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Travel of pregnant women in emergency situations to hospital and maternal mortality in Lagos, Nigeria: a retrospective cohort study

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ABSTRACT

Introduction Prompt access to emergency obstetrical care (EmOC) reduces the risk of maternal mortality. We assessed institutional maternal mortality by distance and travel time for pregnant women with obstetrical emergencies in Lagos State, Nigeria.

Methods We conducted a facility-based retrospective cohort study across 24 public hospitals in Lagos. Reviewing case notes of the pregnant women presenting between 1 November 2018 and 30 October 2019, we extracted socio-demographic, travel and obstetrical data. The extracted travel data were exported to Google Maps, where driving distance and travel time data were extracted. Multivariable logistic regression was conducted to determine the relative influence of distance and travel time on maternal death.

Findings Of 4181 pregnant women with obstetrical emergencies, 182 (4.4%) resulted in maternal deaths. Among those who died, 60.3% travelled ≤10 km directly from home, and 61.9% arrived at the hospital ≤30 mins. The median distance and travel time to EmOC was 7.6 km (IQR 3.4–18.0) and 26 mins (IQR 12–50). For all women, travelling 10–15 km (2.53, 95% CI 1.27 to 5.03) was significantly associated with maternal death. Stratified by referral, odds remained statistically significant for those travelling 10–15 km in the non-referred group (2.48, 95% CI 1.18 to 5.23) and for travel ≥120 min (7.05, 95% CI 1.10 to 45.32). For those referred, odds became statistically significant at 25–35 km (21.40, 95% CI 1.24 to 36.72) and for journeys requiring travel time from as little as 10–29 min (184.23, 95% CI 5.14 to 608.51). Odds were also significantly higher for women travelling to hospitals in suburban (3.60, 95% CI 1.59 to 8.18) or rural (2.51, 95% CI 1.01 to 6.29) areas.

Conclusion Our evidence shows that distance and travel time influence maternal mortality differently for referred women and those who are not. Larger scale research that uses closer-to-reality travel time and distance estimates as we have done, rethinking of global guidelines, and bold actions addressing access gaps, including within the suburbs, will be critical in reducing maternal mortality by 2030.

WHAT IS ALREADY KNOWN ON THIS TOPIC

⇒ In sub-Saharan Africa, limited and conflicting evidence exists on the effect of travel time and distance on maternal mortality. The available evidence is based on research conducted in rural areas which used straight-line distances, assuming the women went to the nearest facility or health worker 'guestimation' of travel time.

WHAT THIS STUDY ADDS

⇒ Our findings in this study using closer-to-reality distance and travel time estimates showed that in Lagos, almost two-thirds of maternal deaths occur among pregnant women who travelled ≤10 km directly from home and arrived at the hospital in 30 mins.

⇒ There was a higher likelihood of maternal deaths with a 10–15 km distance and travel to a hospital that principally served suburban and rural areas. The odds of maternal death were statistically significant even when travel of 10–29 min was required for those referred.

HOW THIS STUDY MIGHT AFFECT RESEARCH, PRACTICE AND/OR POLICY

⇒ Functional health facilities must be available within 10 km of every woman, with particular attention placed in the suburbs. Across board, robust systems are needed to support travel of pregnant women from the community to a health facility with capacity for emergency obstetrical care, with or without referral.

⇒ The 2-hour benchmark recommended by the WHO warrants a careful review with consideration given to more symptom-specific thresholds, urbanicity and recognition for the other delays that women may experience, including at referring facilities.

INTRODUCTION

Globally, 295 000 maternal deaths occur every year due to complications related to

pregnancy and childbirth, including bleeding, hypertension, infection and abortion.[1] These complications also lead to some pregnant women delivering babies in their third trimester who are born dead, otherwise referred to as stillbirths. It is estimated that approximately 2 million stillbirths occur annually.[2] Approximately 70% of maternal deaths occur in sub-Saharan Africa (SSA), with Nigeria alone accounting for more than two-fifths of the global burden of maternal deaths.[1] For stillbirths, over 40% occurs in SSA, with those occurring in Nigeria being about 10% of the worldwide burden.[2] At present, the consensus strategy to reduce deaths related to pregnancy and childbirth, re-emphasised by the Sustainable Development Goals (SDGs), has predominantly focused on increasing access to prompt emergency obstetrical care (EmOC) provided by skilled health personnel (online supplemental tables S1 and S2A,B).[3 4] Available research evidence indicates that prompt access to EmOC can lead to as much as a 50% reduction in intra-facility maternal deaths and a 45%–75% reduction in stillbirths occurring after the onset of labour but before birth.[5] However, before a pregnant woman arrives at a health facility, delays in the decision to seek care (first delay), travel to reach appropriately equipped health facilities (second delay) and delay in receiving care (third delay) can increase the risk of death of the pregnant woman or that of her yet unborn child.[6]

In 2009, the WHO recommended that health facilities be 'available within 2–3 hours of travel for most women', highlighting that this is the time it takes from onset of symptoms to death for a woman with postpartum haemorrhage as a complication of childbirth.[4] Despite recognising the implication of travel delays on maternal mortality, studies on association of distance and travel time on maternal mortality are limited. When such studies have been conducted in SSA, they have been situated in rural settings and focused on travel time or distance.[7–10] It is critical for studies attempting to understand the second delay to assess both travel time and distance, as though it is intuitive to expect both variables to increase or decrease together, some pregnant women travel for a long time despite living near a health facility.[11] This is even more of an issue in urban and peri-urban settings, where traffic, poor road conditions and high population density are common features.[11] Indeed, focus on these urban settings is crucial now more than ever before as almost 40% of the projected additional 2.5 billion urban residents globally are expected to concentrate in Africa.[12] Our objective in this study was to assess the association between distance, travel time and maternal mortality among pregnant women who presented with obstetrical emergencies at public hospitals in Nigeria's most urbanised state, Lagos.

METHODS

Study design

Our study was a retrospective cohort study of pregnant women who presented as obstetrical emergencies at 1 of the 24 public hospitals (20 non-apex referral and 4 apex referral hospitals) in Lagos State (online supplemental tables S3 and S4).[4]

Setting

Lagos State, located in the southwestern part of Nigeria, has various geographical terrains (including land and water) and settlement types (including a central metropolis, suburbs, towns, slums and informal settlements) (online supplemental table S3). While primarily urban, the state has some rural parts in its extreme east and west. The state has 20 local government areas (LGAs) with population ranging from 117 542 (Ibeju-Lekki LGA) to 11 456 783 (Alimosho LGA). Population across the state was estimated to be about 26 million in 2019, with researchers projecting the state's population will triple by the year 2050.[13]

The most recent national estimate of maternal mortality ratio (MMR) in Nigeria is 917 per 100 000 live births.[1] However, there is no recent state-level MMR estimate. In Lagos State, a ratio as high as 1050 (95% CI 894 to 1215) per 100 000 live births has been reported in one of its urban slums.[14] Institutional MMR between 987 to 2111 per 100 000 live births have also been estimated in Lagos public hospitals. More than one-third of maternal deaths are associated with delayed presentation of pregnant women at facilities.[15]

In Lagos, the most typical mode of transport is by road. However, in many parts of the state, the road infrastructure is poorly maintained, as evidenced by several potholes that sometimes make some roads impassable. Severe traffic congestions are common, with flooding during the rainy season making conditions worse. Road repair works are at best stopgaps and sometimes lead to more travel disruptions.[16–18]

Public health facilities manage more than two-fifths of all births in the state.[19] However, many pregnant women use and indeed prefer public hospitals for many reasons, including the availability of 24/7 care, greater concentration of highly skilled health personnel and equipment and sometimes 'free' or reduced hospital cost.[20] In emergencies, many pregnant women travel to the hospitals without health personnel support.[11] If they require a referral, the Lagos State Ambulance Service occasionally help to transfer pregnant women between public hospitals.[11 19] However, its effectiveness for patient transfer is limited by the traffic congestion and lack of willingness among other commuters to give way to ambulances.[21]

Data sources

Data were extracted from patient records over 6 months by the in-country research team, all of whom were qualified medical doctors, including consultant obstetricians, resident doctors and medical officers who had clinical

experience working in the obstetrical units of the hospitals and were familiar with the patient records system in Lagos public health facilities. All team members were trained on using the pretested online data collection tool and ethical procedures guiding the research.

Participants

In each hospital, we identified and included all pregnant women who presented with an obstetrical emergency, because of themselves or their babies, between 1 November 2018 and 30 October 2019. Women who had an obstetrical emergency while on admission in the hospital were excluded, as their hospital journeys were not deemed critical to the pregnancy outcomes of women or their babies.

Variables

From the case notes, we extracted routinely reported data on socio-demographic characteristics, obstetrical history, travel to the hospital (including the day and period-of-day of travel, street name of women's self-reported address, referring points of care, if any, and the final facility of care), obstetrical complication, mode of birth and pregnancy outcome. These data were collected because they helped us understand key characteristics of each included woman, allowed us to be able to map their journeys in an emergency and establish the outcome of care. All data apart from the pregnancy outcome were treated as dependent variables.

We categorised obstetrical complications in the case notes following WHO's Monitoring EmOC guidelines, which highlights five major complications: obstetrical haemorrhage (antepartum or postpartum haemorrhage), hypertensive disorders in pregnancy (pre-eclampsia or eclampsia), pregnancy-related infections (sepsis), pregnancy with an abortive outcome and prolonged/obstructed labour (online supplemental table S1).[4] We categorised pregnancy complications outside these broad categories, including premature rupture of membranes, oligohydramnios, polyhydramnios, ectopic pregnancy, footling breech, and previous surgical scar, as 'other complications'.

Additional data gathering involving the estimation of driving distance and travel time using Google Maps (Google, Mountain View, California, USA), which offers closer-to-reality estimates compared with other commonly used methods,[22] were required to characterise travel of pregnant women to the hospital fully. To achieve this, we geo-located the place of residence, referral points and destination facility for each woman in the application. For undiscoverable addresses on Google Maps, we contacted persons acquainted with the localities to check for spelling errors and re-attempted to locate the street. In cases where it was impossible to find specific travel points of the women, we labelled the case as untraceable (4% of cases). For those with traceable journeys, we extracted distance (in kilometres (km)) and travel time (in minutes (mins)) from Google Map using its 'typical time of travel' feature for the period-of-day of travel. We used specific time slots to collect travel time estimates for each period (09:00, 15:00, 18:00 and 21:00 for morning, afternoon, evening, or night journeys, respectively). In cases in which we could not tell the period-of-day of travel (33% of cases), travel time was extracted for the afternoon (15:00), as it was a mid-point estimate between the two known travel peak periods in Lagos (06:30 and 11:30 (morning peak period) and 15:00 and 19:30 (evening peak period)).[23] We assumed that all used four-wheeled motor vehicles for travel since these are widely used by pregnant women in emergencies in SSA,[24 25] and alternatives like motorcycles and tricycles had been banned in Lagos at the time of this study.[11 26]

For the dependent variable of maternal death, we aligned with the 10th edition of the International Classification of Diseases which defines maternal mortality as 'the death of a woman while pregnant or within 42 days of termination of pregnancy, irrespective of the duration and site of the pregnancy, from any cause related to or aggravated by the pregnancy or its management, but not from accidental or incidental causes'.[27]

Data analysis

Following data cleaning and validation, we calculated cause-specific case fatality rates and conducted descriptive analysis for pertinent demographic, obstetrical, travel and facility-related variables. In addition, we conducted a comparative analysis of median distances and travel times for pregnant women who travelled directly to the hospital and those referred. We prioritised median values, as these are known to be robust to outliers. We compared median distances and travel times of actual paths to care for referred pregnant women with an assumed scenario if they travelled directly to the hospital. We also compared travel distance and time for various obstetrical complications and types of referral institutions by outcome.

After converting age, travel time and distance into categorical variables, we conducted bivariate logistic regression to test the null hypothesis that there is no association between independent variables and maternal death, presenting crude ORs. By including statistically significant variables and others that have been shown as potential predictors of maternal death but not statistically significant in our analysis, we conducted multivariable logistic regression to determine the relative influence of the independent variables on maternal death while controlling for other variables. We used the Wald test to check if the independent variables in the model were significant. Model 1 incorporated relevant socio-demographic, travel-related and facility-related variables. Model 2A and model 2B are subgroup analyses that stratified model 1 by referral status for non-referred and referred women, respectively, as travel paths to care for both vary (online supplemental table S5). We reported both p values and 95% CIs of adjusted ORs derived from regression coefficients to show the strength of evidence

and considered differences observed as statistically significant when p<0.05. Missing data were excluded from the analysis.

We mapped the location of public hospitals and maternal deaths disaggregated by referral status, using ArcGIS V.10.6 (Esri, Redlands, California, USA). All other analyses were done in Stata SE V.16.1 (StataCorp, College Station, Texas, USA).

Patient and public involvement

Patients and the public were not involved in the design, conduct, reporting or dissemination of this research.

RESULTS

A total of 4181 pregnant women who presented with obstetrical emergencies in Lagos public hospitals were included in the study. Of the total sample, 182 (4.4%) were maternal deaths. Of the maternal deaths, 140 (76.9%) were women who travelled directly to the hospital, the other 40 (23.1%) were referred. Of the maternal deaths who were referred, 17 (40.5%), 10 (23.8%) and 8 (19.1%) were women who first travelled to primary health centres (PHCs), private hospitals and traditional birth attendants (TBAs), respectively. Most maternal deaths occurred in public hospitals based in the suburbs (129 (71.0%)), followed by rural areas (40 (22.0%)). Disaggregated by referral, deaths in both hospitals in the suburbs (94 (72.9%)) and rural areas (35 (87.5%)) were mostly women who travelled directly to a hospital. Cause-specific case fatality rates were 3.3% (pre-eclampsia or eclampsia), 3.5% (haemorrhage), 3.5% (sepsis), 8.8% (ectopic pregnancy), 12.2% (abortion) and 2.6% (other complications).

Maternal deaths involved women who lived across the entire state, with 8 of 182 (4.4%) coming from neighbouring Ogun State. Most maternal deaths occurred in the suburbs of Ajeromi-Ifelodun, Alimosho, Ifako-Ijaiye, Ikorodu, and in rural Badagry. Disaggregated by referral status, most maternal deaths among pregnant women who were referred occurred in suburban Ikorodu. All maternal deaths from rural Epe were referred, all of whom lived within 10 km of the hospital (figure 1).

Among the pregnant women who died, a greater proportion were aged 20–34 years (68.1%), married (86.3%) and self-employed petty traders (44.0%). Most women (93.4%) had no obstetrical complications in previous pregnancies. With the index pregnancy, most were multiparous (42.9%), had a singleton pregnancy (98.9%), were un-booked (ie, not registered for antenatal care (ANC) at the hospital they presented) (94.0%) and presented with abortion requiring evacuation (40.1%). For travel, most of those who died travelled on a weekday (80.8%), travelled afternoon or evening (58.6%) and travelled directly to the facility (76.9%). For those referred, most maternal deaths followed referrals from PHCs (40.5%). Majority presented in non-apex referral hospitals (90.1%), hospitals principally serving suburban areas (69.8%) and non-slum populations (75.8%) (table 1).

For all women, the median distance covered was 7.6 km (IQR 3.4–18.0), and the median travel time was 26 min (IQR 12–50). Pregnant women who travelled from home directly to a hospital travelled a median distance of 6.5 km (IQR 3.0–15.0) and required a median time of 22 min (IQR 11–45). Those who travelled from home to an initial facility before being referred to another travelled a total median distance of 15.6 km (IQR 7.6–30.0) and

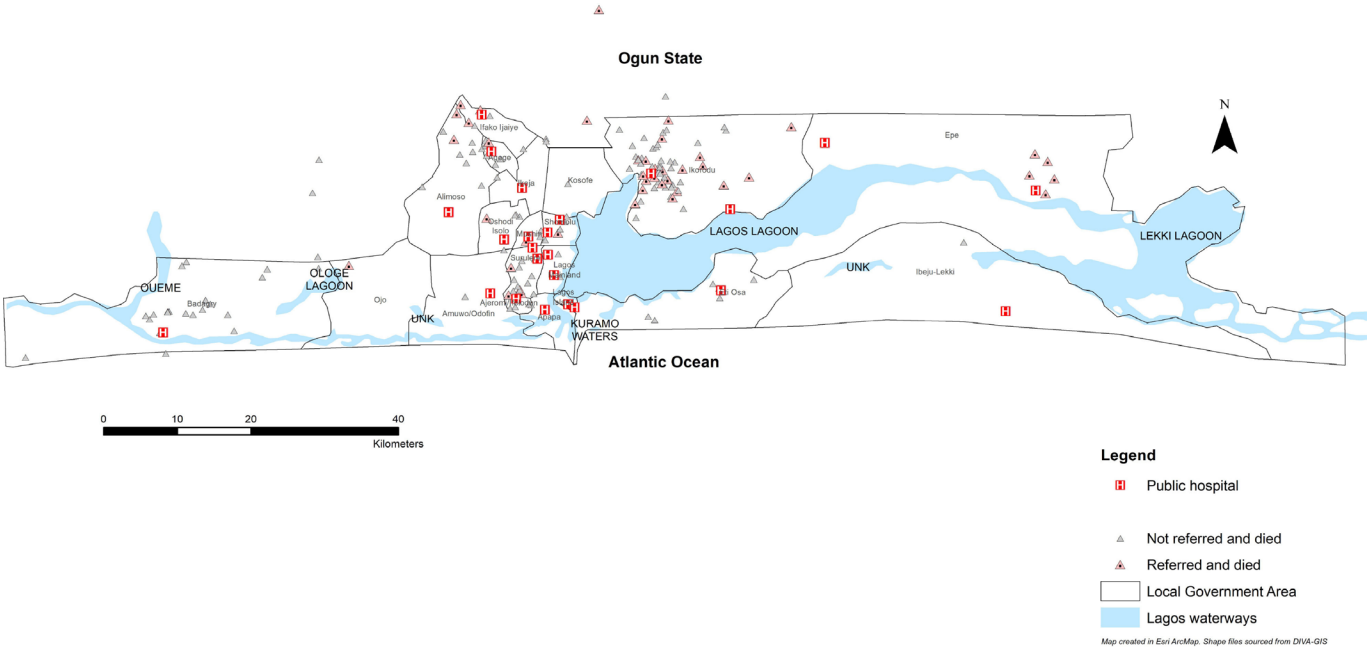

Figure 1 Map of Lagos showing points of origin of referred and non-referred maternal deaths in relation to the location of public hospitals in Lagos.

Table 1 Socio-demographics, obstetrical history and characteristics of the index pregnancy

Characteristics	Number of pregnant women ((%)N=4181)	Number of deaths ((%)n=182)	Number of those alive ((%)n=3999)
Age			
12–19	123 (2.9)	10 (5.5)	113 (2.8)
20–34	3094 (74.0)	124 (68.1)	2970 (74.3)
35–60	964 (23.1)	48 (26.4)	916 (22.9)
Marital status			
Single	304 (7.3)	25 (13.7)	279 (7.0)
Married	3877 (92.7)	157 (86.3)	3720 (93.0)
Employment status			
Unemployed/housewife	721 (17.2)	33 (18.1)	688 (17.2)
Student	274 (6.6)	17 (9.3)	257 (6.4)
Self-employed (petty-trader)	1877 (44.9)	80 (44.0)	1797 (44.9)
Self-employed (mid-high business)	442 (10.6)	17 (9.3)	425 (10.6)
Employed	867 (20.7)	35 (19.2)	832 (20.8)
Obstetric complications in a previous pregnancy			
Yes	733 (17.5)	12 (6.6)	721 (18.0)
No	3448 (82.5)	170 (93.4)	3278 (82.0)
Parity			
Nulliparous (0)	1495 (35.8)	59 (32.4)	1436 (35.9)
Primiparous (1)	1066 (25.5)	40 (22.0)	1026 (25.7)
Multiparous (2–4)	1515 (36.2)	78 (42.9)	1437 (35.9)
Grand-multiparous (5 or more)	105 (2.5)	5 (2.8)	100 (2.5)
Number of gestations			
Singleton	4000 (95.7)	180 (98.9)	3820 (95.5)
Multiple	181 (4.3)	2 (1.1)	179 (4.5)
Booking status			
Booked	1502 (35.9)	11 (6.0)	1491 (37.3)
Unbooked	2679 (64.1)	171 (94.0)	2508 (62.7)
Fetal complications			
No fetal complication, only maternal complication	2748 (65.7)	24 (13.2)	2724 (68.1)
Reduced/absent fetal movement	428 (10.2)	53 (29.1)	375 (9.4)
Intrauterine fetal death	159 (3.8)	10 (5.5)	149 (3.7)
Aborted	846 (20.2)	95 (52.2)	751 (18.8)
Obstetrical complications			
No maternal complication, only fetal complication	145 (3.7)	6 (3.3)	139 (3.5)
Obstructed labour	996 (23.8)	9 (5.0)	987 (24.7)
Haemorrhage	737 (17.6)	26 (14.3)	711 (17.8)
Pre-eclampsia/eclampsia	942 (22.5)	31 (17.0)	911 (22.8)
Sepsis	173 (4.1)	6 (3.3)	167 (4.2)
Abortion	597 (14.3)	73 (40.1)	524 (13.1)
Ectopic pregnancy	249 (6.0)	22 (12.1)	227 (5.7)
Others	342 (8.2)	9 (5.0)	333 (8.3)
Weekend travel to a health facility			
Yes	948 (22.7)	35 (19.2)	913 (22.8)
No	3233 (77.3)	147 (80.8)	3086 (77.2)

Continued

Table 1 Continued

Characteristics	Number of pregnant women ((%)N=4181)	Number of deaths ((%)n=182)	Number of those alive ((%)n=3999)
Period of the day of travel to the facility (n=2813)			
Morning	1021 (36.3)	32 (25.0)	989 (36.8)
Afternoon	751 (26.7)	38 (29.7)	713 (26.6)
Evening	644 (22.9)	37 (28.9)	607 (22.6)
Night	397 (14.1)	21 (16.4)	376 (14.0)
Referral			
Not referred	3143 (75.2)	140 (76.9)	3003 (75.1)
Referred	1037 (24.8)	42 (23.1)	996 (24.9)
The initial point of care for those referred (N=1037)			
Another hospital (public)	164 (15.8)	4 (9.5)	160 (16.1)
Another hospital (private	238 (23.0)	10 (23.8)	228 (22.9)
Clinic (public or private)	79 (7.6)	2 (4.8)	77 (7.7)
Primary health centre	425 (41.0)	17 (40.5)	408 (41.0)
Traditional birth attendant	103 (9.9)	8 (19.1)	95 (9.6)
Nursing/maternity home	6 (0.6)	0 (0.0)	6 (0.6)
Non-formal referral	22 (2.1)	1 (2.4)	21 (2.1)
Mode of birth			
Spontaneous vaginal birth	1240 (29.7)	46 (25.3)	1194 (29.9)
Assisted vaginal birth	151 (3.6)	20 (11.0)	131 (3.3)
Caesarean birth	1944 (46.5)	21 (11.5)	1923 (48.1)
Uterine evacuation	846 (20.2)	95 (52.2)	751 (18.8)
Facility type			
Non-apex referral	3450 (82.5)	164 (90.1)	3286 (82.2)
Apex referral	731 (17.5)	18 (9.9)	713 (17.8)
Principal settlement type served by the hospital			
Urban	858 (20.5)	13 (7.1)	845 (21.1)
Suburban	2332 (55.8)	127 (69.8)	2205 (55.1)
Rural	991 (23.7)	42 (23.1)	949 (23.8)
The majority population type served in the hospital catchment area			
Non-slum	3400 (81.3)	138 (75.8)	3262 (81.6)
Slum	781 (18.7)	44 (24.2)	737 (18.4)

a median time of 54 min (IQR 28–92). Assuming these women had travelled directly to the final facility without being referred, they would have travelled a total median distance of 8.3 km (IQR 3.8–17.2) with a median time of 28 min (IQR 14–55) (figure 2). Women who presented as an emergency with a possible fetal complication and died travelled a longer median distance (16.2 km (IQR 6.8–33.7)) and for a longer time to the hospital (44 min (IQR 28–67)) compared with other complications (online supplemental tables S6a,b). Additionally, women who were referred from PHCs covered the shortest distance from home through the referral to a hospital (13.2 (IQR 6.3–23.8)) while women who were referred from TBAs used the least travel time from home through the referral to reach a hospital (41 mins (IQR 28–58)) (online supplemental table S6c).

Among all the women who died, a larger proportion of them travelled ≤10 km if they came directly from home (60.3%) and arrived at to the hospital ≤30 min (61.9%). For women who were referred and died, 71.4% travelled ≤10 km to the initial facility with 71.5% getting there in ≤30 min, while 65.5% travelled ≤10 km from initial facility to final facility with 72.4% getting there ≤30 min (table 2).

Age, marital status, a complication in a previous pregnancy, number of gestations, booking status, maternal complications, distance and time from home directly to a hospital, total travel time, mode of delivery and principal

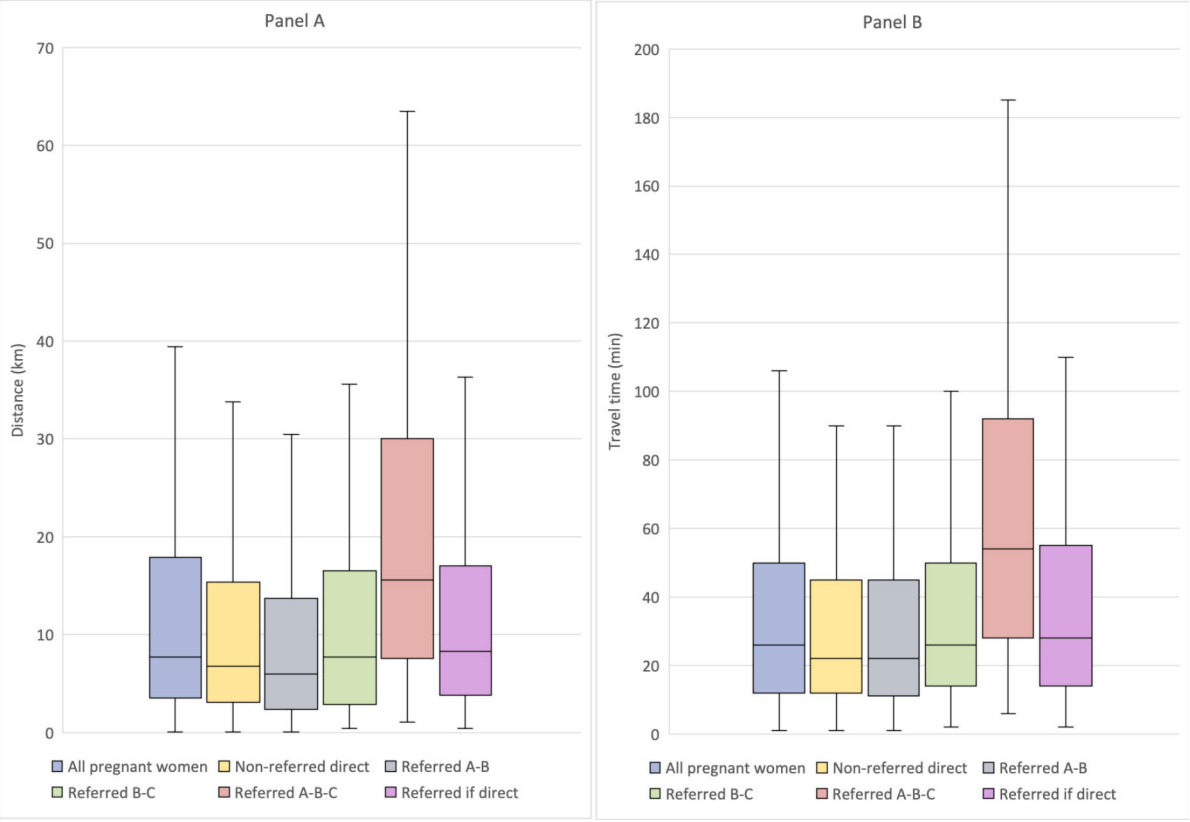

Figure 2 Box and whisker plot displaying distance and travel time to the hospital for pregnant women with traceable journeys. All pregnant women: Complete travel for all women. Non-referred direct: Travel from home directly to a hospital that could provide care. Referred A-B: Travel from home to initial point of care that then referred. Referred B-C: Travel from the initial point of care that then referred to the final facility that could provide care. Referred A-B-C: Total travel for referred women from home through the initial point of care to the final facility. Referred if direct: Total travel for referred women if the journey was tracked from home direct to final facility.

settlement served by the hospital were statistically significant from the bivariate analysis (table 3).

In Model 1, factors that were significantly associated with maternal death were having an obstetrical complication in a previous pregnancy (0.41, 95% CI 0.22 to 0.77), being booked (0.21, 95% CI 0.11 to 0.42), travelling 10–15 km (2.53, 95% CI 1.27 to 5.03) and travelling to a hospital that principally serves suburban (3.60, 95% CI 1.59 to 8.18) and rural areas (2.51, 95% CI 1.01 to 6.29) and delivering via assisted vaginal birth (3.37, 95% CI 1.76 to 6.46) or by caesarean section (0.39, 95% CI 0.22 to 0.71) (table 4).

In Model 2A (subgroup analysis), odds remained statistically significant for those travelling 10–15 km in the non-referred group (2.48, 95% CI 1.18 to 5.23). In addition, odds became statistically significant for those travelling 120–480 min (7.05, 95% CI 1.10 to 45.32). For the referred group (Model 2B), odds became statistically significant for those travelling 25–35 km (21.40, 95% CI 1.24 to 36.72) and >35 km (49.63, 95% CI 2.39 to 103.05). Odds also became statistically significant for those travelling 10–29 min (184.23, 95% CI 5.14 to 608.51), 30–59 min (74.82, 95% CI 3.42 to 163.79) and 60–119 min (13.83, 95% CI 1.11 to 171.51) (online supplemental table S7).

DISCUSSION

This study set out to explore associations between maternal mortality and travel distance and time in Lagos, Nigeria—a geographical area that is Nigeria's most urbanised state and includes SSA's largest megacity. Our findings showed that in such a principally urban SSA setting, the odds of maternal death were significantly higher for all pregnant women with an obstetrical emergency who travelled ≥10–15 km to care. Disaggregated by referral status, similar to all women, those who travelled directly had a higher likelihood of death if they travelled ≥10–15 km to care. As no other study has been conducted in a principally urban SSA setting, there is no comparator to our finding. When a woman is referred, we found that the odds of maternal death significantly increased when ≥25 km was travelled. This aligns with results from studies conducted in rural Guinea-Bissau and Tanzania.[9 10] However, our findings contrast with a previous rural Burkina-Faso study, which concluded that there was no association between maternal mortality and distance.[7] The discord might relate to the fact that this study focused on pregnancy-related deaths and not direct causes of maternal mortality.

Table 2 Description of distance and time to a health facility, by maternal outcome

Characteristics	Total (n (%))	Dead (n (%))	Alive (n (%))
Distance of travel from home directly to a hospital (N=2978*)			
Within 5km	1225 (41.1)	37 (28.2)	1188 (41.7)
5–10 km	704 (23.6)	42 (32.1)	662 (23.2)
>10–15 km	319 (10.7)	24 (18.3)	295 (10.4)
>15–25 km	312 (10.5)	13 (9.9)	299 (10.5)
>25–35 km	192 (6.5)	7 (5.3)	185 (6.5)
>35 km	226 (7.6)	8 (6.1)	218 (7.7)
Distance of travel from home to an initial point of care that then referred (N=611†)			
Within 5 km	283 (46.3)	11 (39.3)	272 (46.7)
5–10 km	120 (19.6)	9 (32.1)	111 (19.0)
>10–15 km	72 (11.8)	4 (14.3)	68 (11.7)
>15–25 km	77 (12.6)	3 (10.7)	74 (12.7)
>25–35 km	29 (4.8)	1 (3.6)	28 (4.8)
>35 km	30 (4.9)	0 (0.0)	30 (5.2)
Distance of travel from an initial point of care to the final facility of care for referred women (N=611†)			
Within 5 km	224 (36.7)	13 (44.8)	211 (36.3)
5–10 km	146 (23.9)	6 (20.7)	140 (24.1)
>10–15 km	76 (12.4)	3 (10.3)	73 (12.5)
>15–25 km	90 (14.7)	3 (10.3)	87 (14.9)
>25–35 km	32 (5.3)	2 (6.9)	30 (5.2)
>35 km	43 (7.0)	2 (6.9)	41 (7.0)
Total traceable distance for all women whose journeys were traceable (N=3590*†‡)			
Within 5 km	1316 (36.7)	41 (25.6)	1275 (37.2)
5–10 km	832 (23.2)	49 (30.6)	783 (22.8)
>10–15 km	395 (11.0)	28 (17.5)	367 (10.7)
>15–25 km	442 (12.3)	19 (11.9)	423 (12.4)
>25–35 km	258 (7.2)	11 (6.9)	247 (7.2)
>35 km	347 (9.7)	12 (7.5)	335 (9.8)
Time of travel from home directly to a hospital (N=2978*)			
0–9 min	617 (20.7)	15 (11.5)	602 (21.2)
10–29 min	1201 (40.3)	66 (50.4)	1135 (39.9)
30–59 min	667 (22.4)	32 (24.4)	635 (22.3)
60–119 min	423 (14.2)	12 (9.2)	411 (14.4)
120–480 min	70 (2.4)	6 (4.6)	64 (2.3)
Time of travel from home to initial facility for referred women (N=611†)			
0–9 min	134 (21.9)	5 (17.9)	129 (22.1)
10–29 min	235 (38.5)	15 (53.6)	220 (37.7)
30–59 min	147 (24.1)	6 (21.4)	141 (24.2)
60–119 min	73 (12.0)	2 (7.1)	71 (12.2)
120–480 min	22 (3.6)	0 (0.0)	22 (3.8)
Time of travel from initial facility to the final facility of care for referred women (N=611†)			
0–9 min	112 (18.4)	4 (13.8)	108 (18.6)
10–29 min	224 (36.5)	17 (58.6)	207 (35.5)
30–59 min	169 (27.6)	5 (17.2)	164 (28.2)
60–119 min	93 (15.2)	3 (10.3)	90 (15.4)

Continued

Table 2 Continued

Characteristics	Total (n (%))	Dead (n (%))	Alive (n (%))
120–480 min	13 (2.3)	0 (0.0)	13 (2.4)
Total traceable time for all women whose journeys were traceable (N=3590*†‡)			
0–9 min	639 (17.8)	15 (9.4)	624 (18.2)
10–29 min	1343 (37.4)	75 (46.9)	1268 (37.0)
30–59 min	844 (23.5)	43 (26.9)	801 (23.4)
60–119 min	609 (17.0)	20 (12.5)	589 (17.2)
120–480 min	155 (4.3)	7 (4.4)	148 (4.3)

*Excludes women whose journey to the facility could not be determined (n=166).
†Excludes women whose referral journey could not be traced (n=415).
‡Excludes 10 missing values.

Disaggregated by referral status, women who travelled directly to the hospital of care in our study had significantly higher odds of maternal death if they travelled ≥120 min. This travel time of statistical significance is lower than findings from a previous rural Mali study which reported a statistically significant association between institutional MMR and travel time only after women had travelled ≥240 min to a hospital.[8] The observed difference might relate to the rural population selected or the method of determining travel time which involved guestimates from hospital workers. In our study, for those referred, odds of maternal death, which were statistically significant, increased appreciably when travel of ≥10 min was required. Keeping in mind that for women who died, over 60% travelled ≤10 km or ≤30 min for both referred and non-referred groups, this significantly increased odds of maternal deaths for women who were referred and travelled ≥10 min. This finding may suggest that they experienced a significant delay in the initial facility before being referred, at which point, so little could be done to improve their odds of survival. In SSA, care delays at referral points have been attributed to long waiting times, lack of skill and shortage of equipment and supplies in health facilities.[6] Also, poor case management involving wrong assessment of risk, diagnosis or treatment has been reported, especially with private facilities and traditional birth attendants.[15]

Though our results support that there is an urban–rural divide, it also shows that even within hospitals situated in suburban areas, the odds of maternal death are even higher than those in the rural areas for all women, irrespective of their referral status. This suggests that there are issues even in the relatively urban–suburban areas. In Lagos, most pregnant women with obstetrical emergencies living in the peripheral rural areas usually travelled to public hospitals around them.[28] In a separate study, we found that travel to care in this settlement type is typically prolonged in the suburbs.[28] This blurring of the so-called 'urban advantage', or at least the 'suburb advantage', may explain the higher odds of maternal death in hospitals situated in the suburbs.

For other factors before and after travel to the hospital, our results showed a maternal death odds-reducing effect of having a previous obstetrical complication, booking and caesarean birth. It might be the case that knowledge and experience gained from previous pregnancies or following booking resulted in comprehensive birth preparedness plans for the index pregnancy, including timely decision to seek care, invariably reducing travel time to a facility.[11] Caesarean birth was 'protective' from maternal death in our study. Contrarily, assisted vaginal birth led to significantly increased odds of maternal death. A clinical audit of these deaths is warranted to understand this association better.

To the best of our knowledge, this is the first study conducted in a principally urban SSA setting that explicitly and comprehensively explored association between travel time, distance and maternal mortality. Our study used driving distance and travel time estimates from Google Maps, which are more reflective of reality, compared with other estimation methods.[22] Previous similar studies used Euclidean (straight-line) distances, assuming the women went to the nearest facility or health worker guestimates of travel time.[7 9 10] However, evidence in the literature queries the realism and accuracy of both approaches to travel time and distance estimates. Women do not always go to the nearest facility, and if they do, their journeys are typically a lot more convoluted than travel in a straight line. Furthermore, since health workers did not make the journeys, they are not likely to make accurate travel time and distance estimates. Even if women themselves were asked, issues of recall bias have been raised by researchers.[28–30] In addition, our study included women with emergencies across the entire pregnancy period and disaggregates by referral status, reflecting the different journeys that women follow to care.[31] These are some of the key strengths of our study.

However, there are some limitations to keep in mind in interpreting our findings. First, while we mapped women's journeys to health facilities based on data reported in their case notes, we cannot be sure that the women took the routes mapped in Google Maps or to other points

Table 3 Bivariate analysis for maternal outcomes

Characteristics	Number of deaths ((%)n=182)	Number of those alive ((%) n=3999)	P value
Age			
12–19	10 (8.1)	113 (91.9)	0.050
20–34	124 (4.0)	2970 (96.0)	
35–60	48 (5.0)	916 (95.0)	
Marital status			
Single	25 (8.2)	279 (91.8)	0.001
Married	157 (4.1)	3, (95.9)	
Employment status			
Unemployed/housewife	33 (4.6)	688 (95.4)	0.581
Student	17 (6.2)	257 (93.8)	
Self-employed (petty-trader)	80 (4.3)	1797 (95.7)	
Self-employed (mid-high business)	17 (3.9)	425 (96.1)	
Employed	35 (4.0)	832 (96.0)	
Obstetric complications in a previous pregnancy			
Yes	12 (1.6)	721 (98.4)	<0.001
No	170 (4.9)	3278 (95.1)	
Parity			
Nulliparous (0)	59 (4.0)	1436 (96.0)	0.277
Primiparous (1)	40 (3.8)	1026 (96.2)	
Multiparous (2–4)	78 (5.2)	1437 (94.2)	
Grand-multiparous (5 or more)	5 (4.8)	100 (95.2)	
Number of gestations			
Singleton	180 (4.5)	3820 (95.5)	0.029
Multiple	2 (1.1)	179 (98.9)	
Booking status			
Booked	11 (0.7)	1491 (99.3)	<0.001
Un-booked	171 (6.4)	2508 (93.6)	
Maternal complications			
No maternal complication, only fetal complication	6 (4.1)	139 (95.9)	<0.001
Obstructed labour	9 (0.9)	987 (99.1)	
Haemorrhage	26 (3.5)	711 (96.5)	
Pre-eclampsia/eclampsia	31 (3.3)	911 (96.7)	
Sepsis	6 (3.5)	167 (96.5)	
Abortion	73 (12.2)	524 (87.8)	
Ectopic pregnancy	22 (8.8)	227 (91.2)	
Others	9 (2.6)	333 (97.4)	
Weekend travel to a facility			
Yes	35 (3.7)	913 (96.3)	0.257
No	147 (4.5)	3086 (95.5)	
Period of the day of travel to the facility (n=2813)			
Morning	32 (3.1)	989 (96.9)	0.063
Afternoon	38 (5.1)	713 (94.9)	
Evening	37 (5.8)	607 (94.2)	
Night	21 (5.3)	376 (94.7)	
Referral			

Continued

Table 3 Continued

Characteristics	Number of deaths ((%)n=182)	Number of those alive ((%) n=3999)	P value
Not referred	140 (4.5)	3003 (95.5)	0.576
Referred	42 (4.1)	996 (95.9)	
Distance of travel from home directly to a hospital (N=2978*)			
Within 5 km	37 (3.0)	1188 (97.0)	0.003
5–10 km	42 (6.0)	662 (94.0)	
>10–15 km	24 (7.5)	295 (92.5)	
>15–25 km	13 (4.2)	299 (95.8)	
>25–35 km	7 (3.7)	185 (96.3)	
>35 km	8 (3.5)	218 (96.5)	
Distance of travel from home to initial facility for referred women (N=611†)			
Within 5 km	11 (3.9)	272 (96.1)	0.491
5–10 km	9 (7.5)	111 (92.5)	
>10–15 km	4 (5.6)	68 (94.4)	
>15–25 km	3 (3.9)	74 (96.1)	
>25–35 km	1 (3.5)	28 (96.5)	
>35 km	0 (0.0)	30 (100.0)	
Distance of travel from initial facility to the final facility of care for referred women (N=611†)			
Within 5 km	13 (5.8)	211 (94.2)	0.933
5–10 km	6 (4.1)	140 (95.9)	
>10–15 km	3 (3.9)	73 (96.1)	
>15–25 km	3 (3.3)	87 (96.7)	
>25–35 km	2 (6.1)	30 (93.9)	
>35 km	2 (4.6)	41 (95.4)	
Total traceable distance for all women whose journeys were traceable (N=3590*†‡)			
Within 5 km	41 (3.1)	1275 (96.9)	0.005
5–10 km	49 (5.9)	782 (94.1)	
>10–15 km	28 (7.1)	367 (95.7)	
>15–25 km	19 (4.3)	423 (95.7)	
>25–35 km	11 (4.3)	247 (95.7)	
>35 km	12 (3.5)	335 (96.5)	
Time of travel from home directly to a hospital (N=2978*)			
0–9 min	15 (2.4)	602 (97.6)	0.005
10–29 min	66 (5.5)	1135 (94.5)	
30–59 min	32 (4.8)	635 (95.2)	
60–119 min	12 (2.8)	411 (97.2)	
120–480 min	6 (8.6)	64 (91.4)	
Time of travel from home to initial facility for referred women (N=611†)			
0–9 min	5 (3.7)	129 (96.3)	0.452
10–29 min	15 (6.4)	220 (93.6)	
30–59 min	6 (4.1)	141 (95.9)	
60–119 min	2 (2.7)	71 (97.3)	
120–480 min	0 (0.0)	22 (100.0)	
Time of travel from initial facility to the final facility of care for referred women (N=611†)			
0–9 min	4 (3.6)	108 (96.4)	0.151
10–29 min	17 (7.6)	207 (92.4)	
30–59 min	5 (2.9)	164 (97.1)	

Continued

Table 3 Continued

Characteristics	Number of deaths ((%)n=182)	Number of those alive ((%) n=3999)	P value
60–119 min	3 (3.2)	90 (96.8)	
120–480 min	0 (0.0)	13 (100.0)	
Total travel time for all women whose journeys were traceable (N=3590*†‡)			
0–9 min	15 (2.3)	624 (97.7)	0.009
10–29 min	75 (5.6)	1268 (94.4)	
30–59 min	43 (5.1)	801 (94.9)	
60–119 min	20 (3.3)	589 (96.7)	
120–480 min	7 (4.5)	148 (95.5)	
Mode of birth			
Spontaneous vaginal birth	46 (3.7)	1194 (96.3)	<0.001
Assisted vaginal birth	20 (13.2)	131 (86.8)	
Caesarean birth	21 (1.1)	1923 (98.9)	
Uterine evacuation	95 (11.2)	751 (88.8)	
Facility type			
Non-apex referral	164 (4.8)	3286 (95.2)	0.006
Apex referral	18 (2.5)	713 (97.5)	
Principal settlement type served by the hospital			
Urban	13 (1.5)	845 (98.5)	<0.001
Suburban	127 (5.5)	2205 (94.5)	
Rural	42 (4.2)	949 (95.8)	
The majority population type served in the hospital catchment area			
Non-slum	138 (4.1)	3262 (95.9)	0.052
Slum	44 (5.6)	737 (94.4)	

Educational level attained was excluded as the level of missingness was too high for computation in the model. Fetal complication was excluded as it does not influence the outcome of this study. Type of referral facility was also excluded, as this variable was not relevant to the entire sample.
*Excludes women whose journey to the facility could not be determined (n=166).
†Excludes women whose referral journey could not be traced (n=415).
‡Excludes 10 missing values.

of care not reported. Second, though Google Maps has been shown to provide closer-to-reality estimates of travel time and distance, it is still not perfect reality, especially in rural and remote areas.[22] However, as already established, our setting for this research is principally urban, where networks of tarred roads allow for improved accuracy with Google Maps.[32 33] Third, while we collected data for a year and accounted for diurnal variations using Google Maps, we could not account for seasonal variations, as this is not a functionality that is presently available on the application. Also, we have not captured the time women could have spent deciding to seek care (delay I). In addition, we did not have data reflecting the time between presentation at the hospital and the initiation of care or referral, as needed (delay III). Though these delays all contribute to maternal death,[6] they would have occurred for both referred and non-referred women. As such, it does not significantly influence our findings. Additionally, we have not included private hospitals as endpoints of care, although public hospitals are recognised as the cornerstone for EmOC in SSA.[34] Moreover, we could not fully capture women's socio-economic and educational characteristics, which are also essential factors that influence access to care. However, both data are not routinely reported inpatient records in many SSA health systems.[35] Furthermore, being a facility-based study, our study does not include pregnant women who died in transit. Finally, we observed wide CIs around the travel time and distance estimates for referred women. However, these wide intervals do not alter the validity of our findings, as it relates more to the absolute number of maternal deaths than the sample size.[36] In any case, our conclusion regarding the association between travel time and distance and maternal death remains true across the interval. Considering this limitation, while recognising that maternal deaths remain a rare event in Africa,[37] larger-scale research that includes more maternal death events, especially among women referred to care, is warranted for future research.

There are some implications for policy and practice for SSA health systems, as our study was conducted in the largest metropolis of the subregion. Before travel is even warranted for an emergency, engaging with ANC early in the pregnancy remains pivotal for optimising

Table 4 Logistic regression showing association between maternal death and the selected independent variables

Factor	Unadjusted (95% CI)	Adjusted—Model 1 (95% CI)
Age		
12–19	2.12 (1.08 to 4.15)*	1.50 (0.62 to 3.63)
20–34	1.00	1.00
35–60	1.25 (0.89 to 1.76)	1.30 (0.88 to 1.92)
Marital status		
Single	2.12 (1.37 to 3.29)**	0.89 (0.49 to 1.61)
Married	1.00	1.00
Obstetrical complications in a previous pregnancy		
No	1.00	1.00
Yes	0.32 (0.18 to 0.58)***	0.41 (0.22 to 0.77)**
Booking status at the hospital of care		
Un-booked	1.00	1.00
Booked	0.11 (0.06 to 0.20)***	0.21 (0.11 to 0.42)***
Maternal complications		
No maternal complication, only fetal complication	1.00	1.00
Obstructed labour	0.21 (0.74 to 0.60)**	0.28 (0.09 to 0.89)*
Haemorrhage	0.85 (0.34 to 2.09)	0.68 (0.26 to 1.79)
Hypertension	0.79 (0.32 to 1.92)	0.76 (0.29 to 1.98)
Sepsis	0.83 (0.26 to 2.64)	0.79 (0.22 to 2.79)
Abortion	3.23 (1.38 to 7.57)**	1.90 (0.74 to 4.87)
Ectopic pregnancy	2.25 (0.89 to 5.67)	1.30 (0.47 to 3.60)
Others	0.63 (0.22 to 1.79)	0.84 (0.27 to 2.60)
Mode of birth		
Spontaneous vaginal birth	1.00	1.00
Assisted vaginal birth	3.96 (2.27 to 6.90)***	3.37 (1.76 to 6.46)***
Caesarean birth	0.28 (0.17 to 0.47)***	0.39 (0.22 to 0.71)**
Uterine evacuation	3.28 (2.28 to 4.72)***	(omitted)
Referral		
Travel from home/other location initial facility	1.00	1.00
Referred from initial facility to final facility	0.90 (0.64 to 1.29)	1.09 (0.67 to 1.77)
Total traceable distance for all women whose journeys were traceable (N=3590†‡§)		
Within 5 km	1.00	1.00
5–10 km	1.95 (1.27 to 2.98)**	1.56 (0.93 to 2.62)
>10–15 km	2.37 (1.45 to 3.89)**	2.53 (1.27 to 5.03)**
>15–25 km	1.39 (0.80 to 2.43)	1.74 (0.74 to 4.09)
>25–35 km	1.38 (0.70 to 2.73)	1.99 (0.67 to 5.91)
>35 km	1.11 (0.58 to 2.14)	1.58 (0.42 to 5.85)
Total traceable time for all women whose journeys were traceable (N=3590†‡¶)		
0–9 min	1.00	1.00
10–29 min	2.46 (1.40 to 4.32)**	1.58 (0.81 to 3.09)
30–59 min	2.23 (1.23 to 4.06)**	1.10 (0.46 to 2.63)
60–119 min	1.41 (0.72 to 2.79)	0.79 (0.25 to 2.50)
120–480 min	1.97 (0.79 to 4.91)	1.39 (0.28 to 6.85)
Facility type		
Non-apex referral	1.98 (1.21 to 3.24)**	0.79 (0.38 to 1.65)
Apex referral	1.00	1.00

Continued

Table 4 Continued

Factor	Unadjusted (95% CI)	Adjusted—Model 1 (95% CI)
Principal settlement type served by the hospital		
Urban	1.00	1.00
Suburban	3.74 (2.10 to 6.66)***	3.60 (1.59 to 8.18)**
Rural	2.88 (1.54 to 5.40)***	2.51 (1.01 to 6.29)*
The majority population type served in the hospital catchment area		
Non-slum	1.00	1.00
Slum	1.41 (1.00 to 2.00)*	1.53 (0.99 to 2.34)

Model description: Model 1: adjusted for all variables in the model including socio-demographic, distance and time of travel as well as facility characteristics for all women whose journey from home to the hospital could be traced, Model 2A: subgroup analysis for all women who travelled from home directly to a health facility, Model 2B: subgroup analysis for all women who were referred in their journey from home to a health facility.
***p≤0.001; **p≤0.010; *p≤0.050.
†Excludes 10 missing values.
‡Excludes women whose referral journey could not be traced (n=415).
§Excludes women whose journey to a hospital could not be determined (n=166).

pregnancy outcomes. Skilled health personnel need to discuss danger signs, hospitals with the capacity to manage specific emergencies should they arise and travel plans with couples as part of birth preparedness. In addition to other points, this discussion should highlight the urgency of travel straight to a hospital for women even if they are only concerned about the health of their unborn child. Furthermore, negative experiences of health facility delivery that cause women to bypass nearer facilities in emergency to travel further need to be minimised.[11 38] Efforts also need to be geared to reduce intrafacility delays at referring points of care to minimise maternal deaths among referred women. For governments, it is not enough to say health facilities have been 'strategically placed',[39] facility location needs to be evidence-based. Planning geographical distribution of health facilities needs to ensure a functional health facility within 10 km of every woman and a robust referral system supported by patient transfer services to public hospitals. Some authors have suggested that the way forward to achieve the SDGs is to focus on hospital-level care instead of PHCs.[40] Recognising concerns with costs associated with building new hospitals and the need for such investments to demonstrate value for money and be sustainable,[41–43] we argue that close-to-community PHCs need to remain the fulcrum for SSA health systems. Sufficient training should be conducted with PHC health workers to help them better recognise complications, resuscitate and refer promptly.[44] Any such capacity-building intervention for PHCs and private sector facilities needs to particularly focus management of abortion, which had the highest cause-specific case fatality rate in our study. As an alternative, governments in principally urban SSA settings should establish partnerships with quality-assured private providers who can be integrated into the EmOC referral network. This will be particularly crucial as private providers manage between 5% (Lusaka) and 64% (Lagos) of facility births in urban SSA settings.[45] In addition, as every minute counts for the mother and her unborn child,[46] ambulance services within the referral network need to be fully optimised to transfer women with obstetrical emergencies efficiently and effectively to hospitals that can manage them. This transfer should also be done at no cost to them, as many women already find the cost of care too high.[47] For those travelling from their homes, access should not be a choice between 'too far' or 'too poor' to afford travel to an appropriate facility.[48] In responding, governments also need to recognise that suburban might be the new rural and should therefore address access issues in the suburbs.

At a global level, our finding of statistical significance at a travel time of 120 min for pregnant women travelling directly to a hospital with the capacity to provide the care needed partly supports the applicability of the globally agreed benchmark of 2-hour travel.[49] However, with many maternal deaths involving women who travelled less than an hour, there is a need to expand these guidelines to reflect delays permissible at referring facilities, recognising that women still face a median additional time of an hour even if they make it to hospitals that can provide the care needed.[50]

CONCLUSION

In conclusion, distance and travel time influence maternal outcomes following pregnancy and childbirth in different ways for women who are referred and those not. Leaving no one behind in achieving global targets of 2-hour travel to a hospital with the capacity to provide essential anaesthesia and surgical services, including caesarean for 80% of the population by 2030,[3 49] will require more research like ours replicated in the many sprawling urban areas of SSA, rethinking of global EmOC geographical access guidelines and bold actions to get women closer and quicker to functional health facilities.

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Supplement to: Travel of pregnant women in emergency situations to hospital and maternal mortality in Lagos, Nigeria: a retrospective cohort study

Definitions

Table S1: Definitions of terms used in the study

Terminology	Definition and source
Maternal death	the death of a woman while pregnant or within 42 days of termination of pregnancy, irrespective of the duration and the site of the pregnancy, from any cause related to or aggravated by the pregnancy or its management, but not from accidental or incidental causes World Health Organization https://www.who.int/classifications/icd/ICD10Volume2_en_2010.pdf
Emergency obstetric care (EmOC)	These are services rendered for the treatment of complications that arise during pregnancy and childbirth.
Maternal complications	
No maternal complication	Women who had no complication of their own but complications with their fetus(es) was the reason they presented with an obstetric emergency
Obstructed labour	Prolonged or obstructed labour (dystocia, abnormal labour) (any of the following) • prolonged established first stage of labour (> 12 h) • prolonged second stage of labour (>1h) • cephalo-pelvic disproportion, including scarred uterus •malpresentation: transverse, brow or face presentation WHO, UNFPA, UNICEF https://apps.who.int/iris/bitstream/handle/10665/44121/9789241547734_eng.pdf?sequence=1&isAllowed=y
Haemorrhage (ante-partum and post-partum)	Antepartum: severe bleeding before and during labour: placenta praevia, placental abruption Postpartum: (any of the following) • bleeding that requires treatment (e.g., provision of intravenous fluids, uterotonic drugs or blood) • retained placenta • severe bleeding from lacerations (vaginal or cervical) • vaginal bleeding more than 500 ml after childbirth • more than one pad soaked in blood in 5 minutes WHO, UNFPA, UNICEF https://apps.who.int/iris/bitstream/handle/10665/44121/9789241547734_eng.pdf?sequence=1&isAllowed=y
Pre-eclampsia/eclampsia	Severe pre-eclampsia: Diastolic blood pressure ≥ 110 mm Hg or proteinuria ≥ 3 after 20 weeks' gestation. Various signs and symptoms: headache, hyperflexia, blurred vision, oliguria, epigastric pain, pulmonary oedema Eclampsia: Convulsions; diastolic blood pressure ≥ 90 mm Hg after 20 weeks' gestation or proteinuria ≥ 2. Signs and symptoms of severe pre-eclampsia may be present WHO, UNFPA, UNICEF https://apps.who.int/iris/bitstream/handle/10665/44121/9789241547734_eng.pdf?sequence=1&isAllowed=y

Sepsis	A temperature of 38°C or higher more than 24h after delivery (with at least two readings, as labour alone can cause some fever) and any one of the following signs and symptoms: lower abdominal pain, purulent, offensive vaginal discharge (lochia), tender uterus, uterus not well contracted, history of heavy vaginal bleeding. (Rule out malaria) WHO, UNFPA, UNICEF https://apps.who.int/iris/bitstream/handle/10665/44121/9789241547734_eng.pdf?sequence=1&isAllowed=y
Abortion	Abortion in our study include voluntary and spontaneous abortions of all forms (missed abortions, inevitable miscarriage and incomplete miscarriage). Voluntary abortion refers to an intervention to terminate an unwanted, mistimed, or unplanned pregnancy. The persons, skills and medical standards considered safe in the provision of abortion are different for medical and surgical abortion and depend on the duration of the pregnancy. https://www.gfmer.ch/SRH-Course-2018/adolescent-health/pdf/WHO-compilation-tool-abortion-section-2018.pdf
Ectopic pregnancy	Internal bleeding from a pregnancy outside the uterus; lower abdominal pain and shock possible from internal bleeding; delayed menses or positive pregnancy test WHO, UNFPA, UNICEF https://apps.who.int/iris/bitstream/handle/10665/44121/9789241547734_eng.pdf?sequence=1&isAllowed=y
Ruptured Uterus	Uterine rupture with a history of prolonged or obstructed labour when uterine contractions suddenly stopped. Painful abdomen (pain may decrease after rupture of uterus). Patient may be in shock from internal or vaginal bleeding WHO, UNFPA, UNICEF https://apps.who.int/iris/bitstream/handle/10665/44121/9789241547734_eng.pdf?sequence=1&isAllowed=y
Others	This includes premature rupture of membranes, oligohydramnios, retained placenta, malpresentation and malposition at term, previous caesarean section, post-dated pregnancies, anaemia in pregnancy and non-obstetric complications (cardiomyopathy in pregnancy, gestational diabetes, asthma in pregnancy) and any other recorded complication that did not fit into the categorized complications above.
Other variables	
Booked at hospital of care	Clinical records indicating that patient was booked for antenatal care at facility where patient gave birth and records were retrieved on travel to delivery care.
Referral	a process in which a health worker at a level of the health system (initiating facility), having insufficient resources (drugs, equipment, skills) to manage a clinical condition, seeks the assistance of a better or differently resourced facility at the same or higher level (receiving facility) to assist in, or take over the management of, the client's case. WHO https://www.who.int/management/Referralnotes.doc
Initial point of care	This is the initial provider of care, which could have been another hospital (public), another hospital (private), clinic (public or private), primary health centre, traditional birth attendant, nursing/maternity home or some non-formal referral

b

Table S2a: Components/Signal Functions of Comprehensive Emergency Obstetric Care

S/No.	Signal function
1.	Administer parenteral antibiotics
2.	Administer parenteral uterotonic drugs (i.e., parenteral oxytocin)
3	Administer anticonvulsants (i.e., magnesium sulphate)
4	Manual removal of placenta
5	Removal of retained products (e.g., manual vacuum extraction or dilation and curettage)
6	Perform assisted vaginal delivery (e.g., vacuum extraction or forceps delivery)
7	Perform basic neonatal resuscitation (e.g., with bag and mask)
8	Perform surgery (e.g., caesarean section)
9	Perform blood transfusion

Note: 1-7 are basic services, 8-9 are comprehensive services. A Comprehensive Emergency Obstetric Care facility is one that performs all nine signal functions.

Table S2b: Components/Signal Functions and related obstetric complications

Major obstetric complication	Signal Function
Haemorrhage	*Antepartum:*
	Perform blood transfusion
	Perform surgery (e.g., caesarean for placenta praevia)
	Postpartum:
	Administer uterotonic drugs
	Perform blood transfusion
	Perform manual removal of placenta
	Perform removal of retained products
	Perform surgery (hysterectomy) for uterine rupture
Prolonged or obstructed labour	Perform assisted vaginal delivery
	Perform surgery (caesarean section)
	Administer uterotonic drugs
	Perform neonatal resuscitation
Postpartum sepsis	Administer parenteral antibiotics
	Remove retained products
	Perform surgery for pelvic abscess
Complications of abortion	*For haemorrhage:*
	Perform blood transfusion
	Remove retained products
	For sepsis:
	Administer parenteral antibiotics
	Remove retained products
	For intra-abdominal injury:
	Administer parenteral antibiotics
	Perform blood transfusion
Pre-eclampsia or eclampsia	Administer parenteral anticonvulsants
	Perform neonatal resuscitation
	Perform surgery (caesarean section)
Ectopic pregnancy	Perform surgery
	Perform blood transfusion
Ruptured uterus	Perform surgery
	Perform blood transfusion
	Administer parenteral antibiotics
Newborn distress (intrapartum)	Perform newborn resuscitation
	Perform surgery (caesarean)

Source: WHO, UNFPA, UNICEF
https://apps.who.int/iris/bitstream/handle/10665/44121/9789241547734_eng.pdf?sequence=1&isAllowed=y

c

Table S3: Geographical characteristics of area principally served by public hospitals offering comprehensive EmOC in Lagos State

S/N	Facility name	Local Government Area	Population density	Water body	Settlement type	Slum population	Access to facility
1	Agbowa General Hospital	Epe	Sparse	No	Town	Non-slum	Easy
2	Ajeromi Ifelodun General Hospital	Ajeromi-Ifelodun	Dense	No	Suburb	Slum	Difficult
3	Alimosho General Hospital	Alimosho	Dense	No	Suburb	Non-slum	Difficult
4	Amuwo-Odofin MCC	Amuwo-odofin	Dense	Yes	Suburb	Non-slum	Easy
5	Apapa General Hospital	Apapa	Sparse	No	Suburb	Non-slum	Difficult
6	Badagry General Hospital	Badagry	Sparse	Yes	Town	Non-slum	Easy
7	Epe General Hospital	Epe	Sparse	Yes	Town	Non-slum	Easy
8	Eti-Osa MCC*	Eti-Osa	Sparse	Yes	Suburb	Non-slum	Easy
9	FMC Ebute-Metta	Lagos Mainland	Dense	No	Suburb	Non-slum	Difficult
10	Gbagada General Hospital	Somolu	Dense	No	Suburb	Non-slum	Easy
11	Harvey Road Health Centre	Mainland	Dense	No	Suburb	Non-slum	Easy
12	Ibeju-Lekki General Hospital	Ibeju-Lekki	Sparse	Yes	Town	Non-slum	Easy
13	Ifako-Ijaiye MCC	Ifako-Ijaiye	Dense	No	Suburb	Non-slum	Easy
14	Ijede Health Care Centre	Ikorodu	Sparse	No	Town	Non-slum	Easy
15	Ikorodu MCC	Ikorodu	Sparse	Yes	Town	Non-slum	Easy
16	Institute of Maternal and Child Health - Àyìnkę House*	Ikeja	Dense	No	Suburb	Non-slum	Easy
17	Isolo MCC	Oshodi-Isolo	Sparse	No	Suburb	Non-slum	Easy
18	Lagos Island Maternity Hospital	Lagos Island	Very dense	No	City	Non-slum	Easy
19	Lagos University Teaching Hospital	Mushin	Very dense	No	City	Non-slum	Easy
20	Mushin General Hospital	Mushin	Very dense	No	Suburb	Slum	Easy
21	Onikan Health Care Centre	Lagos Island	Very dense	No	Suburb	Slum	Easy
22	Orile Agege General Hospital	Agege	Dense	No	City	Non-slum	Easy
23	Randle General Hospital (Gbaja-Surulere MCC)	Surulere	Dense	No	Suburb	Slum	Easy
24	Somolu General Hospital	Somolu	Dense	No	Suburb	Non-slum	Easy

Note: Facilities in towns are in the rural parts of Lagos. Those situated in suburbs and the city are in the urban parts of Lagos (Lagos metropolis).

d

Table S4: Location and service characteristics of public hospitals offering comprehensive EmOC in Lagos State

S/N	Facility name	Latitude (x)	Longitude (y)	Facility type	Type of referral facility	Year of establishment	Number of deliveries in 2018
1	Agbowa General Hospital	6.645643	3.712914	General Hospital	Non-apex referral	2003	157
2	Ajeromi Ifelodun General Hospital	6.455283	3.33362	Maternal and Childcare Centre	Non-apex referral	1983	825
3	Alimosho General Hospital	6.561196	3.250662	Maternal and Childcare Centre	Non-apex referral	2006	2,484
4	Amuwo-Odofin MCC	6.461779	3.301963	Maternal and Childcare Centre	Non-apex referral	2014	2,484
5	Apapa General Hospital	6.441943	3.368962	General Hospital	Non-apex referral	1964	120
6	Badagry General Hospital	6.413752	2.900374	General Hospital	Non-apex referral	1957	973
7	Epe General Hospital	6.586945	3.971665	General Hospital	Non-apex referral	1954	883
8	Eti-Osa MCC*	6.465421	3.585173	Maternal and Childcare Centre	Non-apex referral	2019	-
9	FMC Ebute-Metta	6.484271	3.380194	Tertiary Hospital	Apex Referral	1964	890
10	Gbagada General Hospital	6.551919	3.387304	General Hospital	Non-apex referral	1983	1,729
11	Harvey Road Health Centre	6.50935	3.372629	General Hospital	Non-apex referral	1962	717
12	Ibeju-Lekki General Hospital	6.439312	3.934335	General Hospital	Non-apex referral	2006	982
13	Ifako-Ijaiye MCC	6.680364	3.291382	Maternal and Childcare Centre	Non-apex referral	2006	2,916
14	Ijede Health Care Centre	6.564649	3.596596	General Hospital	Non-apex referral	1983	869
15	Ikorodu MCC	6.608265	3.499394	Maternal and Childcare Centre	Non-apex referral	1983	2,820
16	Institute of Maternal and Child Health - Àyìnkę House*	6.590868	3.34092	Tertiary Hospital	Apex Referral	1955	-
17	Isolo MCC	6.527787	3.318979	Maternal and Childcare Centre	Non-apex referral	1975	2,147
18	Lagos Island Maternity Hospital	6.448543	3.397417	Tertiary Hospital	Apex Referral	1960	3,681
19	Lagos University Teaching Hospital	6.517803	3.353786	Tertiary Hospital	Apex Referral	1962	2,011
20	Mushin General Hospital	6.531566	3.348531	General Hospital	Non-apex referral	1954	524
21	Onikan Health Care Centre	6.444656	3.405436	General Hospital	Non-apex referral	1971	544
22	Orile Agege General Hospital	6.635353	3.303379	General Hospital	Non-apex referral	1982	1,677
23	Randle General Hospital (Gbaja-Surulere MCC)	6.50433	3.359574	Maternal and Childcare Centre	Non-apex referral	1960	2,056
24	Somolu General Hospital	6.536461	3.372251	General Hospital	Non-apex referral	2006	619

*Facilities not running in 2018. As such no details available on number of deliveries.

e

Table S5: Full description of models

Model	Description
Model 1	This model includes socio-demographic factors, pregnancy related factors, distance and time variables, and variables describing characteristics of facility of birth. Each variable in the model was adjusted for by all other variables in the same model.
Model 2 A (Sub-group analysis of women who travelled from home directly to a health facility)	This model is restricted to all women who travelled directly from home to a health facility and includes socio-demographic factors, pregnancy related factors, distance and time variables, and variables describing characteristics of facility of birth. Each variable in the model was adjusted for by all other variables in the same model.
Model 2 B (Sub-group analysis of women who were referred to a health facility)	This model is restricted to all women who were referred in their journey from home to a health facility and includes socio-demographic factors, pregnancy related factors, distance and time variables, and variables describing characteristics of facility of birth. Each variable in the model was adjusted for by all other variables in the same model.

Table S6a: Distance in kilometres by maternal outcome and obstetric complication for mothers with traceable journeys

Variable	N	Total (N=3,590)		Mother alive (n=3,430)		Mother dead (n=160)	
Obstetric complication		**Median (IQR)**	**Mean**	**Median (IQR)**	**Mean**	**Median (IQR)**	**Mean**
All women	3,590			7.6 (3.4, 18)	13.7	8.3 (5.0, 16.6)	13.9
No maternal complications	122	7.2 (3.5, 20.7)	15.7	7.0 (3.2, 20.7)	15.3	16.2 (6.8, 33.7)	23.3
Prolonged/obstructed labour	883	6.0 (2.9, 15.0)	12.0	6.0 (2.9, 15.0)	12.0	10.2 (2.6, 22.4)	11.9
Ante-partum/post-partum haemorrhage	604	8.5 (4.1, 18.5)	14.2	8.5 (4.1, 19.0)	14.4	8.4 (4.3, 14.1)	10.5
Pre-eclampsia/Eclampsia	802	8.4 (3.9, 20.4)	15.3	8.5 (3.8, 20.6)	15.4	7.7 (4.9, 14.8)	12.9
Sepsis	145	5.8 (2.5, 13.4)	11.1	5.5 (2.4, 13.3)	10.8	7.8 (7.3, 22.1)	19.2
Abortion	535	7.4 (3.4, 16.0)	12.2	7.4 (3.2, 16.0)	12.0	7.7 (4.8, 18.9)	14.4
Ectopic pregnancy	209	9.3 (4.7, 21.0)	15.1	8.9 (4.7, 20.7)	14.9	12.1 (6.2, 23.9)	16.1
Others	290	8.7 (3.9, 21.4)	15.4	8.7 (3.8, 21.7)	15.5	6.9 (5.6, 11.5)	9.3

Table S6b: Time in minutes by maternal outcome and obstetric complication for mothers with traceable journeys

Variable	**N**	**Total (N=3,590)**		**Mother alive (n=3,430)**		**Mother dead (n=160)**	
		Median (IQR)	**Mean**	**Median (IQR)**	**Mean**	**Median (IQR)**	**Mean**
All women	3,590			26 (12, 51)	38.6	28 (17, 43)	37.5
No maternal complication	122	30 (12, 65)	47.5	30 (12, 65)	46.5	44 (28, 67)	66.2
Prolonged/obstructed labour	883	20 (10, 45)	33.0	20 (10, 45)	33.0	30 (9, 61)	36.8
Ante-partum/post-partum haemorrhage	604	27 (14, 55)	39.3	27 (14, 55)	39.6	28 (18, 46)	32.9
Pre-eclampsia/Eclampsia	802	30 (14, 58)	43.7	30 (14, 60)	44.0	24 (16, 38)	34.6
Sepsis	145	20 (9, 45)	31.7	19 (8, 45)	31.2	28 (26, 45)	40.4
Abortion	535	24 (12, 45)	34.3	23 (11, 45)	33.8	28 (16, 43)	37.8
Ectopic pregnancy	209	30 (16, 55)	43.3	30 (16, 55)	43.6	29 (18, 53)	40.9
Others	290	30 (14, 58)	43.6	30 (14, 60)	44.2	21 (17, 30)	23.5

Table S6c: Distance in kilometres and time of travel in min to facility of care by facility of referral for all mothers with traceable journeys

Variable	N	Distance travelled		Time of travel	
Facility type		**Median (IQR)**	**Mean**	**Median (IQR)**	**Mean**
All women referred	612	15.6 (7.6 – 29.7)	23.1	54 (28 – 91)	68.0
Another hospital (public)	143	23.4 (9.7 – 40.6)	31.7	80 (51 – 128)	95.0
Another hospital (private	99	15.5 (8.9 – 27.7)	21.1	52 (30 – 95)	70.0
Clinic (public or private)	17	19.2 (8.3 – 31.1)	19.2	51 (26 – 93)	62.6
Primary health centre	337	13.2 (6.3 – 23.8)	20.1	45 (22 – 77)	56.3
Traditional birth attendant	13	15 (6.1 – 19)	20.2	41 (28 – 58)	50.9
Nursing/maternity home	2	36.1 (9.3 – 62.8)	36.1	98 (40 – 155)	97.5
Non-formal referral	2	32.0 (8.5 – 55.4)	32.0	116 (21 – 210)	115.5

Table S7: Logistic regression showing association between maternal death and the selected independent variables

Factor	Model 2A (95% CI)	Model 2B (95% CI)
Age		
12-19	1.60 (0.63 – 4.06)	(empty)
20-34	1.00	1.00
35-60	1.27 (0.82 – 1.97)	1.47 (0.58 – 3.75)
Marital status		
Single	0.87 (0.45 – 1.69)	1.66 (0.27 – 10.01)
Married	1.00	1.00
Obstetric complications in previous pregnancy		
No	1.00	1.00
Yes	0.39 (0.19 – 0.80) *	0.42 (0.10 – 1.70)
Booking status at hospital of care		
Un-booked	1.00	1.00
Booked	0.22 (0.11 – 0.43) ***	(empty)
Maternal complications		
No maternal complication	1.00	1.00
Obstructed labour	0.18 (0.04 – 0.72) *	0.62 (0.04 – 8.74)
Haemorrhage	0.62 (0.21 – 1.85)	0.95 (0.10 – 9.30)
Hypertension	0.77 (0.26 – 2.24)	0.85 (0.08 – 9.20)
Sepsis	0.74 (0.18 – 3.05)	1.56 (0.07 – 36.69)
Abortion	1.82 (0.64 – 5.20)	2.98 (0.05 – 23.12)
Ectopic pregnancy	1.33 (0.43 – 4.10)	1.81 (0.12 – 28.43)
Others	0.85 (0.25 – 2.95)	1.06 (0.12 – 28.43)
Mode of birth		
Spontaneous vaginal birth	1.00	1.00
Assisted vaginal birth	3.17 (1.52–6.62) **	14. 58 (2.02–105.29) **
Caesarean birth	0.49 (0.24–0.97) *	0.27 (0.08–0.88) *
Uterine evacuation	(omitted)	(omitted)
Total traceable distance for all women whose journeys were traceable (N=3,590†‡*)		
Within 5 Km	1.00	1.00
5 – 10 Km	1.57 (0.90–2.76)	1.66 (0.33–8.39)
>10 – 15 Km	2.48 (1.18–5.23) *	2.12 (0.24–19.08)
>15 – 25 Km	1.43 (0.53–3.84)	3.28 (0.32–33.31)
>25 – 35 Km	0.95 (0.25–3.54)	21.40 (1.24–36.72) *
>35 Km	0.52 (0.10–2.77)	49.63 (2.39–103.05) *
Total traceable time for all women whose journeys were traceable (N=3,590†‡*)		
0 – 9 minutes	1.00	1.00
10 – 29 minutes	1.59 (0.79–3.17)	184.23 (5.14–608.51) **
30 – 59 minutes	1.13 (0.45–2.84)	74.82 (3.42–163.79) **
60 – 119 minutes	1.15 (0.31–4.25)	13.83 (1.11–171.51) *
120 – 480 minutes	7.05 (1.10–45.32) *	
Facility type		
Non-apex referral	0.54 (0.24–1.20)	3.33 (0.42–25.91)
Apex referral	1.00	1.00
Principal settlement type served by hospital		
Urban	1.00	1.00
Suburban	3.07 (1.27–7.44) *	7.77 (0.54–112.37)
Rural	3.03 (1.13–8.08) *	0.34 (0.01–11.59)
Majority population type served in facility catchment area		
Non-slum	1.00	1.00
Slum	1.77 (1.08 – 2.90) *	0.79 (0.29 – 2.15)

Footnote: ***$p \leq 0{\cdot}001$; **$p \leq 0{\cdot}010$; *$p \leq 0{\cdot}050$; OR Odds Ratio, CI Confidence Interval

†: Excludes women whose referral journey could not be traced (n=415)

‡: Excludes women whose journey to hospital could not be determined (n=166)

*: Excludes ten missing values

Footnote: Model description: For Model 2A: sub-group analysis for all women who travelled from home directly to a health facility (Total maternal deaths: 140), Model 2B: sub-group analysis for all women who were referred in their journey from home to a health facility (Total maternal deaths: 42). Number of deaths per distance category for referred women: Within 5 Km (4 deaths), 5 – 10 Km (7), >10 – 15 Km (4), >15 – 25 Km (6), >25 – 35 Km (4), >35 Km (4); Number of deaths per distance category for non-referred women: Within 5 Km (37 deaths), 5 – 10 Km (42), >10 – 15 Km (24), >15 – 25 Km (13), >25 – 35 Km (7), >35 Km (8); Number of deaths per travel time category for referred women: Within 0-9mins (0 death), 10-29mins (9), 30-59mins (11), 60-119mins (8), 120-480mins (1); Number of deaths per travel time category for non-referred women: Within 0-9mins (15 deaths), 10-29mins (66), 30-59mins (32), 60-119mins (12), 120-480mins (6).