Displacement patterns of pregnant women: an analysis of 12 years of infant mortality in Brazil

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Abstract

Although infant mortality has decreased over the last years in Brazil, women still face long distances to give birth. This study aims to assess displacement patterns by women whose infant deceased and its causes between years 2006 and 2017.

Background

Despite many advances, infant mortality remains a prevalent issue in health public policy (United Nations Inter-agency Group For Child Mortality Estimation (2021)). While services have been expanded, portions of the world are still distant to health facilities (Weiss et al. (2020)), with significant effects over pregnant women (Viellas et al. (2014); Handley et al. (2021)). In particular, in Brazil, we document that, conditional on infant mortality, the share of women displacing to another municipality in order to give birth and the length of such travels are increasing overtime. Considering it is a country with continental dimensions and regional inequalities, a depiction of this scenario including characteristics of mortality cases is a gap this novel database intends to fill. Although giving birth is considered a simple procedure, supplying appropriate healthcare is needed to prevent mortality if any complicating factors occur.

Many theoretical frameworks and models have been proposed for conceptualizing and understanding usage of or access to health services (Andersen (1995); Sawyer et al. (2002); Travassos and Martins (2004)). According to them, several factors may influence utilization: quality of facilities, severity of case, gender and economic conditions. Race/ethnicity, migration and urban/rural status play a part as well, besides public policies and community elements, such as healthcare market's composition, insurance and, our focus, location (Lorch et al. (2021)). Following this, a seminal article has defined difficulty in geographical access as the "second delay", after the decision to look for the service and before actually receiving it (Thaddeus and Maine (1994)).

Previous research has focused on geographical distribution of services in developing countries (Limwattananon et al. (2010); Lopez-Cevallos and Chi (2010); Bixby (2004)), especially in Africa (Tounkara et al. (2022); Sanoussi (2017); Tanou and Kamiya (2019); Yaya et al. (2018); Noor et al. (2006)). Specific to birth-related services, for instance, in Ghana approximately a third of women of childbearing age live more than two hours from standard structure for obstetric and neonatal care (Gething et al. (2012)). Similarly, in Zambia, for half of births, mothers had to travel 25 kilometers to a facility, while two-thirds of mothers give birth at home, likely due to these geographical barriers (Gabrysch et al. (2011)). As shown in context of rural Indonesia, distance also affects antenatal care, which identifies risk factors during pregnancy (Titaley et al. (2010)). In parallel to this large set of studies, inequality in geographical distribution has also been recorded in rich countries, such as Canada (Grzybowski et al. (2011)) and the U.S. (Handley et al. (2021); Lorch et al. (2013); Kozhimannil et al. (2018)). Natural experiments in Portugal (Neto (2006)) and Australia (Bowman et al. (1988)) allow a causal interpretation, removing the selection bias, a classical issue in health studies. Both indicate the benefits in terms of reducing infant mortality of an organized and structured system, including means of transporting patients to the level of care required by each case. Moreover, in the Netherlands, transfers to risk-appropriate centers were associated with better prospects for preterm and low-weight infants (Kollée et al. (1988)).

Regarding Brazil, articles have pointed to a long-existing geographic inequality in usage (Souza et al. (2015); Arruda et al. (2018); Travassos et al. (2006); Monteiro et al. (2017)) and "pilgrimage" was associated with negative birth outcomes (Leal et al. (2020)). A non-representative research found 34.6% of sample births faced the "second delay" and it relates to worse outcomes for mothers as well (Pacagnella et al. (2014)). Another article revealed only 58.7% of mothers were given directions on which facility attend to and 16.2% had to go to multiple facilities before being admitted (Viellas et al. (2014)). Imperfect coordination and information leads to inefficiency, with incompleteness of procedures (Bittencourt et al. (2020)) or the so-called "inverse care law" (Hart (1971); de Azevedo Bittencourt et al. (2015)). Structure and practices vary across the country, some do not fit international standards (Menezes et al. (2018)) and are not rapidly approachable by parts of public (Weiss et al. (2020); Rocha et al. (2017)).

Overall, evidences involved data collection in limited contexts and/or periods, broadly based on *"Nascer no Brasil"* (Birth in Brazil) project (FioCruz (2022)). Although they provide important insights and point to several bottlenecks, our research contributes to this branch about access to health services in Brazil while using extensive administrative birth-level data for a wider time span, emphasizing the role of distances as a main driver for observed displacements and outcomes related to pregnancy and birth. Similar strategies have been employed for Brazil, but at the municipal level and with narrower scopes (Rocha et al. (2017); Almeida and Szwarcwald (2012); Silva et al. (2020)). Still, to the best of our knowledge, this is the first article to describe geographical access via distances in Brazil discriminating birth-specific characteristics, such as timing of death, prevention of cause, type of labor and risk level.

Methods

Our data set was built by linking data from birth-level to infant death register, i.e. live births from the Brazilian Information System of Live Births and mortality from the Brazilian Information System of Mortality, both of the Brazilian Universal Health System. Distances between municipalities were constructed to consider the intensity of displacements. Procedure is described in xxxx. By doing so, we are able to identify causes of death using the ICD-10 code and assess the distances between municipalities of residence, birth and death. Displacements are possible between these three locations, although in different frequencies. Observation count is about 34 million births, restricted to the ones made in health facilities (hence, omitting births at home and other places).

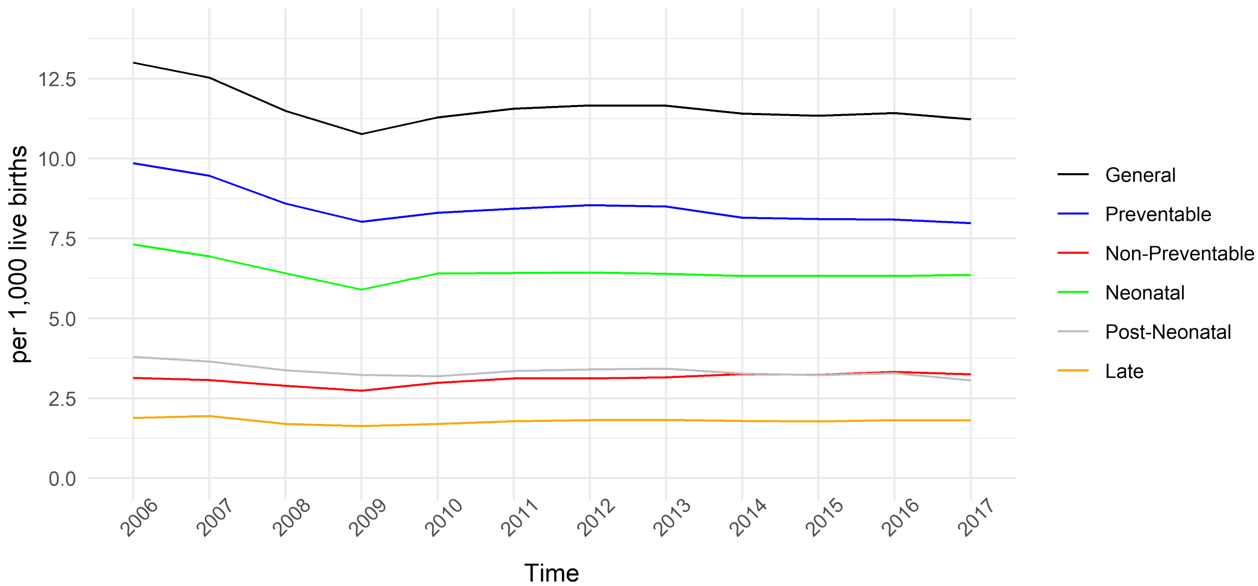
The objective of this study is to describe causes and displacement patterns, prior (and restricted) to infant deaths, in Brazil for over a decade. Information about inequality of access should serve to policymakers as a criteria on where to implement and improve services. Since most women use the health public system in Brazil, it is possible that they are directed to facilities by public agents (Viellas et al. (2014)), so we avoid an interpretation of these as their preferred or chosen displacements. Expanding data and considerations on the supply of health facilities and their services to these women is a natural complement to this agenda, still in progress. Separate on-going analyses will engage on alternative routes and infrastructure of potential facilities, as a supply-side backstory. Besides that, our methodology does not allow any inference of cause-effect link between lengths and outcome of death, as other research designs would. Take-aways presented here serve solely as a descriptive exercise.

Results

To better understand the trend of infant mortality, we calculated infant mortality rate (i.e. until one year) by mother's residence municipality, for years 2006 to 2017. Infant mortality rate is assessed per 1,000 live births. Figure 1 shows national infant mortality rates by year and split according to type of cause and timing of death. Black line represents the general infant mortality, which others add up within criteria. Hence, summing preventable (blue) and non-preventable cause (red) returns the general values, as well as summing neonatal (green), post-neonatal (gray) and late (orange). Note that trends are similar for all series, with a slight decrease until 2009 and stable levels for following years. Moreover, most deaths are classified as preventable and early neonatal, i.e. within 7 days from birth. This shows how interventions are possible to lower mortality and that they should be made shortly.

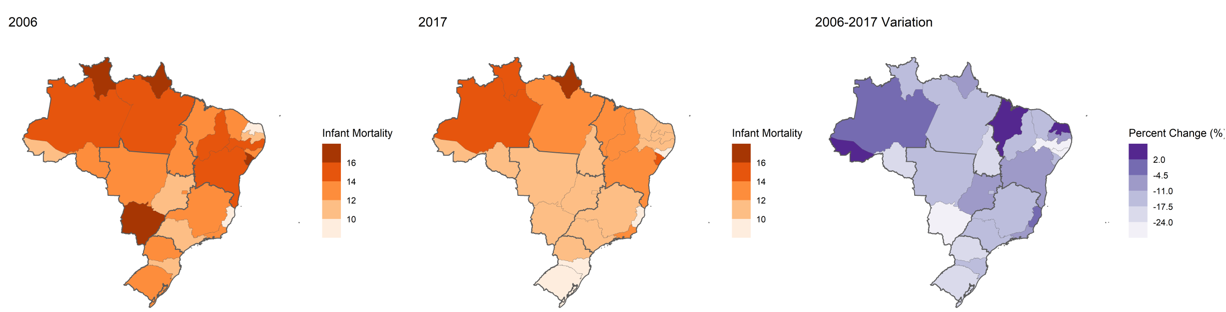
Aggregation by state allows a more detailed description. In Figure 2, we present levels of general infant mortality in 2006, in 2017 and the percentage change during this period. Although most states had negative variations, in line with national trends presented above, three of them have had a positive variation of more than 2 percent: Acre, Maranhão and Rio Grande do Norte. On the other end, three states had the most distinguished decreases, a fall of at least 24 percent: Pernambuco, Alagoas and Mato Grosso do Sul. The latter moved from the top mortality group, registering above 16 deaths by 1,000 liver births, to ranging between 10 and 12 deaths.

Figure 1: Mortality at the national-level by type



Note: Figure shows time trends for each type of mortality from 2006 to 2017. Black line represents General Mortality and others are decompositions. Preventable (blue) and Non-Preventable (red) refer to cause of death. Neonatal (green), Post-Neonatal (grey) and Late (yellow) refer to timing of death.

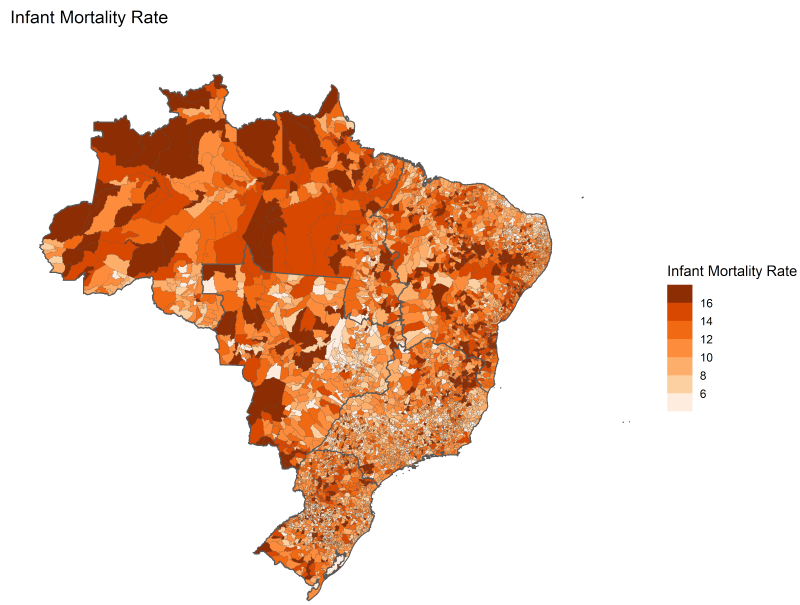
Figure 2: Infant Mortality Rate - Overtime by state



Note: Figure shows general infant mortality by state in 2006 (left) and in 2017 (center), plus variation during this interval.

When looking at infant mortality rate by municipality (Figure 3), we opt to aggregate the whole period of 12 years since most municipalities do not have occurrences every year. Nonetheless, there is still some variation within state, once we can see clearer spots next to dark regions. Visually, it is not as informative as the previous maps: for instance, North regions has larger dark regions but also has more extense municipalities, confounding conclusions.

Figure 3: Infant Mortality Rate - Cumulative by Municipality



Note: Figure shows general infant mortality by municipality from 2006 to 2017.

Infant mortality by type of cause

First, we investigate the most common causes leading to these deaths, according to registered ICD-10 Code group. In this exercise, we eliminated the last digit, which refered to specific timing or location of disease, thus not implying in much information loss. Considering infant mortality, we have comprehensively split causes in preventable and non-preventable. The first group should be a focus for policymakers, as measures during pregnancy, labor or a few days after are able to identify and mitigate them. The second group mainly relates to various fetus malformations, hence there is less margin on how to act upon them. Tables 1 and 2 list such causes and their shares within respective group, so that all add up to 100%.

The ten most frequent causes of infant mortality in either group, preventable or non-preventable, account for about 60% of all causes, while remaining 40% are grouped in "Others" category. Taken together with the percentage of the 10th most common cause around 3%, this indicates there is a wide range of causes, each with less than 3% of share but all together accounting for two fifths of cases. Most common preventable cause of infant death

Table 1: 10 most common preventable causes of infant mortality (2006-2017)

Code	**Description**	**Frequency**
P36	Bacterial sepsis of newborn	12.1%
P22	Respiratory distress syndrome of newborn	11.1%
P07	Disorders related to short gestation and low birth weight	8.5%
P00	Fetus and newborn affected by maternal conditions that may be unrelated to present pregnancy	6.6%
P01	Fetus and newborn affected by maternal complications of pregnancy	5.0%
P21	Birth asphyxia	4.6%
P02	Fetus and newborn affected by complications of placenta, cord and membranes	4.4%
J18	Pneumonia, organism unspecified	3.8%
P24	Neonatal aspiration syndromes	3.6%
P28	Other respiratory conditions originating in the perinatal period	3.2%
Others	Others	36.9%

Note: Table shows main preventable causes of death for infants during 2006-2017 period, according to CID-10 Code without last digit.

Table 2: 10 most common non-preventable causes of infant mortality (2006-2017)

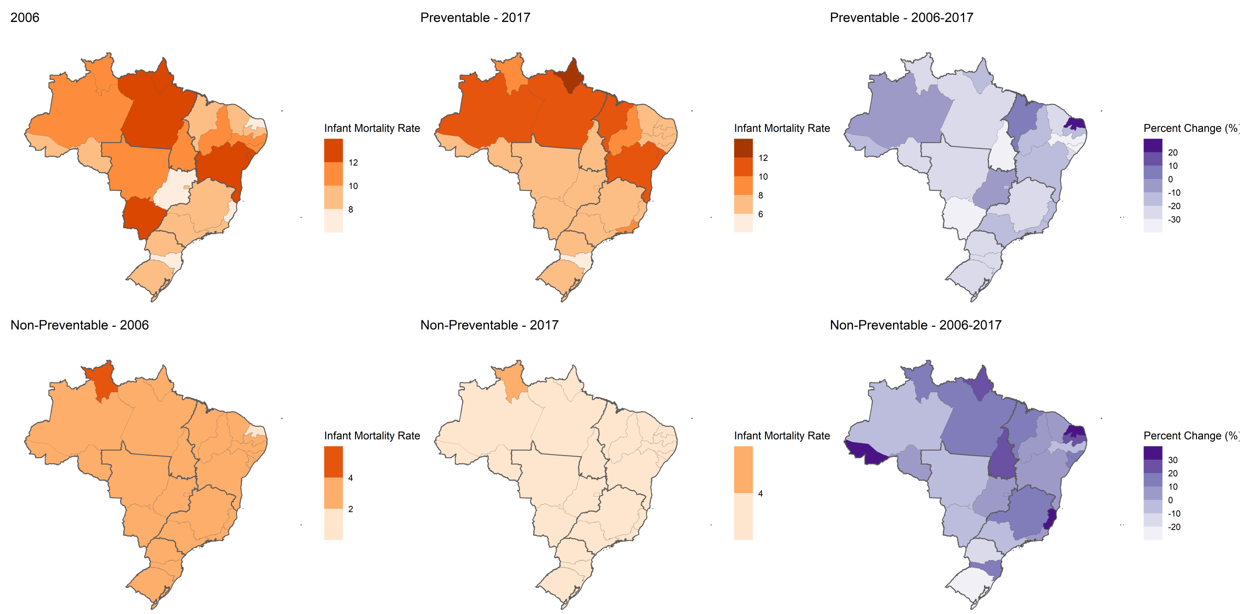
Code	**Description**	**Frequency**
Q24	Other congenital malformations of heart	17.0%
Q89	Other congenital malformations, not elsewhere classified	8.6%
P29	Cardiovascular disorders originating in the perinatal period	7.4%
Q79	Congenital malformations of the musculoskeletal system, not elsewhere classified	5.5%
Q00	Anencephaly and similar malformations	5.3%
Q33	Congenital malformations of lung	4.2%
Q21	Congenital malformations of cardiac septa	3.4%
Q91	Edwards syndrome and Patau syndrome	2.8%
Q25	Congenital malformations of great arteries	2.7%
Q03	Congenital hydrocephalus	2.6%
Others	Others	40.5%

Note: Table shows main non-preventable causes of death for infants during 2006-2017 period, according to CID-10 Code without last digit.

is bacterial sepsis, with 12.1%, followed by respiratory distress syndrome (11.1%). These two account for a third of the cases in the top 10 list. In the non-preventable list, congenital malformations of heart is the main cause, accounting for 17.0% of deaths. Second place, unclassified malformations, has about half of its frequency (8.6%).

In Figure 4, we present same map with initial and final levels plus variation. Top row refers to preventable causes and bottom row to the non-preventable ones. Variation scale is now ampler, with over 20 percent increases, but one must consider that levels are lower to interpret differences. For instance, regarding non-preventable deaths, most states are below 4 deaths per 1,000 live births but still record great variations that do not alter their range through time. Moreover, since they are mainly malformations as depicted in Table 2, human action has little influence on their occurrence. The contrary must hold for preventable: once we observe positive variations in Maranhão and Rio Grande do Norte, public policy is able to modify this scenario and promote the reduction similar to the one shown in remainder states.

Figure 4: Infant Mortality Rate - Preventable vs. Non-Preventable, Overtime by state



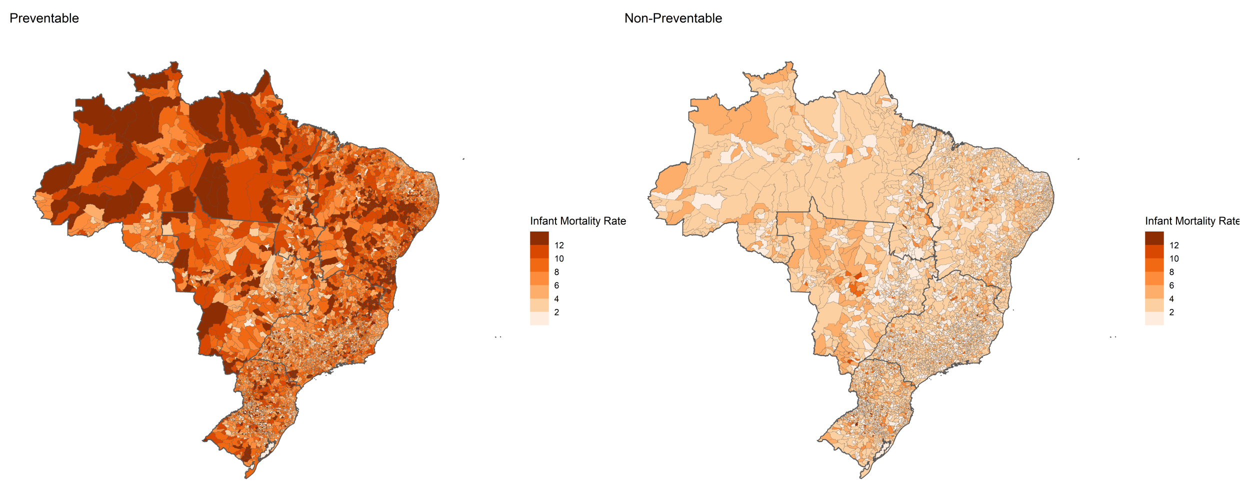
Note: Figure shows Preventable (top row) and Non-Preventable (bottom row) causes of death for infants. Left column depicts 2006 data, center column 2017 and right column contains the difference for the interval.

In addition, cumulative mortality at the municipal level can be split in these categories, as depicted in Figure 5. The same variability within state of general mortality applies for both types of cause.

Infant Mortality by timing

Turning to the timing criteria, infant mortality can be classified as neonatal (at least 7 days after birth), late (between 7 and 28 days) and post-neonatal (from 28 days to one year). In Figure 6, we also observe how a national picture hides state level disparities, with growth in mortality in some units. Rio Grande do Norte, for instance, had an increase of at least 20% in all three categories of timing. The late infant death, i.e. between 7 and 28 days, presents

Figure 5: Infant Mortality Rate - Preventable vs. Non-Preventable, Cumulative by Municipality

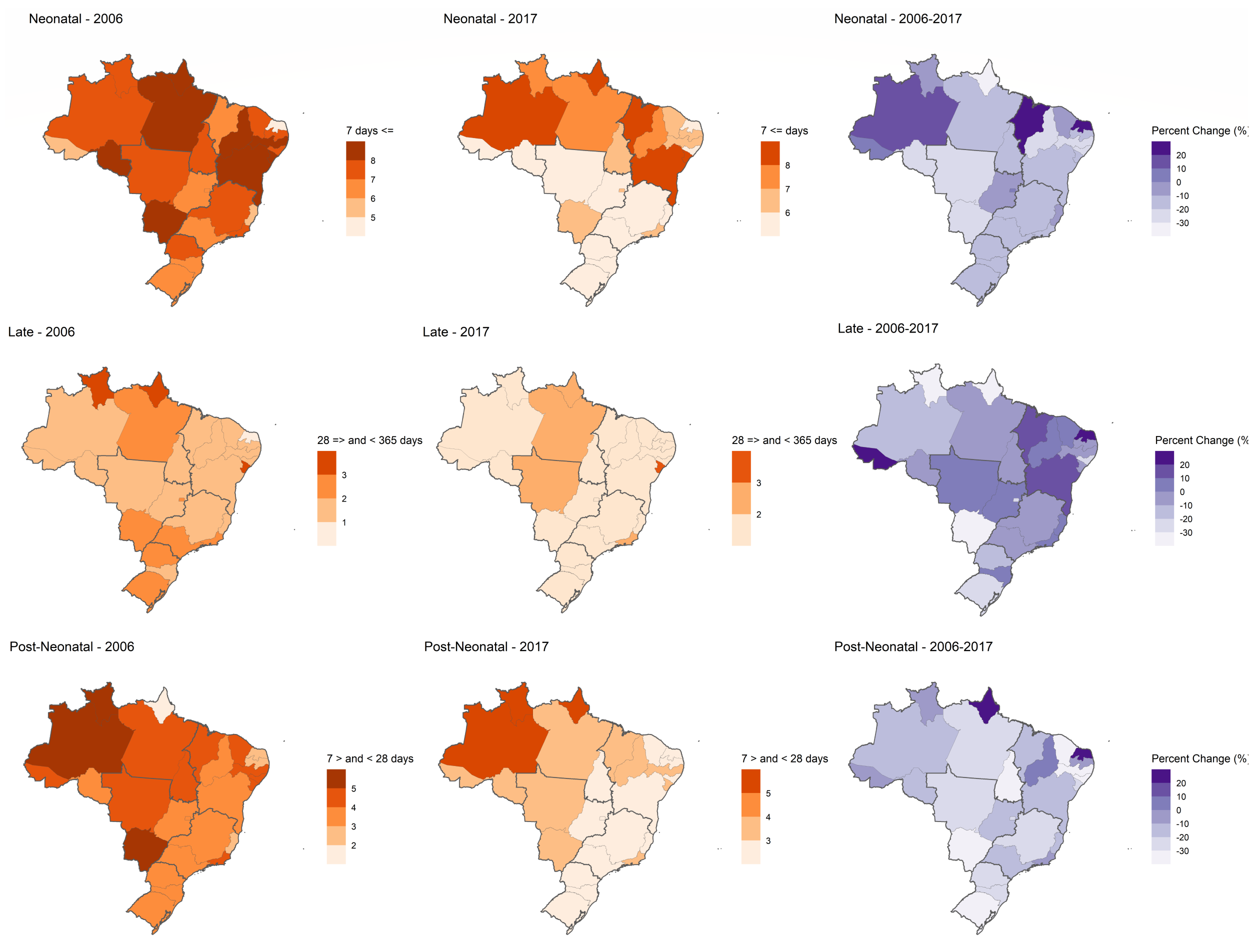


Note: Figure shows Preventable (left) and Non-Preventable (right) Infant Mortality, considering the period from 2006 to 2017 at the municipal-level.

the most states with positive percentage variation, but it is also the one with lowest levels, below 3 deaths for 1,000 live births. The reason might be a composition effect: death is being postponed to after 7 days and the reduction we observe in early neonatal mortality is pushed to the subsequent period. Category which is driving results seems to be the post-neonatal: states such as Tocantins, Ceará and Rio Grande do Sul had over 30% fall in mortality between 28 and 365 days. Nonetheless, moving away from birth date, it is less likely that cause of death relates to birth conditions or any potential interventions by public agents.

In addition, cumulative mortality at the municipal level can be split in these categories, as depicted in Figure 7. The same variability within state of general mortality apply for both types of cause separately.

Figure 6: Infant Mortality Rate - Timing, Overtime by state

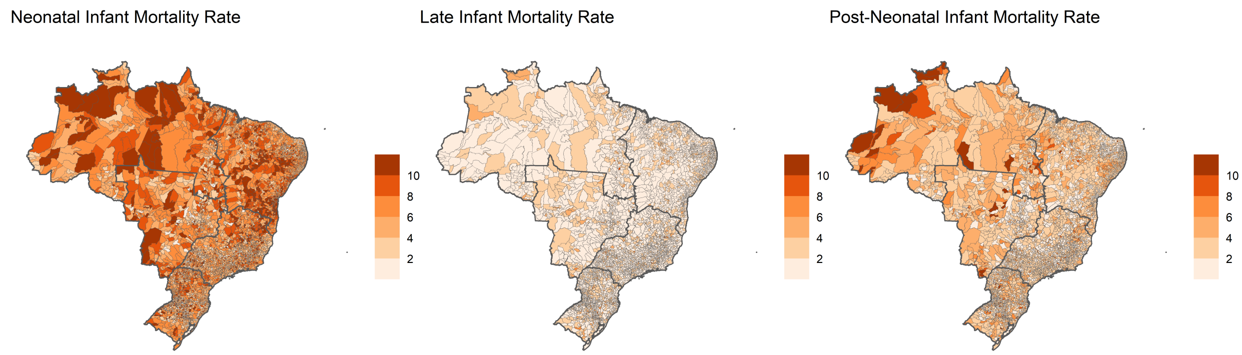


Note: Figure shows Neonatal (top row), post-neonatal (middle row) and Late (bottom row) Mortality for infants. Left column depicts 2006 data, center column 2017 data and right column contains the difference for the interval.

Displacement: shares and distances conditional on infant death and on displacing

To describe displacement patterns, we have calculated: (i) percentage of births which took place outside of mother's resident municipality; (ii) percentage of deaths which took place outside of mother's resident municipality; (iii) percentage of deaths which took place in a municipality differing from birth; and (iv) percentage of births whose residence, birth and death municipality all differ, as well as their respective average displacement distance. Figures 8 shows the country-level time trends for shares (8a, top panel) and distances in

Figure 7: Infant Mortality Rate - Timing, Cumulative by Municipality



Note: Figure shows Neonatal (top row), post-neonatal (middle row) and Late (bottom row) Mortality for infants, considering the period from 2006 to 2017 at the municipal-level.

kilometers (8b, bottom panel).

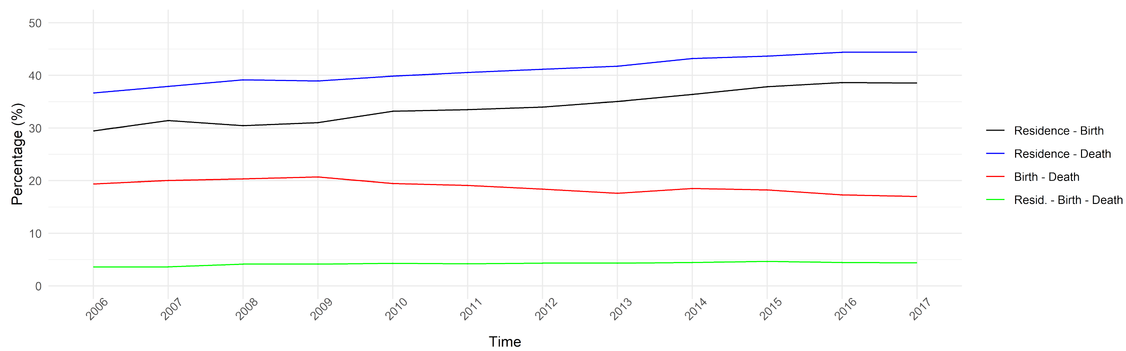
Routes from residence to birth and residence to death have presented an upward trend, with a growing share of women making such displacements. Displacing from birth to death, nonetheless, has become slightly less frequent, around 20%, pointing that newborns are not transferred to another municipality between these two events. The double displacement, i.e. from residence to birth followed by another from birth to death, is a rare phenomenon, accounting for less than 5% of births, and has remained stable.

Regarding distances, the less frequent displacement is the one which demands greater distances, driven by an increase on the distance from residence to birth of around 50% (from 50 to 75 kilometers). Birth to death component is approximately on the same level as the beginning of the series, despite a peak in 2008-2009. Finally, residence to death distances are also rising, departing from around 100 kilometers and reaching almost 125 kilometers on average.

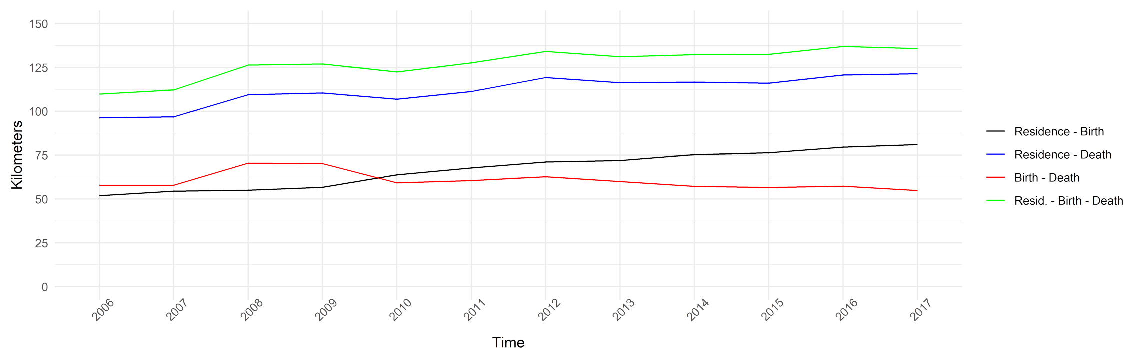
Looking at the municipal level gathering all years of sample, we identify that regions with lower share of displacements are the ones where distances are the longest, as depicted in Figure 9. While on the left column, North and Central-West regions present lighter tones - and thus lower shares -, the opposite holds for rigth column, with over 200 kilometers

Figure 8: Displacement Patterns By Type

(a) Share of Displacements



(b) Average Displacement Distance

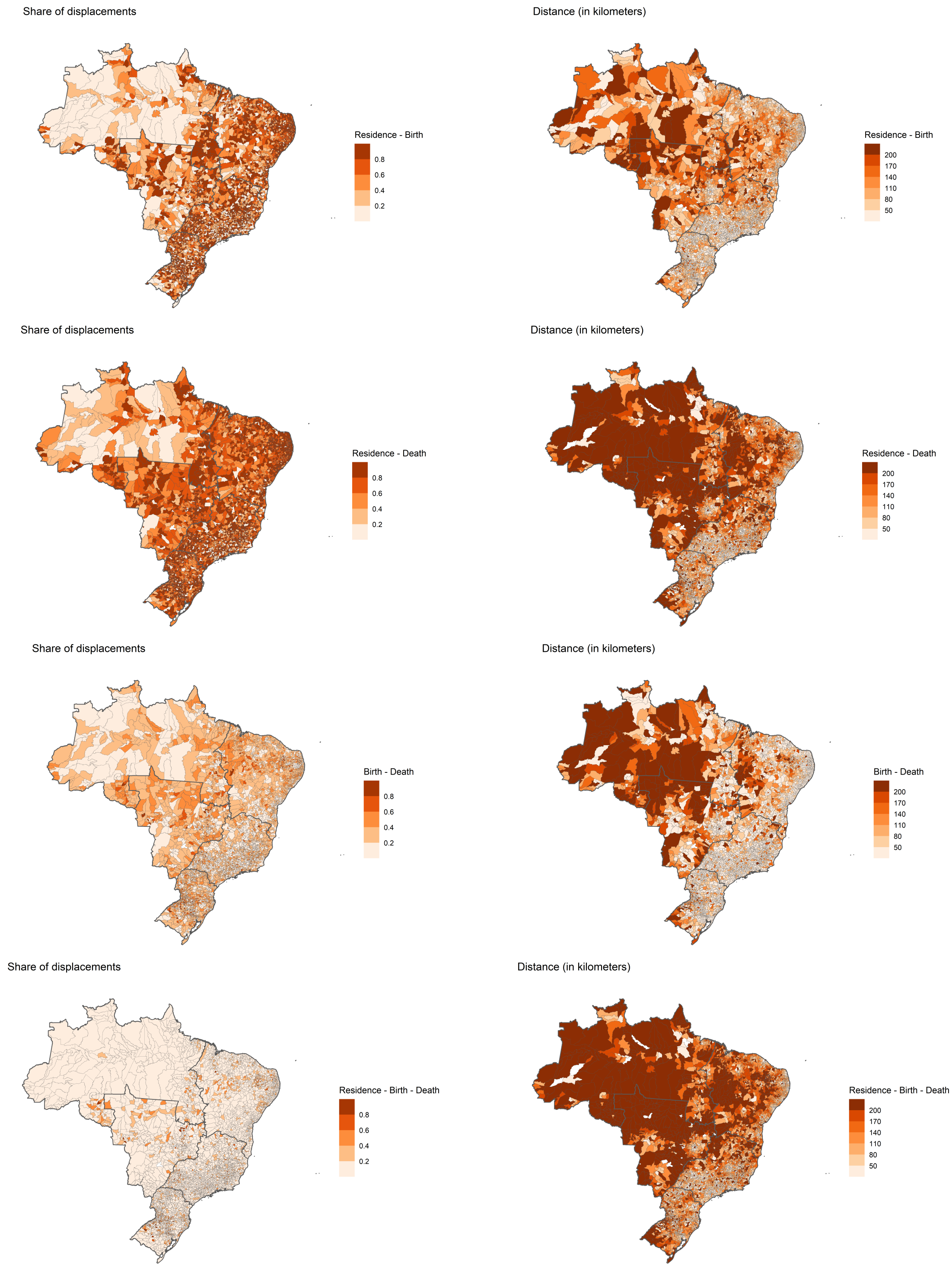


Note: Figure (a), top panel, shows trends in share of displacements regarding origin-destination pairs between 2006 and 2017. Figure (b), bottom panel, shows trends in displacement distances by the same pairs. Displacing may happen from residence to birth, from residence to death, from birth to death and residence, birth and death in different places.

distances for a great portion of these areas.

Regional inequalities are noticeable as well. For every type of distance, maps are brighter in most South and Southeast states. The Northeast coast, where the majority of state capitals are located, is also a stretch of short distances, likely due to the health facilities and establishments concentrated in these cities.

Figure 9: Displacement patterns by type of displacement at the municipal level



Note: Figure shows municipal-level share of displacements (left column) and average distances (right column) regarding origin-destination pairs between 2006 and 2017. Displacing may happen from residence to birth (first row), from residence to death (second row), from birth to death (third row) and residence, birth and death in different places (fourth row).

Infant Mortality: by population range

Besides the geographic aggregation levels, an interesting grouping uses population as criteria. We have defined ranges by number of inhabitants, which allows a comparison of municipalities across the country with similar size and infra-structure. For instance, most populous range includes state capitals and cities in large metropolitan centers, which often host several health facilities. Moving down to the least populous, facilities are more scarce and have lower complexity, following Brazilian Universal Health System (SUS) organization principles. This is reflected on the type of displacements we identify in Table 3, columns (1)-(5). From (1) to (3), displacements are across municipalities: from residence to birth, residence to death and birth to death, respectively.[1] Column (4) represents displacements between facilities of birth and death within the same municipality, i.e. newborn was transferred and deceased in a second health establishment. Finally, column (5) considers displacements from residence to birth across municipalities and from birth to death within municipality (across facilities), thus a special case of column (4). Table 3 shows years 2006, 2011 and 2017 for each range, to depict trends over the decade.

In line with previous findings, we observe an overall upward trend in residence-birth and residence-death percentages: there is an increase on the share of mothers who displace for every population range. For municipalities below 5000 inhabitants, percentage has surpassed 90% and the following range, between 5000 and 10000, is very close to hitting that same mark. Since these are small municipalities, mothers must displace to have proper healthcare. This is also verifiable by how close shares in columns (4) and (5) are: the vast majority of newborns who are transferred across facilities have faced the previous displacement, when leaving the residence municipality. Note that these figures bridge as we turn to larger municipalities.

Columns (3)-(5), on the other hand, present a scenario of some stability or decrease. Keeping in mind that these displacements are conditional on infant mortality, deaths must be

[1] Another possibility is a "double-displacement", when residence, birth and death take place in different municipalities, but we omitted these particular percentages since this is a rare event.

happening in the same facility. In this case, two phenomena might occur: while mothers are displacing more from home to such facilities, it might be possible that a second displacement is (a) not needed, whether mothers go directly to a more prepared facility; or (b) not feasible, say due to lack of safe conditions and/or appropriate equipment to do so.

Table 3: Displacement Patterns by Population Range and Type of Displacement - Overall

Year	Pop. Range	(1) Resid. - Birth	(2) Resid. - Death	(3) Birth - Death	(4) Facility	(5) Resid. - Facil.
2006	(<,5000]	87,5%	85,5%	31,4%	10,9%	10,4%
2011	(<,5000]	92,9%	89,0%	30,8%	7,0%	6,8%
2017	(<,5000]	93,8%	92,9%	23,6%	6,5%	6,4%
2006	(5000,10000]	74,2%	78,8%	31,6%	12,3%	10,6%
2011	(5000,10000]	81,2%	83,6%	31,0%	10,2%	9,5%
2017	(5000,10000]	89,3%	89,6%	25,9%	4,8%	4,7%
2006	(10000,25000]	52,5%	64,5%	29,8%	11,6%	8,9%
2011	(10000,25000]	64,4%	75,2%	29,6%	10,1%	9,1%
2017	(10000,25000]	74,1%	81,3%	26,7%	5,3%	4,8%
2006	(25000,50000]	35,3%	53,6%	28,2%	12,7%	7,5%
2011	(25000,50000]	45,8%	62,6%	29,4%	9,9%	7,8%
2017	(25000,50000]	58,2%	71,6%	27,1%	5,7%	4,7%
2006	(50000,100000]	26,2%	43,0%	23,7%	19,3%	8,7%
2011	(50000,100000]	33,1%	51,4%	25,8%	13,0%	7,3%
2017	(50000,100000]	42,6%	59,4%	24,4%	7,3%	3,8%
2006	(100000,>]	17,6%	19,1%	12,1%	39,6%	5,6%
2011	(100000,>]	19,2%	21,4%	11,9%	30,6%	4,8%
2017	(100000,>]	21,2%	23,3%	10,4%	20,3%	2,5%

Note: Table shows municipal-level share of displacements which led to an infant death by population size intervals and selected years (2006, 2011, 2017). Displacing may happen from residence to birth (column 1), from residence to death (column 2), from birth to death (column 3). It also occurs between facilities inside the same municipality (column 4) and when pregnant also traveled from municipality where she resides (column 5).

Table 4 presents the same numbers as in Table 3, restricted to infant deaths which happened on the first week of life, meaning they are very close to birth. Columns (1) and (2) have remained in similar levels, but others show a significant change. First, share of mothers who displaced between birth and death, column (3), is now lower, but reduction in percentage points across years remained stable. As for columns (4) and (5), 2006 levels are very close but reduction over time was more drastic. For instance, the lower range went from 11.2% to 3% in Table 4, column (4), while overall deaths reduced from 10.9% to 6.5%, in Table 3, column (4). Hence, the fall in displacements by the "closer" cases is driving the overall results.[2] When looking into the classification in preventable and non-preventable causes, patterns are the same as overall table and neither group is more relevant in terms of change (not shown).

Table 4: Displacement Patterns by Population Range and Type of Displacement - 7 days

Year	Pop. Range	(1) Resid. - Birth	(2) Resid. - Death	(3) Birth - Death	(4) Facility	(5) Resid. - Facil.
2006	(<,5000]	87,6%	90,5%	17,6%	11,2%	10,7%
2011	(<,5000]	92,1%	95,3%	21,2%	5,6%	5,5%
2017	(<,5000]	93,5%	95,8%	11,3%	3,0%	3,0%
2006	(5000,10000]	75,9%	82,8%	18,6%	11,0%	9,3%
2011	(5000,10000]	83,9%	88,6%	17,0%	8,3%	8,0%
2017	(5000,10000]	88,4%	91,0%	12,6%	2,0%	1,9%
2006	(10000,25000]	55,6%	65,8%	18,0%	11,1%	8,6%
2011	(10000,25000]	65,1%	75,9%	18,3%	8,2%	7,5%
2017	(10000,25000]	75,0%	81,9%	14,9%	3,1%	2,8%
2006	(25000,50000]	38,4%	52,6%	18,9%	10,9%	7,1%
2011	(25000,50000]	46,8%	60,2%	19,0%	7,6%	6,3%
2017	(25000,50000]	59,1%	70,5%	16,3%	3,1%	2,6%
2006	(50000,100000]	25,7%	37,0%	15,3%	17,3%	7,4%
2011	(50000,100000]	32,5%	44,9%	15,8%	10,8%	6,1%
2017	(50000,100000]	42,9%	53,3%	14,0%	4,5%	1,8%
2006	(100000,>]	16,9%	17,3%	7,4%	32,0%	5,5%
2011	(100000,>]	18,1%	19,3%	6,8%	22,7%	4,2%
2017	(100000,>]	20,6%	21,5%	4,9%	9,9%	1,4%

Note: Table shows municipal-level share of displacements which led to an infant death in the first week of life by population size intervals and selected years (2006, 2011, 2017). Displacing may happen from residence to birth (column 1), from residence to death (column 2), from birth to death (column 3). It also occurs between facilities inside the same municipality (column 4) and when pregnant also traveled from municipality where she resides (column 5).

Conclusion

Long distances remain a challenge for obtaining available and appropriate healthcare for pregnant women and newborns. It may be a factor of distress and lead to complications. Politicians and policymakers need to understand demands when deciding whether and, most specifically, where to implement investments and expand services. In Brazil, we document that infant mortality has become less frequent, but, regarding still prevalent cases, a larger

[2] Percentages for deaths between 7 and 28 days are closer to overall table (results not shown). The remainder category is between 28 days and one year.

share of women have displaced from their residence municipality to the birth and they are traveling greater extents. On the contrary, birth and death have occurred at the same place, shown by a lower share of birth-death displacements and of transfers within municipalities. Furthermore, disparities arise across regions and within more granular geographic divisions.

References

Almeida, W. d. S. d. and C. L. Szwarcwald (2012). Infant mortality and geographic access to childbirth in brazilian municipalities. *Revista de Saúde Pública 46*, 68–76.

Andersen, R. M. (1995). Revisiting the behavioral model and access to medical care: does it matter? *Journal of health and social behavior*, 1–10.

Arruda, N. M., A. G. Maia, and L. C. Alves (2018). Desigualdade no acesso à saúde entre as áreas urbanas e rurais do brasil: uma decomposição de fatores entre 1998 a 2008. *Cadernos de Saúde Pública 34*.

Bittencourt, S. D. d. A., E. M. Cunha, R. M. S. M. Domingues, B. A. S. Dias, M. A. B. Dias, J. A. Torres, and M. d. C. Leal (2020). Nascer no brasil: continuidade do cuidado na gestação e pós-parto à mulher e ao recém-nato. *Revista de Saúde Pública 54*.

Bixby, L. R. (2004). Evaluación del impacto de la reforma del sector de la salud en costa rica mediante un estudio cuasiexperimental. *Revista Panamericana de salud pública 15*, 94–103.

Bowman, E., L. W. Doyle, L. J. Murton, R. Roy, and W. H. Kitchen (1988). Increased mortality of preterm infants transferred between tertiary perinatal centres. *British Medical Journal 297*(6656), 1098–1100.

de Azevedo Bittencourt, S. D., R. Queiroz Gurgel, M. A. da Silva Menezes, L. S. Bastos, and M. d. Carmo Leal (2015). Neonatal care in brazil: hospital structure and adequacy according to newborn obstetric risk. *Paediatrics and International Child Health 35*(3), 206–212.

FioCruz (2022). Nascer no brasil, saúde da mulher, da criança e do adolescente – determinantes sociais, epidemiologia e avaliações políticas, programas e serviços.

Gabrysch, S., S. Cousens, J. Cox, and O. M. Campbell (2011). The influence of distance and level of care on delivery place in rural zambia: a study of linked national data in a geographic information system. *PLoS medicine 8*(1), e1000394.

Gething, P. W., F. A. Johnson, F. Frempong-Ainguah, P. Nyarko, A. Baschieri, P. Aboagye, J. Falkingham, Z. Matthews, and P. M. Atkinson (2012). Geographical access to care at birth in ghana: a barrier to safe motherhood. *BMC public health 12*(1), 1–13.

Grzybowski, S., K. Stoll, and J. Kornelsen (2011). Distance matters: a population based study examining access to maternity services for rural women. *BMC health services research 11*(1), 1–8.

Handley, S. C., M. Passarella, H. M. Herrick, J. D. Interrante, S. A. Lorch, K. B. Kozhimannil, C. S. Phibbs, and E. E. Foglia (2021). Birth volume and geographic distribution of us hospitals with obstetric services from 2010 to 2018. *JAMA network open 4*(10), e2125373–e2125373.

Hart, J. T. (1971). The inverse care law. *The Lancet 297*(7696), 405–412.

Kollée, L., P. P. Verloove-Vanhorick, R. A. Verwey, R. Brand, and J. Ruys (1988). Maternal and neonatal transport: results of a national collaborative survey of preterm and very low birth weight infants in the netherlands. *Obstetrics and gynecology 72*(5), 729–732.

Kozhimannil, K. B., P. Hung, C. Henning-Smith, M. M. Casey, and S. Prasad (2018). Association between loss of hospital-based obstetric services and birth outcomes in rural counties in the united states. *Jama 319*(12), 1239–1247.

Leal, M. d. C., A. P. Esteves-Pereira, E. F. Viellas, R. M. S. M. Domingues, and S. G. N. d. Gama (2020). Assistência pré-natal na rede pública do brasil. *Revista de Saúde Pública 54*.

Limwattananon, S., V. Tangcharoensathien, and P. Prakongsai (2010). Equity in maternal and child health in thailand. *Bulletin of the World Health Organization 88*, 420–427.

Lopez-Cevallos, D. F. and C. Chi (2010). Health care utilization in ecuador: a multilevel analysis of socio-economic determinants and inequality issues. *Health policy and planning 25*(3), 209–218.

Lorch, S. A., J. Rogowski, J. Profit, and C. S. Phibbs (2021). Access to risk-appropriate hospital care and disparities in neonatal outcomes in racial/ethnic groups and rural–urban populations. In *Seminars in Perinatology*, Volume 45, pp. 151409. Elsevier.

Lorch, S. A., S. K. Srinivas, C. Ahlberg, and D. S. Small (2013). The impact of obstetric unit closures on maternal and infant pregnancy outcomes. *Health Services Research 48*(2pt1), 455–475.

Menezes, M. A. S., R. Gurgel, S. D. A. Bittencourt, V. E. Pacheco, R. Cipolotti, and M. d. C. Leal (2018). Health facility structure and maternal characteristics related to essential newborn care in brazil: a cross-sectional study. *BMJ Open 8*(12).

Monteiro, C. N., M. A. Beenackers, M. Goldbaum, M. B. d. A. Barros, R. J. Gianini, C. L. G. Cesar, and J. P. Mackenbach (2017). Use, access, and equity in health care services in são paulo, brazil. *Cadernos de Saúde Pública 33*, e00078015.

Neto, M. T. (2006). Perinatal care in portugal: effects of 15 years of a regionalized system. *Acta Paediatrica 95*(11), 1349–1352.

Noor, A. M., A. A. Amin, P. W. Gething, P. M. Atkinson, S. I. Hay, and R. W. Snow (2006). Modelling distances travelled to government health services in kenya. *Tropical Medicine & International Health 11*(2), 188–196.

Pacagnella, R. C., J. G. Cecatti, M. A. Parpinelli, and et al. (2014). Delays in receiving obstetric care and poor maternal outcomes: results from a national multicentre cross-sectional study. *BMC Pregnancy Childbirth 14 159.*

Rocha, T., N. da Silva, P. Amaral, A. Barbosa, J. Rocha, V. Alvares, D. de Almeida, E. Thume, E. Thomaz, R. de Sousa Queiroz, et al. (2017). Access to emergency care services: a transversal ecological study about brazilian emergency health care network. *Public Health 153*, 9–15.

Sanoussi, Y. (2017). Measurement and analysis of inequality of opportunity in access of maternal and child health care in togo. *BMC health services research 17*(2), 81–87.

Sawyer, D. O., I. d. C. Leite, and R. Alexandrino (2002). Perfis de utilização de serviços de saúde no brasil. *Ciência & Saúde Coletiva 7*, 757–776.

Silva, N. C. d., T. A. H. Rocha, P. V. Amaral, C. Elahi, E. Thumé, E. B. A. F. Thomaz, R. C. d. S. Queiroz, J. R. N. Vissoci, C. Staton, and L. A. Facchini (2020). Comprehending the lack of access to maternal and neonatal emergency care: Designing solutions based on a space-time approach. *PLoS One 15*(7), e0235954.

Souza, M. S. P. L., R. Aquino, S. M. Pereira, M. d. C. N. Costa, M. L. Barreto, M. Natividade, R. Ximenes, W. Souza, O. M. Dantas, and J. U. Braga (2015). Fatores associados ao acesso geográfico aos serviços de saúde por pessoas com tuberculose em três capitais do nordeste brasileiro. *Cadernos de Saúde Pública 31*, 111–120.

Tanou, M. and Y. Kamiya (2019). Assessing the impact of geographical access to health facilities on maternal healthcare utilization: evidence from the burkina faso demographic and health survey 2010. *BMC Public Health 19*(1), 1–8.

Thaddeus, S. and D. Maine (1994). Too far to walk: maternal mortality in context. *Social science & medicine 38*(8), 1091–1110.

Titaley, C. R., M. J. Dibley, and C. L. Roberts (2010). Factors associated with underutilization of antenatal care services in indonesia: results of indonesia demographic and health survey 2002/2003 and 2007. *BMC public health 10*(1), 1–10.

Tounkara, M., O. Sangho, M. Beebe, L. J. Whiting-Collins, R. R. Goins, H. C. Marker, P. J. Winch, and S. Doumbia (2022). Geographic access and maternal health services utilization in sélingué health district, mali. *Maternal and child health journal 26*(3), 649–657.

Travassos, C., E. X. de Oliveira, and F. Viacava (2006). Desigualdades geográficas e sociais no acesso aos serviços de saúde no brasil: 1998 e 2003. *Ciência & Saúde Coletiva 11*, 975–986.

Travassos, C. and M. Martins (2004). A review of concepts in health services access and utilization. *Cadernos de Saúde Pública 20*, S190–S198.

United Nations Inter-agency Group For Child Mortality Estimation, U. N. I. G. M. E. (2021). Levels & trends in child mortality: Report 2021, estimates developed by the united nations inter-agency group for child mortality estimation.

Viellas, E. F., R. M. S. M. Domingues, M. A. B. Dias, S. G. N. d. Gama, M. M. Theme Filha, J. V. d. Costa, M. H. Bastos, and M. d. C. Leal (2014). Prenatal care in brazil. *Cadernos de saude publica 30*, S85–S100.

Weiss, D., A. Nelson, C. Vargas-Ruiz, K. Gligorić, S. Bavadekar, E. Gabrilovich, A. Bertozzi-Villa, J. Rozier, H. Gibson, T. Shekel, et al. (2020). Global maps of travel time to healthcare facilities. *Nature Medicine 26*(12), 1835–1838.

Yaya, S., O. A. Uthman, A. Amouzou, M. Ekholuenetale, and G. Bishwajit (2018). Inequalities in maternal health care utilization in benin: a population based cross-sectional study. *BMC pregnancy and childbirth 18*(1), 1–9.