook for monitoring Emergency Obstetric and Newborn Care (EmONC) advises a minimum of five EmONC facilities per 500,000 population and access within two hours of travel time.[17] Of the five facilities, one should be a comprehensive EmONC service.

EmNeC services consist of seven signal functions complementing the EmONC signal functions. The signal functions include antenatal corticosteroids, antibiotics for premature rupture of membranes, antibiotics for neonatal infections, kangaroo mother care, resuscitation with bag and mask, administration of oxygen, and IV fluids.[18] Health facilities providing all these signal functions are considered to be fully EmNeC health facilities.

In Ethiopia, the diverse environmental, climatic, socio-economic, and terrain significantly affect health access and outcomes. Inadequate access to healthcare is of particular concern in the rural part of the country, where road and transportation infrastructure are under-developed and access to health services is limited.[19] It is important to understand the contribution of access to health services to the variation of neonatal mortality across sub-national regions in Ethiopia. However, the distribution of EmNeC health services and their access among sub-

national areas have not been yet explored.[20,21] Therefore, understanding the accessibility of neonatal health services may assist health planning and service administration.[22,23]

Ethiopia's latest health sector development programme strongly emphasise achieving universal health coverage (UHC) for all Ethiopians,[24] mainly focusing on improving women's and children's health.[25] This study aims to analyse the geographic accessibility of emergency neonatal care services at national and sub-national levels in Ethiopia.

METHODS

Study setting

The Ethiopian health system is based on the primary health care (PHC) approach with three levels of care. The primary level includes primary hospitals, health centres and health posts (the lowest-level facility at a village level). The secondary level includes speciality centres (e.g., maternal and child health specialty centres), speciality clinics and general hospitals that serve as referral centres for primary hospitals, and the tertiary level includes specialised referral hospitals.[26] Most of the EmNeC signal functions are performed in hospitals and maternal and child health (MCH) specialty centres.[18] A specialty centre differs from a specialty clinic as specialty centres have inpatient admissions and offer 24 hours emergency services. A specialty centre differs from a hospital in that they do not offer the full spectrum of specialties required for a general hospital.[27]

Population and Variables

The target population for this analysis were all live births in Ethiopia taken from the 2016 UN estimates of numbers of live births per grid square (a grid square measures 1° latitude by 2° longitude and measures approximately 70 × 100 miles).[28]

The primary outcome variable in this study was accessibility to fully functioning Emergency Neonatal Care service (EmNeC) within 30 minutes, one hour and two hours at a national and

regional level. Secondary outcomes include accessibility of fully functioning health services through walking travel and access to health facilities with partial EmNeC signal functions. Accessibility was defined as the access from a residence to a health facility within two hours of travel time based on the WHO optimal access definition.[29] The facilities were considered to be fully functioning if all the seven signal functions for EmNeC were available.

Patient and Public Involvement

No patient involved

Data source

We used three data groups for this analysis: statistical, geospatial, and national norms data. The statistical data included national and regional population sizes and the number of functional EmNeC health facilities. The geospatial data were regional administrative boundary data, geographic location of all health facilities providing delivery services, road network, hydrographic network, land cover, Digital Elevation Model (DEM) data, and spatial distribution of live births in Ethiopia in 2015. The national norms data includes the maximum travel speed expected for a motor vehicle on the different road types and the average capacity of health facilities that they could serve.

We used the Ethiopian 2016 EmONC survey, which is a national census of health facilities [18]. A total of 3,804 health facilities providing delivery services were included in the EmONC survey. Ethiopia's 2016 produced boundary shapefile, a geospatial vector data format matching the level of desegregation of the sub-national statistical data, was accessed through OpenAFRICA;[30] land cover and digital evaluation model (DEM) data of 2015, a representation of the bare ground topographic surface of the Earth were accessed from the DIVA-GIS webpage.[31] The 2015 raster data for live births per 1km grid square was accessed via the WorldPop webpage.[28] We used OpenStreetMaps via the World Food Program data

repository of 2017[32] to estimate travel speeds for motorised vehicles based on the primary, secondary, and tertiary and unclassified road surfaces. We used DEM data to estimate the effects of slopes on travel time.[33] The barrier to travel (hydrographic data) was obtained from RCMRD GeoPortal[34] and DIVA-GIS[31] web pages produced in 2015.

We created a travel scenario for walking and motorised transportation based on the land cover structure and road types. We assumed that walking speed ranged from zero km/hr for water bodies to 2.5 km/hr for established residential areas, assuming a pregnant woman in her last month of pregnancy would be able to walk at half the average walking speed as used elsewhere.[35] We assumed travel speeds of 100, 70, 50, and 30 km per hour for primary, secondary, tertiary, and unclassified road types based on the country's speed limit.[36] We used these speeds as ambulances would be able to travel at the maximum speed in emergency situations. The road network data were classified based on Ethiopian speed limit norms. The main road classifications in Ethiopia are primary, secondary, tertiary, and unclassified. However, the road network data available online includes several classifications, including the linking roads between primary roads-so we need to reclassify into the above four main classifications. Primary, primary link, motorway and trunk roads were classified as primary, secondary and secondary links as secondary, tertiary and tertiary links as tertiary and track and unclassified were merged as unclassified road classes.

We assigned the maximum capacity for each health facility category based on the standard WHO assumption of births per skilled birth attendants per year.[37] we assigned 175, 100, 75 and 50 births per skilled birth attendant per year for hospitals, MCH speciality centres, health centres, and clinics. We then multiplied the number of births per year by the number of skilled birth attendants at each facility to estimate the total number of possible births per year at each health facility.

Data processing and analysis

We integrated multiple geospatial datasets in AccessMod, which is a free, open-source software package developed by the WHO. AccessMod analyses the physical accessibility and the geographic coverage of a health facility using Geographic Information Systems (GIS)[38], "computer-based systems to capture, store, retrieve, analyse and display spatial data".[39] AccessMod models the coverage of catchment areas linked to an existing health facility network integrating population distribution, travel time and the population coverage capacity specific to each health facility in the network.[40] AccessMod computes catchment areas using the least-cost path algorithm.[41] The least-cost path approach calculates the distance between a focal location and all cells in the surroundings, dividing surface areas into grid cells. It identifies the best path from one point to another over a cost surface, identifying the cost of travelling through each grid cell, which has been given to cost how expensive, it is to pass through that cell.[42] The cost given to each cell is the travelling time to cross the grid cell, which is determined through the travelling speed attributed to the elevation and land cover of the cell. Finally, it produces a point estimate of cumulative access coverage of health services to catchment areas population.

The vector and raster geospatial data files were projected based on Ethiopia's geographic coordinate system at Adindan UTM zone 37N[43] to make it suitable for analysis. A projection is the means by which we display the coordinate system and data on a flat surface, such as a piece of paper or a digital screen. A projected coordinate system is a two-dimensional flat surface, and locations, in this case, are identified by x,y coordinates.[44]

RESULTS

Characteristics of health facilities

A total of 3,804 health facilities (100% response rate) were assessed in the 2016 EmONC survey, of which 3,789 were providing routine delivery services. A total of 3,308 (87.0%) health facilities were fully functional, 458 (12.0%) were fully functional and under redevelopment to expand service coverage, and the remaining 38 (1.0%) were partially functional and under redevelopment during the time of the survey. The majority (91.0%) of health facilities providing delivery services were health centres, and the largest number of fully EmNeC services were primary hospitals (43%). Only 4 (3.4%) fully EmNeC services were health centres (see Table 1).

Table 1: Frequency and percentages of health facilities providing routine delivery and emergency neonatal care (EmNeC) services, 2016.

Health facility type	**Normal Delivery**		**Partially EmNeC (5 or 6 signal functions)**		**Fully EmNeC**	
	n	**%**	n	**%**	n	**%**
Referral/specialized hospital	29	0.8	12	0.4	18	15.5
General hospital	103	2.7	59	1.8	39	33.6
Primary hospital	160	4.2	104	3.2	50	43.1
MCH specialized sentre	22	0.6	17	0.5	5	4.3
Health centre	3447	91.0	2999	93.3	4	3.4
MCH speciality clinic	15	0.4	10	0.3	0	0.0
Higher clinic	13	0.3	13	0.4	0	0.0
Total	3789	100	3214	100	116	100

Most health facilities (n=3,662, 96.3%, not included in the table) were public, while 83 (2.2%) were private for-profit and 59 (1.6%) were private not-for-profit (faith-based and non-

governmental). A total of 116 (3.0%) health facilities were fully EmNeC, and 471 (12.5%) health facilities were with no EmNeC signal functions (see Table 2).

Table 2: Health facility types by EmNeC functionality, EmONC 2016

Health facility type	Number of signal functions performed									
	7		5 or 6		3 or 4		1 or 2		0	
	n	%	n	%	n	%	n	%	n	%
Referral/specialized hospital	18	60.0	8	26.7	2	6.7	2	6.7	0	0.0	30	100
General hospital	39	37.9	36	35.0	12	11.7	11	10.7	5	4.9	103	100
Primary hospital	50	31.3	56	35.0	29	18.1	19	11.9	6	3.8	160	100
MCH specialized Centre	5	21.7	8	35.8	5	21.7	4	17.4	1	4.3	23	100
Health centre	4	0.1	117	3.4	1119	32.4	1763	51.0	456	13.2	3459	100
MCH speciality clinic	0	0.0	2	12.5	3	18.8	5	31.3	6	37.5	16	100
Higher clinic	0	0.0	4	30.8	5	38.5	4	30.8	0	0.0	13	100
Total	116	3.0	231	6.1	1175	30.9	1808	47.5	474	12.5	3804	100

MCH- Maternal and Child Health, SF-Signal Function

Access to health facilities

We estimated that 46.4% of live births in 2016 lived within two hours of travel time to fully EmNeC facilities. Approximately one-third of live births (35.9%) had access to a fully EmNeC facility within one hour, and 21.4% within 30 minutes travel time. The access coverage for partially EmNeC facilities (i.e., missing 1 or 2 signal functions) was 69.1%, 52.2%, and 33.5% within two hours, one hour and 30 minutes, respectively. The geographic access coverage to health facilities providing routine delivery services was 78.8% within two hours of travel time. Access to fully EmNeC services varied widely among regions, ranging from 15.3% to 100% coverage within two hours of travel time (see Figure 1).

Of all live births in Ethiopia in 2016, 7.9% were in areas where fully EmNeC services could be accessed within two hours of walking, and only 5.4% were in areas in which a fully EmNeC service could be accessed within one hour of walking travel time. Somali, Oromia, Benshangul Gumuz and Amhara regional states had the lowest access coverages to EmNeC facilities for access within two hours. The estimates of total live births by regional states are presented as a supplementary table (see Appendix 1).

Figure 1 displays the areas that had access to health facilities at different travel times. Access to facilities providing full EmNeC services within two hours was lower in the country's eastern, north-eastern, and peripheral areas (areas away from the centre and near borders) compared to the coverage of services providing routine delivery services (see Figure 2).

DISCUSSION

We found that more than one in two children born in Ethiopia did not have access to EmNeC health services in 2016 within a travel time of two hours. Nearly two-thirds of live births would have involved travel of more than an hour, and more than three-quarters would have travelled for more than 30 minutes to access fully EmNeC health facilities.

The coverages we found are considerably below the universal health coverage target of maternal and child health services, defined by the WHO as 95% for low- and middle-income countries, including Ethiopia.[45] It is also lower than expected universal health coverage stated by the United Nations (UN), with a resolution adopted stating that 90% of all births in the country would be within two hours of travel from EmONC/EmNeC facilities to ensure maternal and child universal health coverage.[37,46]

The current access coverage is lower than the study findings on access to basic emergency obstetric and newborn care services in Bangladesh and Malawi. In Bangladesh, 72.0% of live

births lived within two hours, and 59.0% lived within an hour of travel time from an EmONC facility in 2012.[47] In Malawi, 88.1% of live births could access emergency obstetric and newborn care services within two hours and 65.3% within an hour travel time in 2015.[37]

More than three-quarters of live births had access to health facilities providing routine delivery services within two hours of travel time. This figure implies that a significant improvement to access EmNeC services could be achieved if more health facilities currently providing routine delivery services had been equipped with EmNeC services. However, it still would be lower than the 90% universal health coverage standard for newborns care services. If we consider access to facilities with EmNeC services that missed zero, one or two signal functions, coverage was 69.0%. Along with expanding infrastructures, meeting the human resource requirements should be also taken into account. The current workforce in the Ethiopian health system is far below the WHO standard of 4.45 skilled health workers per 1000 population.[48] Ethiopia has a very low health workforce (Medical Doctors, Health Officers, Nurses and Midwives) density per population which was 0.96 per 1000 population in 2018.[49]

Access to fully EmNeC services varied widely among administrative regions. Addis Ababa, Hareri and Dire Dawa had the best access to EmNeC services within two hours, and the Afar and Somali regional states had the lowest access coverage. Addis Ababa had full access to EmNeC health facilities within 30 minutes of travel time. Addis Ababa is the country's capital city, with a large number of public and private health services concentrated in the city. The majority of Hareri and Dire Dawa regions also consist of urban areas, and there is a significant health service access disparity between urban and rural areas in Ethiopia.[50] This suggests the need for a stronger emphasis on the development of health infrastructure in rural areas and the less developed regional states by equipping health centres with neonatal service signal functions. While a larger number of health centres were built in the country's rural areas serving

the majority of the population compared to metropolitan areas, only a few health centres had all seven signal functions, and half of the health centres had one or two signal function services.

In line with this finding, studies showed discrepancies between administrative regions in health services coverage. For example, a study on access to emergency maternal and newborn care services in the neighbouring two regional states (Amhara and Tigray) showed a difference in access to emergency services with 68.0% vs 80.0% in accessing within two hours of travel time, and 8.0% vs 25.0% in the percentage of recommended EmONC coverage in Amhara and Tigray, respectively. The public health expenditure per capita was also approximately double in the Tigray regional state compared to the Amhara regional state (US$2.81vs US$1.50).[51] In the current study, the access coverages in Amhara and Tigray regional states were 48.7% and 60.0% within two hours of travel time. The difference between these neighbouring regions indicates the trends of inequitable distributions of health services across administrative regions, which could be attributed to the inequitable distributions of resources across regional states in the last three decades related to the corrupted Ethno-nationalist government system.[52] Another study finding from a review of 54 countries on equity of health services showed that Ethiopia is the top among countries with the most significant maternal and newborn service coverage inequalities.[53]

The catchment areas with limited access to EmNeC services within two hours, an hour and 30 minutes are in the eastern (Somali region), north-eastern (Afar region), and western and north-western areas near the borders to South Sudan and Kenya. Only a few areas were located within 30 minutes of reach to fully EmNeC health facilities, with most EmNeC health services being concentrated in the central, northern, and north-western parts of Ethiopia. Afar, Somali, and most parts of Benshangul Gumuz and Gambela regional states were mapped with a lower density of access coverage. These are known as comparatively less developed regional states of Ethiopia with considerably lower coverage of maternal and child health outcomes.[25]

Furthermore, most areas with lower EmNeC services coverage largely encompassed pastoralist communities that base their livelihood on agricultural activity of animal husbandry.[54]

This finding strengthens previous findings, showing low health coverage and low utilisation of services among the pastoralist communities in Ethiopia.[55,56]

CONCLUSION AND RECOMMENDATIONS

We estimated the geographic access coverage to emergency neonatal care services taking into account travel barriers and health facility capacity. The geographic access to emergency newborn care services in Ethiopia is considerably below the universal health coverage expectations. Information on geographic accessibility to EmNeC health services should systematically be monitored to observe progress towards universal health coverage to neonatal health services, thereby optimising the strategies towards reaching sustainable development goals. In addition, scaling up the signal functions to health facilities currently providing routine delivery services would significantly increase the geographic access coverage of EmNeC services.

Our results reinforce the need to revise the service allocations across administrative regions and strong financial support for the disadvantaged areas in future health service planning endeavours. More emphasis needs to be given to less-developed regional states to narrow the inequalities in the accessibility of newborn emergency services.

Ethical considerations

Ethical approval was granted from the University of Technology Sydney. Anonymous facility data were accessed from Ethiopian Public Health Institute with permission, and the other geospatial data were freely available online and did not require ethical approval

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Consent for publication

Not applicable

Competing interests

The authors declare that they have no competing interests

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Authors' contributions

GDK, AH and DD conceptualised the study approach and analyses. GD analysed the data and wrote the manuscript. AH and DD critically reviewed the manuscript for its intellectual content. All authors read and approved the manuscript for submission.

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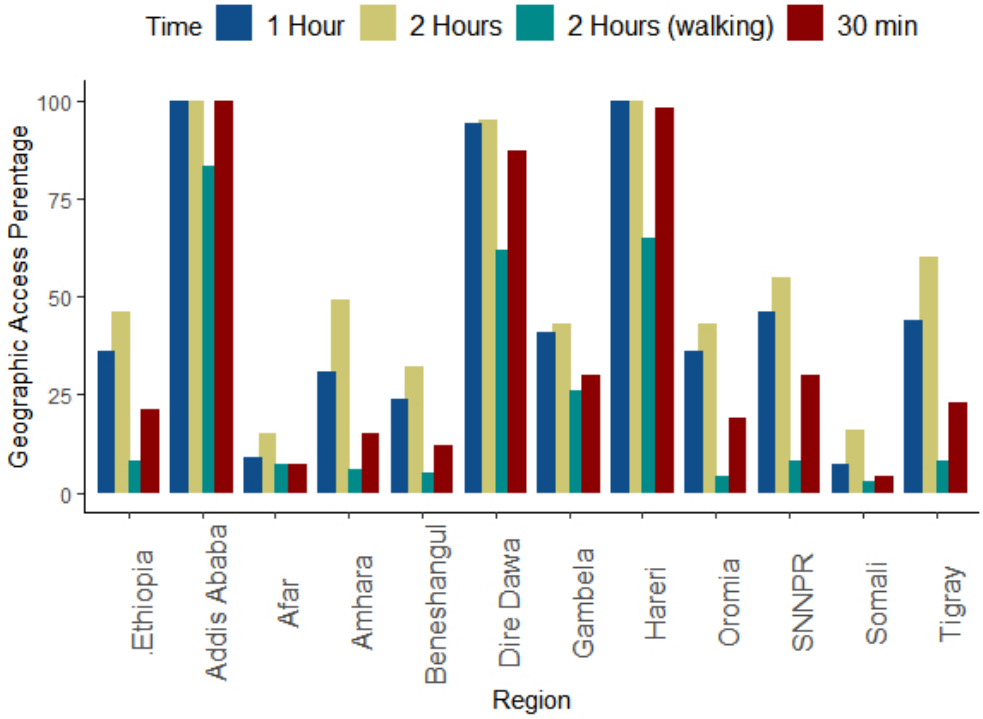
Figure legends

Figure 1:National and regional geographic access coverage to fully functioning EmNeC health facilities within two hours, one hour, and 30 minutes travel time using all forms of transportation and within two hours through walking in Ethiopia, 2016.

Figure 2: Catchment areas (dark green) of facilities providing normal delivery within two hours (upper left panel); accessible to EmNeC facilities within two hours (upper right panel); one hour (lower left panel); and in 30 minutes (lower right panel).



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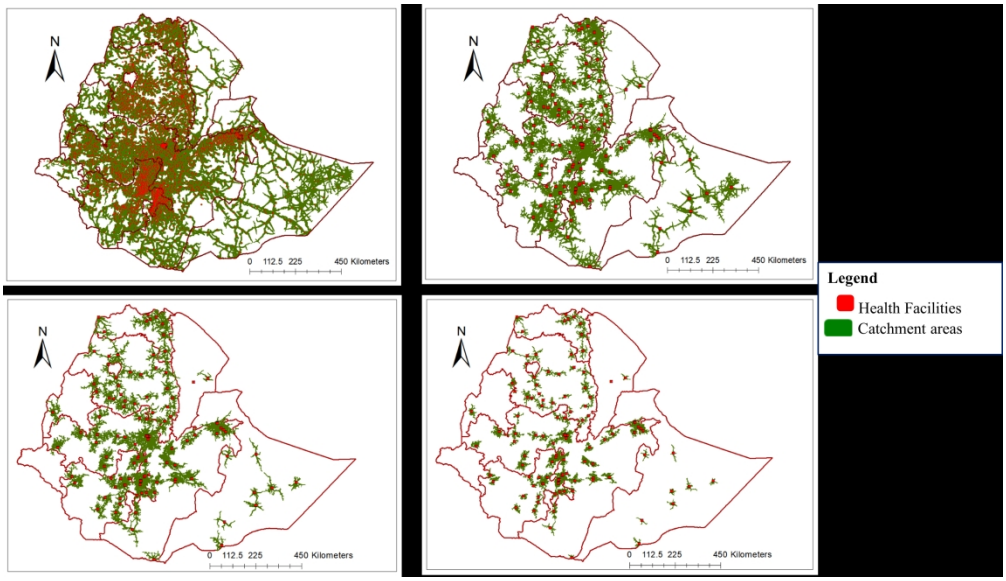

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Appendix 1: Total live births and births that had access to EmNeC health services within two hours by region, as extracted from the population distribution of raster grid data in Ethiopia 2015

Region name	Total live births	Live births covered	% of live births covered
Somali	247364.4	40409.6	16.3
Tigray	163014.8	97878.2	60.0
Addis Ababa	65267.7	65267.7	100.0
Afar	58570.5	8987.0	15.3
Amhara	634339.1	308902.4	48.7
Beneshangul Gumuz	34099.2	10966.9	32.2
Dire Dawa	13256.9	12656.9	95.5
Gambela	11521.7	4996.9	43.4
Hareri	6202.6	6194.3	99.9
Oromia	1149758.6	497256.0	43.2
SNNPR	547821.2	302910.0	55.3

SNNPR- South Nations, Nationalities and People Region

Note: live births covered are those who had access to EmNeC health services within two hours travel time

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Geographic Accessibility of Emergency Neonatal Care Services in Ethiopia: Analysis using the 2016 Ethiopian Emergency Obstetric and Neonatal Care Survey

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ABSTRACT

Introduction: Access to emergency neonatal health services has not been explored widely in the Ethiopian context. Accessibility to health services is a function of the distribution and location of services, including distance, travel time, cost and convenience. Measuring the physical accessibility of health services contributes to understanding the performance of health systems, thereby enabling evidence-based health planning and policies. The physical accessibility of Ethiopian health services, particularly emergency neonatal care services, is unknown.

Objective: To analyse the physical accessibility of emergency neonatal care services at the national and sub-national levels in Ethiopia

Methods: We analysed the physical accessibility of emergency neonatal care (EmNeC) services within 30, 60 and 120 minutes of travel time in Ethiopia at a national and sub-national level. We used the 2016 Ethiopian Emergency Obstetric and Neonatal Care (EmONC) survey in addition to several geospatial data sources.

Results: We estimated that 21.4%, 35.9%, and 46.4% of live births in 2016 were within 30, 60, and 120 minutes of travel time of fully EmNeC services, but there was considerable variation across regions. Addis Ababa and the Hareri regional state had full access (100% coverage) to EmNeC services within two hours travel time, while the Afar (15.3%) and Somali (16.3%) regional states had the lowest access.

Conclusions: The physical access to emergency neonatal care services in Ethiopia is well below the universal health coverage expectations stated by the United Nations. Increasing the availability of EmNeC to health facilities where routine delivery services currently are taking place would significantly increase physical access. Our results reinforce the need to revise

service allocations across administrative regions and consider improving disadvantaged areas in future health service planning.

Keywords: Access, Geographic, Neonatal, Health Services

Strengths and limitations of this study

- This is the first study to investigate the accessibility of emergency neonatal care (EmNeC) services in Ethiopia, estimating the geographic accessibility of health services accounting for land cover, elevation, hydrographic, road network travel barriers, and human resource availability.
- This approach can be used in other applications of access to healthcare in Ethiopia and elsewhere.
- Our study addressed only geographic accessibility while access can be measured considering other aspects, including financial feasibility, and consumer preferences.
- While we relied on assumptions about the maximum permitted travel speed in Ethiopia, this was not sensitive to a 25% reduction in the maximum travel speed.
- The health facilities' maximum capacity data were based partly on the WHO estimate of births per skilled birth attendant per year due to the lack of standard records in Ethiopia.

INTRODUCTION

Access is an essential concept in health policy and health services provision.[1-3] It is an important part of health, enabling the opportunity to obtain healthcare when needed.[4] Access to health services has multiple dimensions, including financial and physical access.[5,6] Factors such as income, media exposure, level of education, and healthcare-seeking behaviours are accessibility factors that facilitate or hinder access to health care. Physical accessibility indicates the relationship between healthcare location and the population seeking access, considering transportation infrastructure, travel time, distance, and cost.[2,3,7]

Health services access and utilisation are strongly associated, as utilisation is an indication of revealed accessibility.[8] Accessibility to health services is a function of the distribution and location of health services, including distance, travel time, travel cost and convenience.[9] Traditional approaches to measuring accessibility typically estimate the availability of health facilities within a certain distance of a given population.[10,11] However, methods to estimate the travel time to services, accounting for travel time across varying terrain and road surfaces, and financial availability are crucial to understanding the actual accessibility to health services.[12,13]

Accessibility to Emergency Obstetric and Neonatal Care (EmONC) and Emergency Newborn Care (EmNeC) services are important determinants of maternal and neonatal survival.[14] Lack of access to these services hinders facility-based delivery and skilled care provider follow-up.[15,16] EmONC and EmNeC have some services in common, but EmONC contains maternal and newborn care, whilst EmNeC focuses solely on neonatal care services. The WHO handbook for monitoring Emergency Obstetric and Newborn Care (EmONC) advises a minimum of five EmONC facilities per 500,000 population and access within two hours of travel time.[17] Of the five facilities, one should be a comprehensive EmONC service.

EmNeC services consist of seven signal functions complementing the EmONC signal functions. The signal functions include antenatal corticosteroids, antibiotics for premature rupture of membranes, antibiotics for neonatal infections, kangaroo mother care, resuscitation with bag and mask, administration of oxygen, and IV fluids.[18] Health facilities providing all these signal functions are considered to be fully EmNeC health facilities.

In Ethiopia, the diverse environmental, climatic, socio-economic, and terrain significantly affect health access and outcomes. Inadequate access to healthcare is of particular concern in the rural part of the country, where road and transportation infrastructure are under-developed and access to health services is limited.[19] It is important to understand the contribution of

access to health services to the variation of neonatal mortality across sub-national regions in Ethiopia. However, the distribution of EmNeC health services and their access among sub-national areas have not been yet explored.[20,21] Therefore, understanding the accessibility of neonatal health services may assist health planning and service administration.[22,23]

Ethiopia's latest health sector development programme strongly emphasise achieving universal health coverage (UHC),[24] mainly focusing on improving women's and children's health.[25] This study aims to analyse the geographic accessibility of emergency neonatal care services at national and sub-national levels in Ethiopia.

METHODS

Study setting

The Ethiopian health system is based on the primary health care (PHC) approach with three levels of care. The primary level includes primary hospitals, health centres and health posts (the lowest-level facility at a village level). The secondary level includes speciality centres (e.g., maternal and child health specialty centres), speciality clinics and general hospitals that serve as referral centres for primary hospitals, and the tertiary level includes specialised referral hospitals.[26] Most of the EmNeC signal functions are performed in hospitals and maternal and child health (MCH) specialty centres.[18] A specialty centre differs from a specialty clinic as specialty centres have inpatient admissions and offer 24 hours emergency services. A specialty centre differs from a hospital in that they do not offer the full spectrum of specialties required for a general hospital.[27]

Population and Variables

The target population for this analysis were all live births in Ethiopia taken from the 2016 UN estimates of numbers of live births per 1 km grid square.[28] The primary outcome variable in this study was accessibility to fully functioning Emergency Neonatal Care service (EmNeC)

within 30 minutes, one hour and two hours at a national and regional level. Secondary outcomes include accessibility of fully functioning health services through walking travel and access to health facilities with partial EmNeC signal functions. Accessibility was defined as the access from a residence to a health facility within two hours of travel time based on the WHO optimal access definition.[29] The facilities were considered to be fully functioning if all the seven signal functions for EmNeC were available in the past three months before the survey.

Patient and Public Involvement

No patient involved

Data source

We used three data groups for this analysis: statistical, geospatial, and national norms data. The statistical data included national and regional population sizes and the number of functional EmNeC health facilities. The geospatial data were regional administrative boundary data, geographic location of all health facilities providing delivery services, road network, hydrographic network, land cover, Digital Elevation Model (DEM) data, and spatial distribution of live births in Ethiopia in 2015. The national norms data includes the maximum travel speed expected for a motor vehicle on the different road types and the average capacity of health facilities that they could serve.

We used the Ethiopian 2016 EmONC survey, which is a national census of health facilities.[18] A total of 3,804 health facilities providing delivery services were included in the EmONC survey. Ethiopia's 2016 produced boundary shapefile, a geospatial vector data format matching the level of disaggregation of the sub-national statistical data, was accessed through OpenAFRICA;[30] land cover and digital evaluation model (DEM) data of 2015, a representation of the bare ground topographic surface of the Earth were accessed from the DIVA-GIS webpage.[31] The 2015 raster data for live births per 1km grid square was accessed

via the WorldPop webpage.[28] We used OpenStreetMaps via the World Food Program data repository of 2017[32] to estimate travel speeds for motorised vehicles based on the primary, secondary, and tertiary and unclassified road surfaces. We used DEM data to estimate the effects of slopes on travel time.[33] The barrier to travel (hydrographic data) was obtained from RCMRD GeoPortal[34] and DIVA-GIS[31] web pages produced in 2015.

We created a travel scenario for walking and motorised transportation based on the land cover structure and road types. We assumed that walking speed ranged from zero km/hr for water bodies to 2.5 km/hr for established residential areas, assuming a pregnant woman in her last month of pregnancy would be able to walk at half the average walking speed as used elsewhere.[35] We assumed travel speeds of 100, 70, 50, and 30 km per hour for primary, secondary, tertiary, and unclassified road types based on the country's speed limit.[36] We used these speeds as ambulances would be able to travel at the maximum speed in emergency situations. We also conducted a sensitivity analysis for fully EmNeC services coverage, lowering the maximum vehicle speed by 25%. The road network data were classified based on Ethiopian speed limit norms. The main road classifications in Ethiopia are primary, secondary, tertiary, and unclassified.[32] However, the road network data available online includes several classifications, including the linking roads between primary roads-so we need to reclassify into the above four main classifications. Primary, primary link, motorway and trunk roads were classified as primary, secondary and secondary links as secondary, tertiary and tertiary links as tertiary and track and unclassified were merged as unclassified road classes.

We assigned the maximum capacity for each health facility category based on the standard WHO assumption of births per skilled birth attendant per year.[37] we assigned 175, 100, 75 and 50 births per skilled birth attendant per year for hospitals, MCH speciality centres, health centres, and clinics. We then multiplied the number of births per year by the number of skilled

birth attendants at each facility to estimate the total number of possible births per year at each health facility.

Data processing and analysis

We integrated multiple geospatial datasets in AccessMod, which is a free, open-source software package developed by the WHO. AccessMod uses Geographic Information Systems (GIS)[38], which are computer-based systems to gather, store, retrieve, analyse, and display spatial data, to assess health facilities physical accessibility and geographic coverage[39]. AccessMod models the coverage of catchment areas linked to an existing health facility network integrating population distribution, travel time and the population coverage capacity specific to each health facility in the network.[40] AccessMod computes catchment areas using the least-cost path algorithm.[41] The least-cost path approach calculates the distance between a focal location and all cells in the surroundings, dividing surface areas into grid cells. It identifies the best path from one point to another over a cost surface, identifying the cost of travelling through each grid cell, which has been given to cost how expensive, it is to pass through that cell.[42] The cost given to each cell is the travelling time to cross the grid cell, which is determined through the travelling speed attributed to the elevation and land cover of the cell. Finally, it produces a point estimate of cumulative access coverage of health services to catchment areas population.

The vector and raster geospatial data files were projected based on Ethiopia's geographic coordinate system at Adindan UTM zone 37N[43] to make it suitable for analysis. A projection is the means by which we display the coordinate system and data on a flat surface, such as a piece of paper or a digital screen. A projected coordinate system is a two-dimensional flat surface, and locations, in this case, are identified by x,y coordinates.[44]

RESULTS

Characteristics of health facilities

A total of 3,804 health facilities (100% response rate) were assessed in the 2016 EmONC survey, of which 3,789 were providing routine delivery services. A total of 3,308 (87.0%) health facilities were fully operating their routine maternal and child services, 458 (12.0%) were fully operating and under redevelopment to expand service coverage, and the remaining 38 (1.0%) were partially operating or under redevelopment during the time of the survey. The majority (91.0%) of health facilities providing delivery services were health centres, and the largest number of fully EmNeC services were primary hospitals (43%). Only 4 (3.4%) fully EmNeC services were health centres (see Table 1).

Table 1: Frequency and percentages of health facilities providing routine delivery and emergency neonatal care (EmNeC) services, 2016.

Health facility type	Normal Delivery		Partially EmNeC (5 or 6 signal functions)		Fully EmNeC	
	n	%	n	%	n	%
Referral/specialized hospital	29	0.8	12	0.4	18	15.5
General hospital	103	2.7	59	1.8	39	33.6
Primary hospital	160	4.2	104	3.2	50	43.1
MCH specialized sentre	22	0.6	17	0.5	5	4.3
Health centre	3447	91.0	2999	93.3	4	3.4
MCH speciality clinic	15	0.4	10	0.3	0	0.0
Higher clinic	13	0.3	13	0.4	0	0.0
Total	3789	100	3214	100	116	100

Note: Percentage totaled column-wise indicating the shared of EmNeC functioning at each type of health facility

Most health facilities (n=3,662, 96.3%, not included in the table) were public, while 83 (2.2%) were private for-profit and 59 (1.6%) were private not-for-profit (faith-based and non-

governmental). A total of 116 (3.0%) health facilities were fully EmNeC, and 471 (12.5%) health facilities were with no EmNeC signal functions (see Table 2).

Table 2: Health facility types by Emergency Neonatal Care functionality, Emergency Obestetric and Neonatal Care Survey 2016

Health facility type	Number of signal functions performed											
	7		5 or 6		3 or 4		1 or 2		0		Total	
	n	%	n	%	n	%	n	%	n	%	n	%
Referral/specialized hospital	18	60.0	8	26.7	2	6.7	2	6.7	0	0.0	30	100
General hospital	39	37.9	36	35.0	12	11.7	11	10.7	5	4.9	103	100
Primary hospital	50	31.3	56	35.0	29	18.1	19	11.9	6	3.8	160	100
MCH specialized Centre	5	21.7	8	35.8	5	21.7	4	17.4	1	4.3	23	100
Health centre	4	0.1	117	3.4	1119	32.4	1763	51.0	456	13.2	3459	100
MCH speciality clinic	0	0.0	2	12.5	3	18.8	5	31.3	6	37.5	16	100
Higher clinic	0	0.0	4	30.8	5	38.5	4	30.8	0	0.0	13	100
Total	116	3.0	231	6.1	1175	30.9	1808	47.5	474	12.5	3804	100

MCH- Maternal and Child Health,

Access to health facilities

We estimated that 46.4% of live births in 2016 lived within two hours of travel time to fully EmNeC facilities. Approximately one-third of live births (35.9%) had access to a fully EmNeC facility within one hour, and 21.4% within 30 minutes travel time. The access coverage for partially EmNeC facilities (i.e., missing 1 or 2 signal functions) was 69.1%, 52.2%, and 33.5% within two hours, one hour and 30 minutes, respectively. The geographic access coverage to health facilities providing routine delivery services was 78.8% within two hours of travel time. Access to fully EmNeC services varied widely among regions, ranging from 15.3% to 100% coverage within two hours of travel time (see Figure 1). In the sensitivity analysis, when we

considered 25% lower vehicle speeds than the maximum allowed driving speed, the coverage for fully EmNeC facilities was 44.0% (see Appendix 2 for regional access coverage).

Of all live births in Ethiopia in 2016, 7.9% were in areas where fully EmNeC services could be accessed within two hours of walking, and only 5.4% were in areas in which a fully EmNeC service could be accessed within one hour of walking travel time. Somali, Oromia, Benshangul Gumuz and Amhara regional states had the lowest access coverages to EmNeC facilities for access within two hours. The estimates of total live births by regional states are presented as a supplementary table (see Appendix 1).

Figure 2 displays the areas that had access to health facilities that provide normal delivery and fully EmNeC services within 2 hours. Access to facilities providing full EmNeC services within two hours was lower in the country's eastern, north-eastern, and peripheral areas (areas away from the centre and near borders) compared to the coverage of services providing routine delivery services (see Figure 2).

A trend of decreasing access coverage to fully EmNeC services was observed from an hour to 30 minutes travel time (see Figure 3).

DISCUSSION

We found that more than one in two children born in Ethiopia did not have access to fully EmNeC health services in 2016 within a travel time of two hours. Nearly two-thirds of live births would have involved travel of more than an hour, and more than three-quarters would have travelled for more than 30 minutes to access fully EmNeC health facilities.

The coverages we found are considerably below the universal health coverage target of maternal and child health services, defined by the WHO as 95% for low- and middle-income countries, including Ethiopia.[45] It is also lower than expected universal health coverage

stated by the United Nations (UN), with a resolution adopted stating that 90% of all births in the country would be within two hours of travel from EmONC/EmNeC facilities to ensure maternal and child universal health coverage.[37,46]

The current access coverage is lower than the study findings on access to basic emergency obstetric and newborn care services in Bangladesh and Malawi. In Bangladesh, 72.0% of live births lived within two hours, and 59.0% lived within an hour of travel time from an EmONC facility in 2012.[47] In Malawi, 88.1% of live births could access emergency obstetric and newborn care services within two hours and 65.3% within an hour travel time in 2015.[37]

More than three-quarters of live births had access to health facilities providing routine delivery services within two hours of travel time. This figure implies that a significant improvement to access EmNeC services could be achieved if more health facilities currently providing routine delivery services had been equipped with EmNeC services. However, it still would be lower than the 90% universal health coverage standard for newborn care services. If we consider access to facilities with EmNeC services that missed zero, one or two signal functions, coverage was 69.0%. Along with expanding infrastructures, meeting the human resource requirements should also be considered. The current workforce in the Ethiopian health system is far below the WHO standard of 4.45 skilled health workers per 1000 population.[48] Ethiopia has a very low health workforce (Medical Doctors, Health Officers, Nurses and Midwives) density per population which was 0.96 per 1000 population in 2018.[49]

Access to fully EmNeC services varied widely among administrative regions. Addis Ababa, Hareri and Dire Dawa had the best access to EmNeC services within two hours, and the Afar and Somali regional states had the lowest access coverage. Addis Ababa had full access to EmNeC health facilities within 30 minutes of travel time. Addis Ababa is the country's capital city, with a large number of public and private health services concentrated in the city. The

majority of Hareri and Dire Dawa regions also consist of urban areas, and there is a significant health service access disparity between urban and rural areas in Ethiopia.[50] This suggests the need for a stronger emphasis on the development of health infrastructure in rural areas and the less developed regional states by equipping health centres with neonatal service signal functions. While a larger number of health centres were built in the country's rural areas serving the majority of the population compared to metropolitan areas, only a few health centres had all seven signal functions, and half of the health centres had one or two signal function services.

In line with this finding, studies showed discrepancies between administrative regions in health services coverage. For example, a study on access to emergency maternal and newborn care services in the neighbouring two regional states (Amhara and Tigray) showed a difference in access to emergency services with 68.0% vs 80.0% in accessing within two hours of travel time, and 8.0% vs 25.0% in the percentage of recommended EmONC coverage in Amhara and Tigray, respectively. The public health expenditure per capita was also approximately double in the Tigray regional state compared to the Amhara regional state (US$2.81vs US$1.50).[51] In the current study, the access coverages in Amhara and Tigray regional states were 48.7% and 60.0% within two hours of travel time. The difference between these neighbouring regions indicates the trends of inequitable distributions of health services across administrative regions, which could be attributed to the inequitable distributions of resources across regional states in the last three decades.[52] Another study finding from a review of 54 countries on equity of health services showed that Ethiopia is the top among countries with the most significant maternal and newborn service coverage inequalities.[53]

The catchment areas with limited access to EmNeC services within two hours, an hour and 30 minutes are in the eastern (Somali region), north-eastern (Afar region), and western and north-western areas near the borders to South Sudan and Kenya. Only a few areas were located within 30 minutes of reach to fully EmNeC health facilities, with most EmNeC health services being

concentrated in the central, northern, and north-western parts of Ethiopia. Afar, Somali, and most parts of Benshangul Gumuz and Gambela regional states were mapped with a lower density of access coverage. These are known as comparatively less developed regional states of Ethiopia with considerably lower coverage of maternal and child health outcomes.[25] Furthermore, most areas with lower EmNeC services coverage largely encompassed pastoralist communities that base their livelihood on agricultural activity of animal husbandry.[54]

This finding strengthens previous findings, showing low health coverage and low utilisation of services among the pastoralist communities in Ethiopia.[55,56]

STRENGTH AND LIMITATIONS

This is the first study investigating the geographic accessibility of emergency newborn care in Ethiopia. We estimated the geographic accessibility to health services accounting for land cover, elevation, hydrographic and road network travel barriers as well as human resources availability. The findings indicated the overall gaps and regional disparities in EmNeC services. It is important to note that accessibility can be measured and evaluated from multiple aspects, while our study focuses on the geographic dimension of accessibility. We assumed that ambulances could travel at the maximum permitted speed in Ethiopia. However, we also showed that reducing this maximum speed by 25% did not affect the coverage estimates considerably. Furthermore, the health facilities' maximum capacity considered in the model for each health facility category was based on the WHO assumption of births per skilled birth attendant per year, due to the lack of standard records in Ethiopia.

CONCLUSION AND RECOMMENDATIONS

We estimated the geographic access coverage to emergency neonatal care services taking into account travel barriers and health facility capacity. The geographic access to emergency newborn care services in Ethiopia is considerably below the universal health coverage

expectations. Information on geographic accessibility to EmNeC health services should systematically be monitored to observe progress towards universal health coverage to neonatal health services, thereby optimising the strategies towards reaching sustainable development goals. In addition, scaling up the EmNeC signal functions to health facilities currently providing EmONC services and, in the long run, to facilities that currently provide routine delivery services would significantly increase the geographic access coverage of EmNeC services.

Our results reinforce the need to revise the service allocations across administrative regions and strong financial support for the disadvantaged areas in future health service planning endeavours. Extensive monitoring and evaluation at every level need to be carried out in order to narrow the inequalities in the accessibility of newborn emergency services across administrative regions.

Ethical considerations

Ethical approval was granted from the University of Technology Sydney (ETH19-4488). Anonymous facility data were accessed from Ethiopian Public Health Institute with permission, and the other geospatial data were freely available online and did not require ethical approval

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Consent for publication

Not applicable

Data availability statement

The data we used for analysis were accessed from a third part (Ethiopian public Health institute) and are not publicly available.

Competing interests

The authors declare that they have no competing interests

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No fund was received for this study.

Authors' contributions

GDK, AH and DD conceptualised the study approach and analyses. GD analysed the data and wrote the manuscript. AH and DD critically reviewed the manuscript for its intellectual content. All authors read and approved the manuscript for submission.

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Figure legends

Figure 1:National and regional geographic access coverage to fully functioning EmNeC health facilities within two hours, one hour, and 30 minutes travel time using motorised transportation and within two hours through walking in Ethiopia, 2016.

Figure 2: Catchment areas (dark green) of facilities accessible to routine delivery services (upper panel) and fully EmNeC services within two hours (lower panel) travel time.

Figure 3: Catchment areas (dark green) of facilities accessible to fully EmNeC services within an hour (upper panel) and 30 minutes (lower panel) travel time.

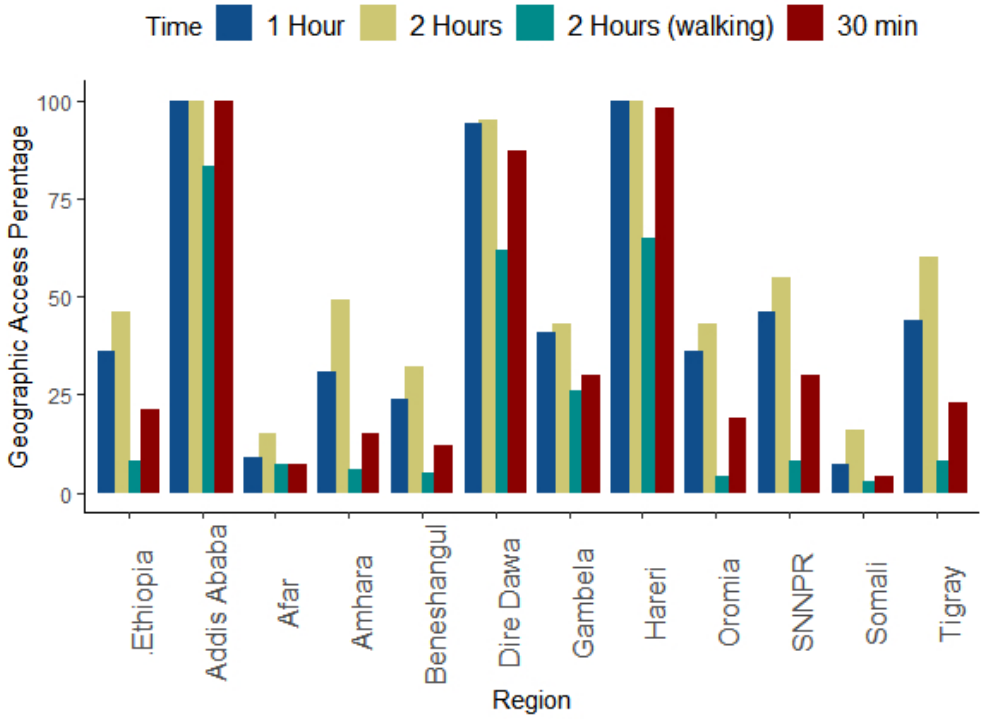

Figure 1:National and regional geographic access coverage to fully functioning EmNeC health facilities within two hours, one hour, and 30 minutes travel time using motorised transportation and within two hours through walking in Ethiopia, 2016.

49x36mm (300 x 300 DPI)

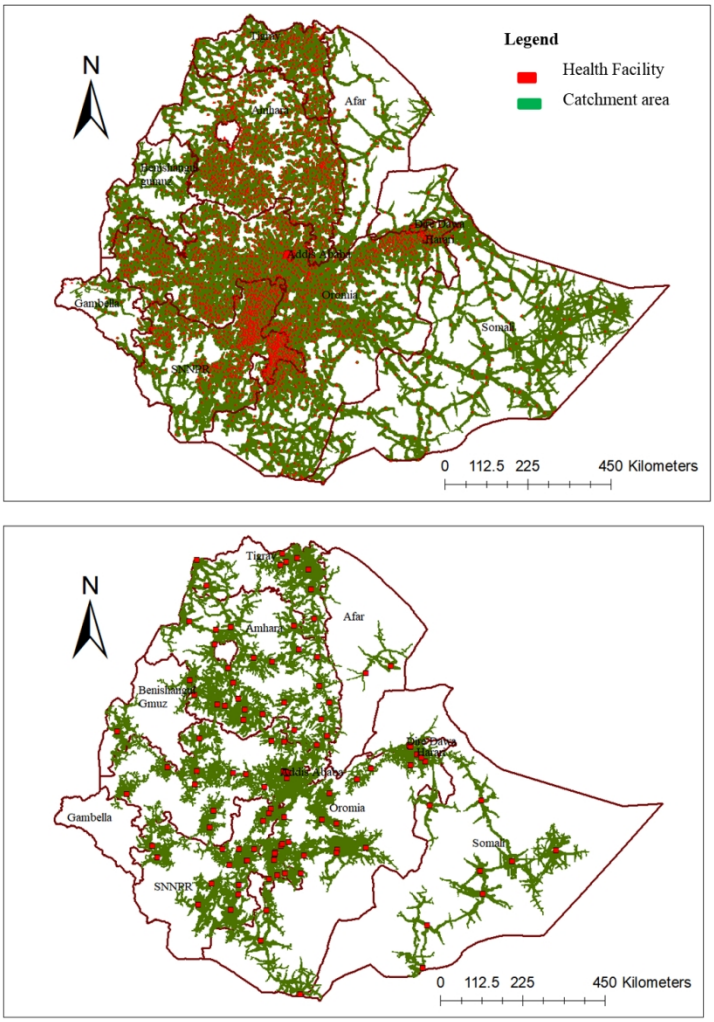

Figure 2: Catchment areas (dark green) of facilities accessible to routine delivery services (upper panel) and fully EmNeC services within two hours (lower panel) travel time.

209x297mm (150 x 150 DPI)

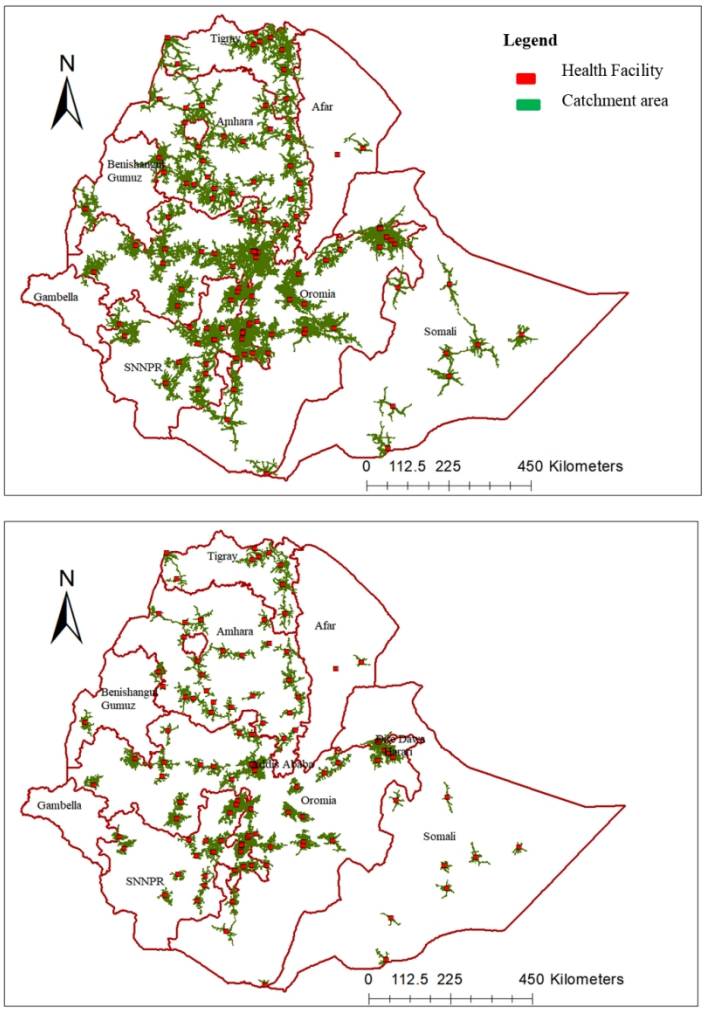

Figure 3: Catchment areas (dark green) of facilities accessible to fully EmNeC services within an hour (upper panel) and 30 minutes (lower panel) travel time.

209x297mm (150 x 150 DPI)

Appendix 1: Total live births and births that had access to EmNeC health services within two hours by region, as extracted from the population distribution of raster grid data in Ethiopia 2015

Region name	Total live births	Live births covered	% 0f live births covered
Somali	247364	40410	16.3
Tigray	163015	97878	60.0
Addis Ababa	65268	65268	100.0
Afar	58571	8987	15.3
Amhara	634339	308902	48.7
Beneshangul Gumuz	34099	10967	32.2
Dire Dawa	13257	12657	95.5
Gambela	11522	4997	43.4
Hareri	6203	6194	99.9
Oromia	1149759	497256	43.2
SNNPR	547821	302910	55.3

SNNPR- South Nations, Nationalities and People Region

Note: live births covered are those who had access to EmNeC health services within two hours travel time

Appendix 2: Geographic access coverage of fully emergency neonatal care services considering travel scenarios of the maximum allowed driving speed and 25% lower than the maximum allowed driving speed.

Region name	% Access coverage	
	Maximum travel time assumed	25% lower than maximum travel time
Addis Ababa	100.0	100.0
Afar	13.5	15.3
Amhara	45.1	48.7
Beneshangul Gumu	33.3	32.2
Dire Dawa	95.8	95.5
Gambela	43.3	43.4
Hareri	100.0	99.9
Oromia	41.6	43.3
Somali	10.9	16.3
SNNPR	53.4	55.3
Tigray	56.0	60.0

Supplement 3: Checklist for Reporting Of Survey Studies (CROSS)

Section/topic	Item	Item description	Reported on page #
Title and abstract			
Title and abstract	1a	State the word "survey" along with a commonly used term in title or abstract to introduce the study's design.	1
	1b	Provide an informative summary in the abstract, covering background, objectives, methods, findings/results, interpretation/discussion, and conclusions.	1
Introduction			
Background	2	Provide a background about the rationale of study, what has been previously done, and why this survey is needed.	3
Purpose/aim	3	Identify specific purposes, aims, goals, or objectives of the study.	4
Methods			
Study design	4	Specify the study design in the methods section with a commonly used term (e.g., cross-sectional or longitudinal).	5
Data collection methods	5a	Describe the questionnaire (e.g., number of sections, number of questions, number and names of instruments used).	NA
	5b	Describe all questionnaire instruments that were used in the survey to measure particular concepts. Report target population, reported validity and reliability information, scoring/classification procedure, and reference links (if any).	NA
	5c	Provide information on pretesting of the questionnaire, if performed (in the article or in an online supplement). Report the method of pretesting, number of times questionnaire was pre-tested, number and demographics of participants used for pretesting, and the level of similarity of demographics between pre-testing participants and sample population.	NA
	5d	Questionnaire, if possible, should be fully provided (in the article, or as appendices or as an online supplement).	NA-secondary data
Sample characteristics	6a	Describe the study population (i.e., background, locations, eligibility criteria for participant inclusion in survey, exclusion criteria).	5
	6b	Describe the sampling techniques used (e.g., single stage or multistage sampling, simple random sampling, stratified sampling, cluster sampling, convenience sampling). Specify the locations of sample participants whenever clustered sampling was applied.	5
	6c	Provide information on sample size, along with details of sample size calculation.	5
	6d	Describe how representative the sample is of the study population (or target population if possible), particularly for population-based surveys.	5

Survey administration	7a	Provide information on modes of questionnaire administration, including the type and number of contacts, the location where the survey was conducted (e.g., outpatient room or by use of online tools, such as SurveyMonkey).	5
	7b	Provide information of survey's time frame, such as periods of recruitment, exposure, and follow-up days.	5
	7c	Provide information on the entry process: –>For non-web-based surveys, provide approaches to minimize human error in data entry. –>For web-based surveys, provide approaches to prevent "multiple participation" of participants.	NA
Study preparation	8	Describe any preparation process before conducting the survey (e.g., interviewers' training process, advertising the survey).	NA
Ethical considerations	9a	Provide information on ethical approval for the survey if obtained, including informed consent, institutional review board [IRB] approval, Helsinki declaration, and good clinical practice [GCP] declaration (as appropriate).	14
	9b	Provide information about survey anonymity and confidentiality and describe what mechanisms were used to protect unauthorized access.	NA
Statistical analysis	10a	Describe statistical methods and analytical approach. Report the statistical software that was used for data analysis.	7
	10b	Report any modification of variables used in the analysis, along with reference (if available).	
	10c	Report details about how missing data was handled. Include rate of missing items, missing data mechanism (i.e., missing completely at random [MCAR], missing at random [MAR] or missing not at random [MNAR]) and methods used to deal with missing data (e.g., multiple imputation).	7
	10d	State how non-response error was addressed.	NA
	10e	For longitudinal surveys, state how loss to follow-up was addressed.	
	10f	Indicate whether any methods such as weighting of items or propensity scores have been used to adjust for non-representativeness of the sample.	NA-census
	10g	Describe any sensitivity analysis conducted.	6
Results			
Respondent characteristics	11a	Report numbers of individuals at each stage of the study. Consider using a flow diagram, if possible.	NA - census
	11b	Provide reasons for non-participation at each stage, if possible.	
	11c	Report response rate, present the definition of response rate or the formula used to calculate response rate.	8

	11d	Provide information to define how unique visitors are determined. Report number of unique visitors along with relevant proportions (e.g., view proportion, participation proportion, completion proportion).	
Descriptive results	12	Provide characteristics of study participants, as well as information on potential confounders and assessed outcomes.	8
Main findings	13a	Give unadjusted estimates and, if applicable, confounder-adjusted estimates along with 95% confidence intervals and p-values.	NA
	13b	For multivariable analysis, provide information on the model building process, model fit statistics, and model assumptions (as appropriate).	NA
	13c	Provide details about any sensitivity analysis performed. If there are considerable amount of missing data, report sensitivity analyses comparing the results of complete cases with that of the imputed dataset (if possible).	10
Discussion			
Limitations	14	Discuss the limitations of the study, considering sources of potential biases and imprecisions, such as non-representativeness of sample, study design, important uncontrolled confounders.	13
Interpretations	15	Give a cautious overall interpretation of results, based on potential biases and imprecisions and suggest areas for future research.	9
Generalizability	16	Discuss the external validity of the results.	14
Other sections			
Role of funding source	17	State whether any funding organization has had any roles in the survey's design, implementation, and analysis.	NA
Conflict of interest	18	Declare any potential conflict of interest.	14
Acknowledgements	19	Provide names of organizations/persons that are acknowledged along with their contribution to the research.	15

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Geographic Accessibility of Emergency Neonatal Care Services in Ethiopia: Analysis using the 2016 Ethiopian Emergency Obstetric and Neonatal Care Survey

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Geographic Accessibility of Emergency Neonatal Care Services in Ethiopia: Analysis using the 2016 Ethiopian Emergency Obstetric and Neonatal Care Survey

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ABSTRACT

Introduction: Access to emergency neonatal health services has not been explored widely in the Ethiopian context. Accessibility to health services is a function of the distribution and location of services, including distance, travel time, cost and convenience. Measuring the physical accessibility of health services contributes to understanding the performance of health systems, thereby enabling evidence-based health planning and policies. The physical accessibility of Ethiopian health services, particularly emergency neonatal care services, is unknown.

Objective: To analyse the physical accessibility of emergency neonatal care services at the national and sub-national levels in Ethiopia

Methods: We analysed the physical accessibility of emergency neonatal care (EmNeC) services within 30, 60 and 120 minutes of travel time in Ethiopia at a national and sub-national level. We used the 2016 Ethiopian Emergency Obstetric and Neonatal Care (EmONC) survey in addition to several geospatial data sources.

Results: We estimated that 21.4%, 35.9%, and 46.4% of live births in 2016 were within 30, 60, and 120 minutes of travel time of fully EmNeC services, but there was considerable variation across regions. Addis Ababa and the Hareri regional state had full access (100% coverage) to EmNeC services within two hours travel time, while the Afar (15.3%) and Somali (16.3%) regional states had the lowest access.

Conclusions: The physical access to emergency neonatal care services in Ethiopia is well below the universal health coverage expectations stated by the United Nations. Increasing the availability of EmNeC to health facilities where routine delivery services currently are taking place would significantly increase physical access. Our results reinforce the need to revise

service allocations across administrative regions and consider improving disadvantaged areas in future health service planning.

Keywords: Access, Geographic, Neonatal, Health Services

Strengths and limitations of this study

- This is the first study to investigate the accessibility of emergency neonatal care (EmNeC) services in Ethiopia, estimating the geographic accessibility of health services accounting for land cover, elevation, hydrographic, road network travel barriers, and human resource availability.
- This approach can be used in other applications of access to healthcare in Ethiopia and elsewhere.
- Our study addressed only geographic accessibility while access can be measured considering other aspects, including financial feasibility, and consumer preferences.
- While we relied on assumptions about the maximum permitted travel speed in Ethiopia, this was not sensitive to a 25% reduction in the maximum travel speed.
- The health facilities' maximum capacity data were based partly on the WHO estimate of births per skilled birth attendant per year due to the lack of standard records in Ethiopia.

INTRODUCTION

Access is an essential concept in health policy and health services provision.[1-3] It is an important part of health, enabling the opportunity to obtain healthcare when needed.[4] Access to health services has multiple dimensions, including financial and physical access.[5,6] Factors such as income, media exposure, level of education, and healthcare-seeking behaviours are accessibility factors that facilitate or hinder access to health care. Physical accessibility indicates the relationship between healthcare location and the population seeking access, considering transportation infrastructure, travel time, distance, and cost.[2,3,7]

Health services access and utilisation are strongly associated, as utilisation is an indication of revealed accessibility.[8] Accessibility to health services is a function of the distribution and location of health services, including distance, travel time, travel cost and convenience.[9] Traditional approaches to measuring accessibility typically estimate the availability of health facilities within a certain distance of a given population.[10,11] However, methods to estimate the travel time to services, accounting for travel time across varying terrain and road surfaces, and financial availability are crucial to understanding the actual accessibility to health services.[12,13]

Accessibility to Emergency Obstetric and Neonatal Care (EmONC) and Emergency Newborn Care (EmNeC) services are important determinants of maternal and neonatal survival.[14] Lack of access to these services hinders facility-based delivery and skilled care provider follow-up.[15,16] EmONC and EmNeC have some services in common, but EmONC contains maternal and newborn care, whilst EmNeC focuses solely on neonatal care services. The WHO handbook for monitoring Emergency Obstetric and Newborn Care (EmONC) advises a minimum of five EmONC facilities per 500,000 population and access within two hours of travel time.[17] Of the five facilities, one should be a comprehensive EmONC service.

EmNeC services consist of seven signal functions complementing the EmONC signal functions. The signal functions include antenatal corticosteroids, antibiotics for premature rupture of membranes, antibiotics for neonatal infections, kangaroo mother care, resuscitation with bag and mask, administration of oxygen, and IV fluids.[18] Health facilities providing all these signal functions are considered to be fully EmNeC health facilities.

In Ethiopia, the diverse environmental, climatic, socio-economic, and terrain significantly affect health access and outcomes. Inadequate access to healthcare is of particular concern in the rural part of the country, where road and transportation infrastructure are under-developed and access to health services is limited.[19] It is important to understand the contribution of

access to health services to the variation of neonatal mortality across sub-national regions in Ethiopia. However, the distribution of EmNeC health services and their access among sub-national areas have not been yet explored.[20,21] Therefore, understanding the accessibility of neonatal health services may assist health planning and service administration.[22,23]

Ethiopia's latest health sector development programme strongly emphasise achieving universal health coverage (UHC),[24] mainly focusing on improving women's and children's health.[25] This study aims to analyse the geographic accessibility of emergency neonatal care services at national and sub-national levels in Ethiopia.

METHODS

Study setting

The Ethiopian health system is based on the primary health care (PHC) approach with three levels of care. The primary level includes primary hospitals, health centres and health posts (the lowest-level facility at a village level). The secondary level includes speciality centres (e.g., maternal and child health specialty centres), speciality clinics and general hospitals that serve as referral centres for primary hospitals, and the tertiary level includes specialised referral hospitals.[26] Most of the EmNeC signal functions are performed in hospitals and maternal and child health (MCH) specialty centres.[18] A specialty centre differs from a specialty clinic as specialty centres have inpatient admissions and offer 24 hours emergency services. A specialty centre differs from a hospital in that they do not offer the full spectrum of specialties required for a general hospital.[27]

Population and Variables

The target population for this analysis were all live births in Ethiopia taken from the 2016 UN estimates of numbers of live births per 1 km grid square.[28] The primary outcome variable in this study was accessibility to fully functioning Emergency Neonatal Care service (EmNeC)

within 30 minutes, one hour, and two hours travel time at a national and regional level. Secondary outcomes include accessibility of fully functioning health services through walking travel and access to health facilities with partial EmNeC signal functions. Accessibility was defined as the access from a residence to a health facility within two hours of travel time based on the WHO optimal access definition.[29] The facilities were considered to be fully functioning if all the seven signal functions for EmNeC were available in the past three months before the survey.

Patient and Public Involvement

No patient involved

Data source

We used three data groups for this analysis: statistical, geospatial, and national norms data. The statistical data included national and regional population sizes and the number of functional EmNeC health facilities. The geospatial data were regional administrative boundary data, geographic location of all health facilities providing delivery services, road network, hydrographic network, land cover, Digital Elevation Model (DEM) data, and spatial distribution of live births in Ethiopia in 2015. The national norms data includes the maximum travel speed expected for a motor vehicle on the different road types and the average capacity of health facilities that they could serve.

We used the Ethiopian 2016 EmONC survey, which is a national census of health facilities.[18] A total of 3,804 health facilities providing delivery services were included in the EmONC survey. Ethiopia's 2016 produced boundary shapefile, a geospatial vector data format matching the level of disaggregation of the sub-national statistical data, was accessed through OpenAFRICA;[30] land cover and digital evaluation model (DEM) data of 2015, a representation of the bare ground topographic surface of the Earth were accessed from the

DIVA-GIS webpage.[31] The 2015 raster data for live births per 1km grid square was accessed via the WorldPop webpage.[28] We used OpenStreetMaps via the World Food Program data repository of 2017[32] to estimate travel speeds for motorised vehicles based on the primary, secondary, and tertiary and unclassified road surfaces. We used DEM data to estimate the effects of slopes on travel time.[33] The barrier to travel (hydrographic data) was obtained from RCMRD GeoPortal[34] and DIVA-GIS[31] web pages produced in 2015.

We created a travel scenario for walking and motorised transportation based on the land cover structure and road types. We assumed that walking speed ranged from zero km/hr for water bodies to 2.5 km/hr for established residential areas, assuming a pregnant woman in her last month of pregnancy would be able to walk at half the average walking speed as used elsewhere.[35] We assumed driving speeds of 100, 70, 50, and 30 km per hour for primary, secondary, tertiary, and unclassified road types based on the country's speed limit.[36] We used these speeds as ambulances would be able to travel at the maximum speed in emergency situations. We also conducted a sensitivity analysis for fully EmNeC services coverage, lowering the maximum vehicle speed by 25%. The road network data were classified based on Ethiopian speed limit norms. The main road classifications in Ethiopia are primary, secondary, tertiary, and unclassified.[32] However, the road network data available online includes several classifications, including the linking roads between primary roads-so we need to reclassify into the above four main classifications. Primary, primary link, motorway and trunk roads were classified as primary, secondary and secondary links as secondary, tertiary and tertiary links as tertiary and track and unclassified were merged as unclassified road classes.

We assigned the maximum capacity for each health facility category based on the standard WHO assumption of births per skilled birth attendant per year.[37] we assigned 175, 100, 75 and 50 births per skilled birth attendant per year for hospitals, MCH speciality centres, health centres, and clinics. We then multiplied the number of births per year by the number of skilled

birth attendants at each facility to estimate the total number of possible births per year at each health facility.

Data processing and analysis

We integrated multiple geospatial datasets in AccessMod, which is a free, open-source software package developed by the WHO. AccessMod uses Geographic Information Systems (GIS)[38], which are computer-based systems to gather, store, retrieve, analyse, and display spatial data, to assess health facilities physical accessibility and geographic coverage[39]. AccessMod models the coverage of catchment areas linked to an existing health facility network integrating population distribution, travel time and the population coverage capacity specific to each health facility in the network.[40] AccessMod computes catchment areas using the least-cost path algorithm.[41] The least-cost path approach calculates the distance between a focal location and all cells in the surroundings, dividing surface areas into grid cells. It identifies the best path from one point to another over a cost surface, identifying the cost of travelling through each grid cell, which has been given to cost how expensive, it is to pass through that cell.[42] The cost given to each cell is the travelling time to cross the grid cell, which is determined through the travelling speed attributed to the elevation and land cover of the cell. Finally, it produces a point estimate of cumulative access coverage of health services to catchment areas population.

The vector and raster geospatial data files were projected based on Ethiopia's geographic coordinate system at Adindan UTM zone 37N[43] to make it suitable for analysis. A projection is the means by which we display the coordinate system and data on a flat surface, such as a piece of paper or a digital screen. A projected coordinate system is a two-dimensional flat surface, and locations, in this case, are identified by x,y coordinates.[44]

RESULTS

Characteristics of health facilities

A total of 3,804 health facilities (100% response rate) were assessed in the 2016 EmONC survey, of which 3,789 were providing routine delivery services. A total of 3,308 (87.0%) health facilities were fully operating their routine maternal and child services, 458 (12.0%) were fully operating and under redevelopment to expand service coverage, and the remaining 38 (1.0%) were partially operating or under redevelopment during the time of the survey. The majority (91.0%) of health facilities providing delivery services were health centres, and the largest number of fully EmNeC services were primary hospitals (43%). Only 4 (3.4%) fully EmNeC services were health centres (see Table 1).

Table 1: Frequency and percentages of health facilities providing routine delivery and emergency neonatal care (EmNeC) services, 2016.

Health facility type	Normal Delivery		Partially EmNeC (5 or 6 signal functions)		Fully EmNeC	
	n	%	n	%	n	%
Referral/specialized hospital	29	0.8	12	0.4	18	15.5
General hospital	103	2.7	59	1.8	39	33.6
Primary hospital	160	4.2	104	3.2	50	43.1
MCH specialized sentre	22	0.6	17	0.5	5	4.3
Health centre	3447	91.0	2999	93.3	4	3.4
MCH speciality clinic	15	0.4	10	0.3	0	0.0
Higher clinic	13	0.3	13	0.4	0	0.0
Total	3789	100	3214	100	116	100

Note: Percentage totaled column-wise indicating the shared of EmNeC functioning at each type of health facility

Most health facilities (n=3,662, 96.3%, not included in the table) were public, while 83 (2.2%) were private for-profit and 59 (1.6%) were private not-for-profit (faith-based and non-

governmental). A total of 116 (3.0%) health facilities were fully EmNeC, and 471 (12.5%) health facilities were with no EmNeC signal functions (see Table 2).

Table 2: Health facility types by Emergency Neonatal Care functionality, Emergency Obestetric and Neonatal Care Survey 2016

Health facility type	Number of signal functions performed											
	7		5 or 6		3 or 4		1 or 2		0		Total	
	n	%	n	%	n	%	n	%	n	%	n	%
Referral/specialized hospital	18	60.0	8	26.7	2	6.7	2	6.7	0	0.0	30	100
General hospital	39	37.9	36	35.0	12	11.7	11	10.7	5	4.9	103	100
Primary hospital	50	31.3	56	35.0	29	18.1	19	11.9	6	3.8	160	100
MCH specialized Centre	5	21.7	8	35.8	5	21.7	4	17.4	1	4.3	23	100
Health centre	4	0.1	117	3.4	1119	32.4	1763	51.0	456	13.2	3459	100
MCH speciality clinic	0	0.0	2	12.5	3	18.8	5	31.3	6	37.5	16	100
Higher clinic	0	0.0	4	30.8	5	38.5	4	30.8	0	0.0	13	100
Total	116	3.0	231	6.1	1175	30.9	1808	47.5	474	12.5	3804	100

MCH- Maternal and Child Health,

Access to health facilities

We estimated that 46.4% of live births in 2016 lived within two hours of travel time to fully EmNeC facilities. Approximately one-third of live births (35.9%) had access to a fully EmNeC facility within one hour, and 21.4% within 30 minutes travel time. The access coverage for partially EmNeC facilities (i.e., missing 1 or 2 signal functions) was 69.1%, 52.2%, and 33.5% within two hours, one hour and 30 minutes, respectively. The geographic access coverage to health facilities providing routine delivery services was 78.8% within two hours of travel time. Access to fully EmNeC services varied widely among regions, ranging from 15.3% to 100% coverage within two hours of travel time (see Figure 1). In the sensitivity analysis, when we

considered 25% lower vehicle speeds than the maximum allowed driving speed, the coverage for fully EmNeC facilities was 44.0% (see Appendix 1 for regional access coverage).

Of all live births in Ethiopia in 2016, 7.9% were in areas where fully EmNeC services could be accessed within two hours of walking, and only 5.4% were in areas in which a fully EmNeC service could be accessed within one hour of walking travel time. Somali, Oromia, Benshangul Gumuz and Amhara regional states had the lowest access coverages to EmNeC facilities for access within two hours. The estimates of total live births by regional states are presented as a supplementary table (see Appendix 2).

Figure 2 displays the areas that had access to health facilities that provide normal delivery and fully EmNeC services within 2 hours. Access to facilities providing full EmNeC services within two hours was lower in the country's eastern, north-eastern, and peripheral areas (areas away from the centre and near borders) compared to the coverage of services providing routine delivery services (see Figure 2).

A trend of decreasing access coverage to fully EmNeC services was observed from an hour to 30 minutes travel time (see Figure 3).

DISCUSSION

We found that more than one in two children born in Ethiopia did not have access to fully EmNeC health services in 2016 within a travel time of two hours. Nearly two-thirds of live births would have involved travel of more than an hour, and more than three-quarters would have travelled for more than 30 minutes to access fully EmNeC health facilities.

The coverages we found are considerably below the universal health coverage target of maternal and child health services, defined by the WHO as 95% for low- and middle-income countries, including Ethiopia.[45] It is also lower than expected universal health coverage

stated by the United Nations (UN), with a resolution adopted stating that 90% of all births in the country would be within two hours of travel from EmONC/EmNeC facilities to ensure maternal and child universal health coverage.[37,46]

The current access coverage is lower than the study findings on access to basic emergency obstetric and newborn care services in Bangladesh and Malawi. In Bangladesh, 72.0% of live births lived within two hours, and 59.0% lived within an hour of travel time from an EmONC facility in 2012.[47] In Malawi, 88.1% of live births could access emergency obstetric and newborn care services within two hours and 65.3% within an hour travel time in 2015.[37]

More than three-quarters of live births had access to health facilities providing routine delivery services within two hours of travel time. This figure implies that a significant improvement to access EmNeC services could be achieved if more health facilities currently providing routine delivery services had been equipped with EmNeC services. However, it still would be lower than the 90% universal health coverage standard for newborn care services. If we consider access to facilities with EmNeC services that missed zero, one or two signal functions, coverage was 69.0%. Along with expanding infrastructures, meeting the human resource requirements should also be considered. The current workforce in the Ethiopian health system is far below the WHO standard of 4.45 skilled health workers per 1000 population.[48] Ethiopia has a very low health workforce (Medical Doctors, Health Officers, Nurses and Midwives) density per population which was 0.96 per 1000 population in 2018.[49]

Access to fully EmNeC services varied widely among administrative regions. Addis Ababa, Hareri and Dire Dawa had the best access to EmNeC services within two hours, and the Afar and Somali regional states had the lowest access coverage. Addis Ababa had full access to EmNeC health facilities within 30 minutes of travel time. Addis Ababa is the country's capital city, with a large number of public and private health services concentrated in the city. The

majority of Hareri and Dire Dawa regions also consist of urban areas, and there is a significant health service access disparity between urban and rural areas in Ethiopia.[50] This suggests the need for a stronger emphasis on the development of health infrastructure in rural areas and the less developed regional states by equipping health centres with neonatal service signal functions. While a larger number of health centres were built in the country's rural areas serving the majority of the population compared to metropolitan areas, only a few health centres had all seven signal functions, and half of the health centres had one or two signal function services.

In line with this finding, studies showed discrepancies between administrative regions in health services coverage. For example, a study on access to emergency maternal and newborn care services in the neighbouring two regional states (Amhara and Tigray) showed a difference in access to emergency services with 68.0% vs 80.0% in accessing within two hours of travel time, and 8.0% vs 25.0% in the percentage of recommended EmONC coverage in Amhara and Tigray, respectively. The public health expenditure per capita was also approximately double in the Tigray regional state compared to the Amhara regional state (US$2.81vs US$1.50).[51] In the current study, the access coverages in Amhara and Tigray regional states were 48.7% and 60.0% within two hours of travel time. The difference between these neighbouring regions indicates the trends of inequitable distributions of health services across administrative regions, which could be attributed to the inequitable distributions of resources across regional states in the last three decades.[52] Another study finding from a review of 54 countries on equity of health services showed that Ethiopia is the top among countries with the most significant maternal and newborn service coverage inequalities.[53]

The catchment areas with limited access to EmNeC services within two hours, an hour and 30 minutes are in the eastern (Somali region), north-eastern (Afar region), and western and north-western areas near the borders to South Sudan and Kenya. Only a few areas were located within 30 minutes of reach to fully EmNeC health facilities, with most EmNeC health services being

concentrated in the central, northern, and north-western parts of Ethiopia. Afar, Somali, and most parts of Benshangul Gumuz and Gambela regional states were mapped with a lower density of access coverage. These are known as comparatively less developed regional states of Ethiopia with considerably lower coverage of maternal and child health outcomes.[25] Furthermore, most areas with lower EmNeC services coverage largely encompassed pastoralist communities that base their livelihood on agricultural activity of animal husbandry.[54]

This finding strengthens previous findings, showing low health coverage and low utilisation of services among the pastoralist communities in Ethiopia.[55,56]

STRENGTH AND LIMITATIONS

This is the first study investigating the geographic accessibility of emergency newborn care in Ethiopia. We estimated the geographic accessibility to health services accounting for land cover, elevation, hydrographic and road network travel barriers as well as human resources availability. The findings indicated the overall gaps and regional disparities in EmNeC services. It is important to note that accessibility can be measured and evaluated from multiple aspects, while our study focuses on the geographic dimension of accessibility. We assumed that ambulances could travel at the maximum permitted speed in Ethiopia. However, we also showed that reducing this maximum speed by 25% did not affect the coverage estimates considerably. Furthermore, the health facilities' maximum capacity considered in the model for each health facility category was based on the WHO assumption of births per skilled birth attendant per year, due to the lack of standard records in Ethiopia.

CONCLUSION AND RECOMMENDATIONS

We estimated the geographic access coverage to emergency neonatal care services taking into account travel barriers and health facility capacity. The geographic access to emergency newborn care services in Ethiopia is considerably below the universal health coverage

expectations. Information on geographic accessibility to EmNeC health services should systematically be monitored to observe progress towards universal health coverage to neonatal health services, thereby optimising the strategies towards reaching sustainable development goals. In addition, scaling up the EmNeC signal functions to health facilities currently providing EmONC services and, in the long run, to facilities that currently provide routine delivery services would significantly increase the geographic access coverage of EmNeC services.

Our results reinforce the need to revise the service allocations across administrative regions and strong financial support for the disadvantaged areas in future health service planning endeavours. Extensive monitoring and evaluation at every level need to be carried out in order to narrow the inequalities in the accessibility of newborn emergency services across administrative regions.

Ethical considerations

Ethical approval was granted from the University of Technology Sydney (ETH19-4488). Anonymous facility data were accessed from Ethiopian Public Health Institute with permission, and the other geospatial data were freely available online and did not require ethical approval

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Consent for publication

Not applicable

Data availability statement

The data we used for analysis were accessed from a third part (Ethiopian public Health institute) and are not publicly available.

Competing interests

The authors declare that they have no competing interests

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Authors' contributions

GDK, AH and DD conceptualised the study approach and analyses. GD analysed the data and wrote the manuscript. AH and DD critically reviewed the manuscript for its intellectual content. All authors read and approved the manuscript for submission.

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Figure legends

Figure 1:National and regional geographic access coverage to fully functioning EmNeC health facilities within two hours, one hour, and 30 minutes using motorised and walking composite transportation scenario and within two hours through walking travel time in Ethiopia, 2016.

Figure 2: Catchment areas (dark green) of facilities accessible to routine delivery services (upper panel) and fully EmNeC services within two hours (lower panel) travel time.

Figure 3: Catchment areas (dark green) of facilities accessible to fully EmNeC services within an hour (upper panel) and 30 minutes (lower panel) travel time.

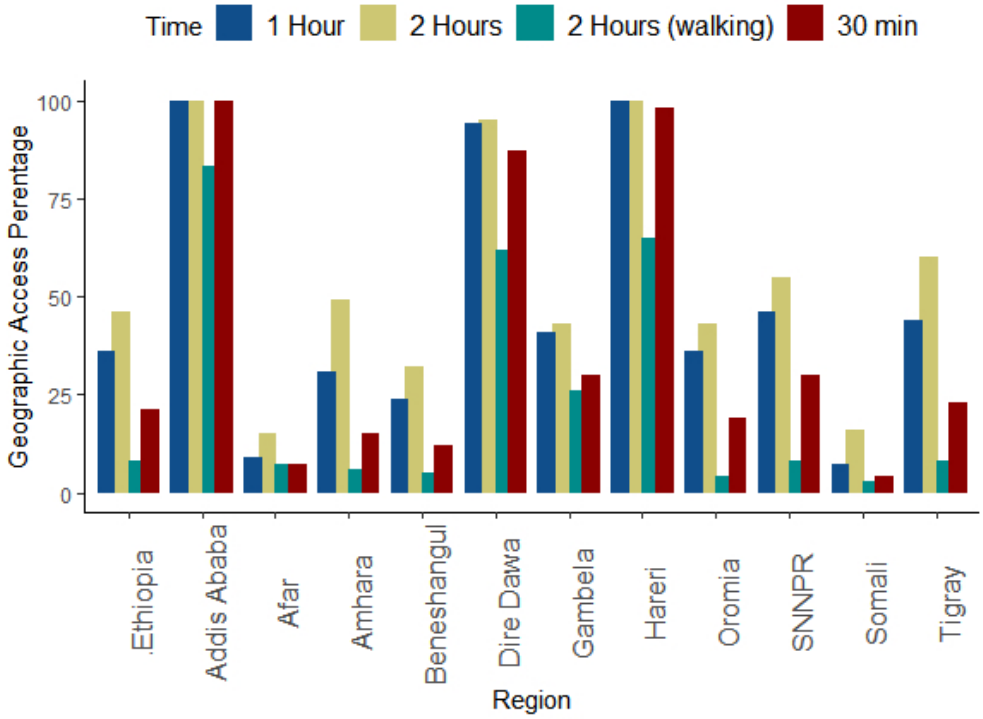

Figure 1:National and regional geographic access coverage to fully functioning EmNeC health facilities within two hours, one hour, and 30 minutes travel time using motorised transportation and within two hours through walking in Ethiopia, 2016.

49x36mm (300 x 300 DPI)

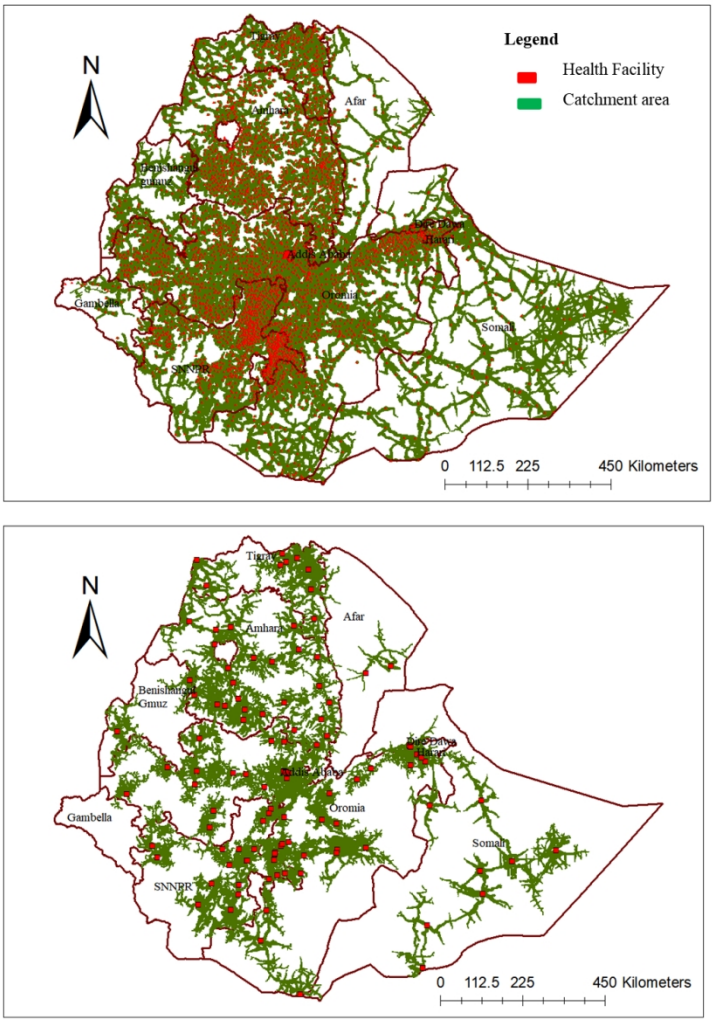

Figure 2: Catchment areas (dark green) of facilities accessible to routine delivery services (upper panel) and fully EmNeC services within two hours (lower panel) travel time.

209x297mm (150 x 150 DPI)

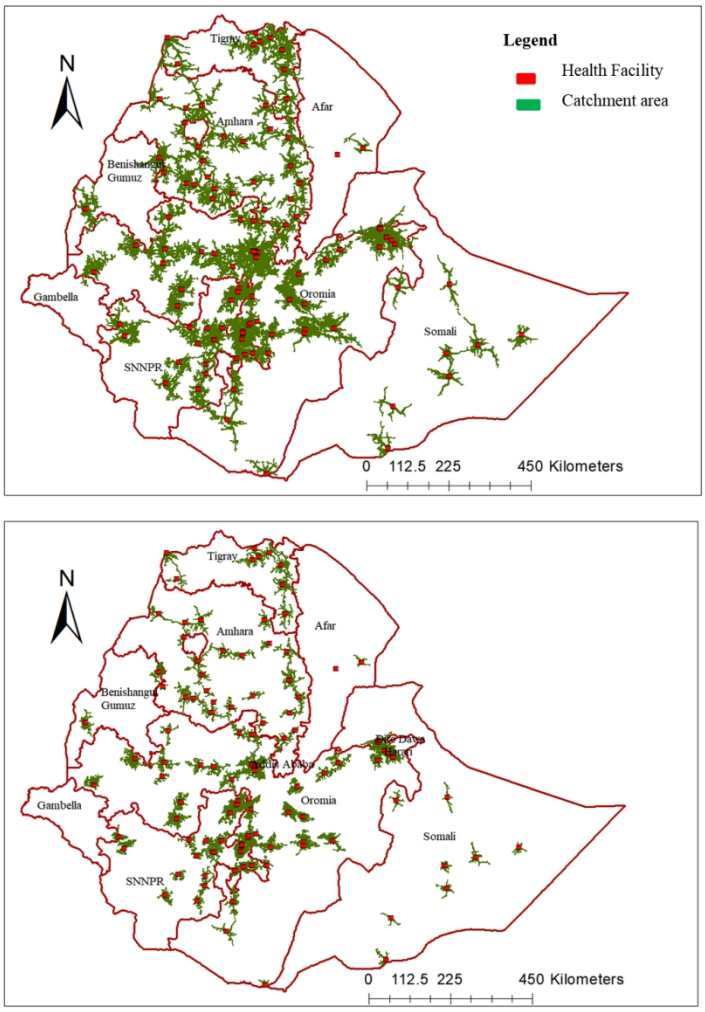

Figure 3: Catchment areas (dark green) of facilities accessible to fully EmNeC services within an hour (upper panel) and 30 minutes (lower panel) travel time.

209x297mm (150 x 150 DPI)

Appendix 1: Geographic access coverage of fully emergency neonatal care services considering travel scenarios of the maximum allowed driving speed and 25% lower than the maximum allowed driving speed.

Region name	% Access coverage	
	Maximum travel time assumed	25% lower than maximum travel time
Addis Ababa	100.0	100.0
Afar	13.5	15.3
Amhara	45.1	48.7
Beneshangul Gumu	33.3	32.2
Dire Dawa	95.8	95.5
Gambela	43.3	43.4
Hareri	100.0	99.9
Oromia	41.6	43.3
Somali	10.9	16.3
SNNPR	53.4	55.3
Tigray	56.0	60.0

Appendix 2: Total live births and births that had access to EmNeC health services within two hours by region, as extracted from the population distribution of raster grid data in Ethiopia 2015

Region name	Total live births	Live births covered	% 0f live births covered
Somali	247364	40410	16.3
Tigray	163015	97878	60.0
Addis Ababa	65268	65268	100.0
Afar	58571	8987	15.3
Amhara	634339	308902	48.7
Beneshangul Gumuz	34099	10967	32.2
Dire Dawa	13257	12657	95.5
Gambela	11522	4997	43.4
Hareri	6203	6194	99.9
Oromia	1149759	497256	43.2
SNNPR	547821	302910	55.3

SNNPR- South Nations, Nationalities and People Region

Note: live births covered are those who had access to EmNeC health services within two hours travel time

Checklist for Reporting Of Survey Studies (CROSS)

Section/topic	Item	Item description	Reported on page #
Title and abstract			
Title and abstract	1a	State the word "survey" along with a commonly used term in title or abstract to introduce the study's design.	1
	1b	Provide an informative summary in the abstract, covering background, objectives, methods, findings/results, interpretation/discussion, and conclusions.	1
Introduction			
Background	2	Provide a background about the rationale of study, what has been previously done, and why this survey is needed.	3
Purpose/aim	3	Identify specific purposes, aims, goals, or objectives of the study.	4
Methods			
Study design	4	Specify the study design in the methods section with a commonly used term (e.g., cross-sectional or longitudinal).	5
Data collection methods	5a	Describe the questionnaire (e.g., number of sections, number of questions, number and names of instruments used).	NA
	5b	Describe all questionnaire instruments that were used in the survey to measure particular concepts. Report target population, reported validity and reliability information, scoring/classification procedure, and reference links (if any).	NA
	5c	Provide information on pretesting of the questionnaire, if performed (in the article or in an online supplement). Report the method of pretesting, number of times questionnaire was pre-tested, number and demographics of participants used for pretesting, and the level of similarity of demographics between pre-testing participants and sample population.	NA
	5d	Questionnaire, if possible, should be fully provided (in the article, or as appendices or as an online supplement).	NA-secondary data
Sample characteristics	6a	Describe the study population (i.e., background, locations, eligibility criteria for participant inclusion in survey, exclusion criteria).	5
	6b	Describe the sampling techniques used (e.g., single stage or multistage sampling, simple random sampling, stratified sampling, cluster sampling, convenience sampling). Specify the locations of sample participants whenever clustered sampling was applied.	5
	6c	Provide information on sample size, along with details of sample size calculation.	5
	6d	Describe how representative the sample is of the study population (or target population if possible), particularly for population-based surveys.	5

Survey administration	7a	Provide information on modes of questionnaire administration, including the type and number of contacts, the location where the survey was conducted (e.g., outpatient room or by use of online tools, such as SurveyMonkey).	5
	7b	Provide information of survey's time frame, such as periods of recruitment, exposure, and follow-up days.	5
	7c	Provide information on the entry process: –>For non-web-based surveys, provide approaches to minimize human error in data entry. –>For web-based surveys, provide approaches to prevent "multiple participation" of participants.	NA
Study preparation	8	Describe any preparation process before conducting the survey (e.g., interviewers' training process, advertising the survey).	NA
Ethical considerations	9a	Provide information on ethical approval for the survey if obtained, including informed consent, institutional review board [IRB] approval, Helsinki declaration, and good clinical practice [GCP] declaration (as appropriate).	14
	9b	Provide information about survey anonymity and confidentiality and describe what mechanisms were used to protect unauthorized access.	NA
Statistical analysis	10a	Describe statistical methods and analytical approach. Report the statistical software that was used for data analysis.	7
	10b	Report any modification of variables used in the analysis, along with reference (if available).	
	10c	Report details about how missing data was handled. Include rate of missing items, missing data mechanism (i.e., missing completely at random [MCAR], missing at random [MAR] or missing not at random [MNAR]) and methods used to deal with missing data (e.g., multiple imputation).	7
	10d	State how non-response error was addressed.	NA
	10e	For longitudinal surveys, state how loss to follow-up was addressed.	
	10f	Indicate whether any methods such as weighting of items or propensity scores have been used to adjust for non-representativeness of the sample.	NA-census
	10g	Describe any sensitivity analysis conducted.	6
Results			
Respondent characteristics	11a	Report numbers of individuals at each stage of the study. Consider using a flow diagram, if possible.	NA - census
	11b	Provide reasons for non-participation at each stage, if possible.	
	11c	Report response rate, present the definition of response rate or the formula used to calculate response rate.	8

	11d	Provide information to define how unique visitors are determined. Report number of unique visitors along with relevant proportions (e.g., view proportion, participation proportion, completion proportion).	
Descriptive results	12	Provide characteristics of study participants, as well as information on potential confounders and assessed outcomes.	8
Main findings	13a	Give unadjusted estimates and, if applicable, confounder-adjusted estimates along with 95% confidence intervals and p-values.	NA
	13b	For multivariable analysis, provide information on the model building process, model fit statistics, and model assumptions (as appropriate).	NA
	13c	Provide details about any sensitivity analysis performed. If there are considerable amount of missing data, report sensitivity analyses comparing the results of complete cases with that of the imputed dataset (if possible).	10
Discussion			
Limitations	14	Discuss the limitations of the study, considering sources of potential biases and imprecisions, such as non-representativeness of sample, study design, important uncontrolled confounders.	13
Interpretations	15	Give a cautious overall interpretation of results, based on potential biases and imprecisions and suggest areas for future research.	9
Generalizability	16	Discuss the external validity of the results.	14
Other sections			
Role of funding source	17	State whether any funding organization has had any roles in the survey's design, implementation, and analysis.	NA
Conflict of interest	18	Declare any potential conflict of interest.	14
Acknowledgements	19	Provide names of organizations/persons that are acknowledged along with their contribution to the research.	15