DELIVERING PRENATAL CARE THROUGH TELEMEDICINE IN RURAL LATIN AMERICA: A REVIEW

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Abstract

One hundred and twenty million individuals reside in the rural areas of Latin America, and they exhibit worse health than their urban counterparts by nearly every indicator, from disease incidence to mortality. Many barriers contribute to these disparities, including difficulties in accessing isolated communities, a lack of health care professionals, and a deficiency of well-equipped facilities. These inequalities are especially prominent among pregnant women and infants, two of the most vulnerable groups in any population. Rural women lack access to prenatal care, an important determinant of maternal and infant health. One method of overcoming this problem is through telemedicine, the use of information and communication technology to assess and treat patients remotely. Through a literature review, this thesis assesses the state of current programs and research related to providing prenatal care through telemedicine in Latin America. Although eighteen relevant sources were identified, a stark lack of research was evident. Further research and development must be done to continue to evaluate and improve these programs to better serve the needs of rural populations.

Delivering Prenatal Care through Telemedicine in Rural Latin America: A Review

Introduction

The health status of the over 3 billion individuals living in rural areas across the globe often lags behind that of their urban counterparts by nearly every measure (Population Reference Bureau [PRB], 2015). With the health of such a large group at stake, these disparities demand a response. Rural pregnant women and infants, both deemed vulnerable populations by the World Health Organization, experience these inequalities severely, especially with regards to prenatal and neonatal care. According to the Population Reference Bureau, rural women are less likely than urban women to receive the four recommended prenatal care visits, less likely to have a skilled birth attendant present during delivery, and more likely to give birth at home. For example, only 42% of rural women in Ecuador received the four recommended prenatal care visits compared to 71% of urban women in 2014 (PRB, 2015). All of these factors increase the likelihood of complications during and after birth, which contribute to the higher mortality and disease burden present in this population. One method of overcoming many of the barriers to health care access in rural areas is telemedicine, which is the use of information and communication technology to assess and treat patients remotely. Health care professionals can use technology to provide prenatal care, an influential factor in maternal and infant health outcomes, and other vital services to expecting mothers and infants. Telemedicine programs exist in nearly every Latin American country but few of them do focus on caring for pregnant women and infants ("mHealth Deployment Tracker", 2017). Furthermore, the global health community considers maternal health and infant health to be among the most important and informative health indicators because improving outcomes for these populations often amounts to progress in the overall health status of a community. Additionally, the resources used to improve the health

care access of mothers and infants could also more widely impact the wellbeing of all members of rural populations.

Although various telemedicine programs exist in Latin America, few focus on maternal health, or specifically prenatal care, and insufficient analysis exists regarding their effectiveness. As other obstetrics telemedicine programs exist in other parts of the world, this is likely due to the lack of development of these initiatives in the region. This paper will focus on the maternal and infant health problems and telemedicine programs that exist in Latin America, specifically the mainland countries of Central and South America as well as Mexico. Through the analysis of telemedicine initiatives in the region and of publications related to them, this paper will assess existing interventions and address the practicality and efficacy of implementing further programs. It will also evaluate the state of the research available in this field. This investigation was done via a literature review of relevant databases to assess the availability of pertinent research and identify studies and publications that address programs in the region.

The scarcity of relevant studies and reviews revealed the lack of knowledge and research in this field as well as the scarcity of programs of this type in the region. It established the need for further research to evaluate the continuing utilization, ongoing costs, and long-term health impacts of telemedicine programs. There have been several previous systematic reviews examining the use of telemedicine for prenatal care (Odibo, Wendel, & Magann, 2013; mHealth Alliance, 2012; Lewis, Synowiec, Lagomarsino, & Schweitzer, 2012; Tamrat & Kachnowski, 2011; Vital Wave Consulting, 2009). These reviews demonstrated the effectiveness of using telemedicine in this way and showed successful examples of these methods in other regions. However, none of these previous review focused on Latin America specifically, instead only including one program implemented in Latin America within their global studies. This review

focuses on Latin America in order to assess the state of telemedicine in the region and advocate for its expansion with regards to prenatal care. Researchers and governments must continue to develop new, more affordable, and more practical technologies to better equip health care professionals to serve rural, isolated communities, while continuing to implement and improve upon programs to care for this population.

Background

Indicators

According to the World Health Organization, in 2015, around 303,000 women died during or soon after pregnancy, 2.6 million babies were stillborn, and 2.7 million babies died in their first 28 days of life (World Health Organization [WHO], 2015). These data demonstrate huge disparities in the quality of health care and access to health services around the world. Two-thirds of the global maternal and newborn disease burden is preventable with known interventions and the vast majority of these deaths occur in developing countries. For example, a staggering 99% of maternal deaths occur in low resource settings, which includes developing countries and especially their rural regions (WHO, 2016). The above statistics are among the many measures of maternal and infant health used to evaluate population health. Three of the most important and widely used of these are the neonatal mortality rate, the maternal mortality rate, and the infant mortality rate. The World Health Organization defines neonatal mortality rate (NMR) as the number of newborns who die between 0 and 28 days of age per 1,000 live births. They define the maternal mortality rate (MMR) as the number of women who die during pregnancy or within 42 days of giving birth per 100,000 live births. Finally, they define infant mortality rate (IMR) as the probability of an infant dying between birth and one year of age per 1,000 live births (WHO, 2011).

The international community considers neonatal mortality to be a useful gauge of the quality of available maternal and neonatal care as well as the overall health and status of infants and women in a population. Scholars also often use infant mortality rate as an indicator of total population health, the efficacy of a healthcare system, and the general status of a population. This is due to its sensitivity to change and the vulnerability of the population it considers (WHO, 2011). IMR is also relatively easy to measure, compared to more complex indicators. For example, although disability adjusted life years (DALYs) provide more precise demographic information, their calculation requires detailed morbidity and mortality data and the use of an involved scoring system. This necessitates greater investment of funds, infrastructure, and manpower from governments or research organizations. Infant deaths are also more commonly reported than other public health metrics, facilitating more accurate calculation and less estimation. As such, IMR is often a more reliable source of health information from countries with poor infrastructure for data collection (Allotey & Reidpath, 2003). In light of this, the international health community holds maternal and infant mortality metrics in high regard. The United Nations included both measures in Millennium Development Goals (MDG) 3 and 4 as well as Sustainable Development Goal (SDG) 3. The largest gathering of world leaders in history created the MDGs in 2000 and their replacements, the SDGs, in 2015 to facilitate improvements in global quality of life through reducing poverty and addressing inequality (United Nations, 2017). The prominence of women and children's health evidences their universal significance and prominence on the global stage.

Many of the leading causes of maternal and infant death are preventable or treatable with known interventions through the provision of quality health care. Worldwide, according to The United Nations International Children's Fund (UNICEF), the leading causes of neonatal

mortality as of 2015 were preterm birth complications, accounting for 25% of all neonatal deaths. Complications during labor and delivery made up 24% of total mortality. Preventable conditions, such as sepsis, pneumonia, tetanus, and diarrhea, contributed another 23%. In Latin America, neonatal deaths encompassed 52% of all deaths of children less than five years of age meaning newborns are at high risk (UNICEF, 2015). A 2014 analysis of WHO mortality data determined that in Latin America, hemorrhage made up 23.1% of maternal mortality, hypertension 22.1%, abortion 9.9%, and sepsis 8.3% (Say et al., 2014). Again, these statistics indicate significant disparities, as the vast majority of these deaths are preventable by known methods and mortality and disease burden differ between regions and socioeconomic groups.

Prenatal Care

Increasing access to prenatal care, also known as antenatal care, offers an effective and efficient way to improve maternal and infant health (Pan American Health Organization [PAHO], 2008). Prenatal care is care received by women during pregnancy. One global study found that in developing countries, a one percent increase in the number of women receiving at least four prenatal care visits correlated with a reduction of 0.18 stillbirths per 1,000 live births, a statistically significant finding by their analysis (Bann, Goldenberg, & McClure, 2007). The World Health Organization recommends a minimum of four prenatal contacts with the health care system during a normal pregnancy, but rural women are less likely than urban women to receive these four visits. For example, in 2015, only 60% of rural Bolivian women had four prenatal visits compared to 81% of urban women (PRB, 2015). Prenatal care visits are not only important for direct health reasons, but also for their many indirect effects, such as the provision of education and increasing the mothers confidence in her ability to care for herself and her baby.

Primarily, regular prenatal care allows for the identification and assessment of risks, which can prevent many serious health issues. Health care workers can also promote healthy eating habits, physical activity, and avoidance of unhealthy substances, which reduces the risk of complications during pregnancy and birth such as preeclampsia and fetal alcohol syndrome. Moreover, trained professionals can help women create a plan for the birth of their child and for any emergency situations that may arise, helping both mother and baby to stay safe and healthy. In addition to direct health benefits, these measures help expectant mothers to be confident, comfortable, and prepared throughout the course of their pregnancies. In the long-term, women who receive prenatal care are more likely to utilize health services for themselves and their children in the future. This can affect not only the health of the women and their new child, but also the health of their entire family (WHO, 2016).

One specific impact of prenatal care is reducing the number of low birth weight newborns, which the World Health Organization defines as weighing less than 2,500 grams at birth and is one of the most significant indicators of neonatal and child death. The length of pregnancy and restricted growth in utero, which can be caused by many conditions, are the two main factors that influence this measure. (Valero de Bernabé et al., 2004). Children born with low birth weight are more likely to die prematurely, more likely to have weakened immune systems, and more likely to experience ADHD or other mental disabilities. The effects of low birth weight also extend into adulthood and correlate with increased levels of heart disease, hypertension and type two diabetes (Coutinho, Cecatti, Surita, Souza, & Morais, 2009). A recent study conducted in Colombia, using data on over 10,000 children, found having fewer than recommended prenatal care visits, receiving low quality prenatal care, and beginning prenatal care later in pregnancy to correlate with low birth weight (Pinón-Rozón et al., 2015). Another

study in Brazil of over 43,000 infants also found having fewer than four prenatal care visits and beginning prenatal care later than recommended to correlate with low birth weight (Coutinho et al., 2009). This emphasizes the importance of prenatal care and showcases the potential impact of increasing these services for those unable to access them.

According to the World Health Organization's 2016 publication "Recommendations on antenatal care for a positive pregnancy experience," effective and comprehensive prenatal care includes nutritional recommendations and supplements, maternal assessment, fetal assessment, disease prevention, and symptom monitoring. Nutritional recommendations include education about healthy eating as well as iron, folic acid, calcium, and other supplements. Maternal assessment includes monitoring pregnant mothers for signs of anemia, infection, domestic violence, diabetes, substance use, human papilloma virus, and tuberculosis. Health care providers can also monitor the growth and development of the fetus through the use of ultrasound and other tools. Additional prevention measures, including vaccines and antibiotics, also protect the health of women and their children. Health care workers can monitor and treat many symptoms such as nausea, pain, and cramps, which promotes a more positive and healthy pregnancy experience. Other recommendations related to health systems in general include woman-held case notes, to improve continuity of care and encourage women to take an active role in their treatment, and community based interventions. Another recommendation is task shifting, for appropriate care activities to be shifted to lesser-trained health care professionals, such as community health facilitators, rather than physicians (WHO, 2016).

Rural Populations and Problems

One hundred and twenty million individuals, or 20% of Latin America's population, still reside in rural areas, despite huge waves of urbanization in recent years (PRB, 2015). Many of

these people live in remote, mountain or rainforest communities in the Andes Mountains or the Amazon Basin and typically live agrarian lifestyles. However, the definition of what differentiates a rural area from an urban area varies between countries. For example, Venezuela defines an urban area as a population center with more than 1,000 inhabitants while Argentina defines an urban area as a center with more than 2,000 inhabitants, and Peru considers any population center with more than 100 dwellings to be urban (United Nations, 2005). The lack of a universal definition creates issues in allocating funding and resources, defining research populations, and creating specific policies that address the needs of rural communities (Lourenço, 2012). Regardless of definition, rural populations in the region exhibit worse health outcomes by nearly every metric. For example, in 2015, in Bolivia, the urban infant mortality rate was 43 deaths per 1,000 live births, but the rural infant mortality rate was 75. In Peru in the same year, the urban IMR was 16 while the rural rate was 25 (PRB, 2015).

The disparities in urban and rural infant mortality stem from high rates of socioeconomic disadvantage, lower levels of education, less access to health care resources, and many other barriers that persist in rural areas beyond the direct impacts of the health care system (Strasser, 2003). The Pan-American Health Organization stated in 2015 that 97% of urban Latin Americans had access to improved drinking water sources compared to only 84% of their rural counterparts. Improved drinking water sources protect water from outside contamination, especially fecal matter, and prevent the transmission of disease. Additionally, 88% of urban populations had access to improved sanitation, with excrement sufficiently separated from human contact, while only 63% of rural populations had the same, putting them at greater risk of disease. Fifty-one percent of rural citizens still use solid fuels, such as wood, dung, or charcoal, for cooking and heating their homes compared to just 8% of urbanites. The indoor air pollution

from these fuels put users at increased risk of many respiratory diseases and other health complications (PAHO, 2016). Furthermore, rural cultures often value self-sufficiency and independence, leading to less utilization of available health care services (Strasser, 2003). Lower levels of education exacerbate this issue as people may have a poor understanding of what resources are available or how and when to use them. These factors combine to put rural residents at higher risk for health complications and lower the overall health of populations.

Additionally, the facilities and resources available in rural areas are often deficient. Rural health posts also may not have proper diagnostic tools, which can lead to inaccurate diagnoses and unneeded treatments. Rural facilities often have a shortage of qualified staff because they are less desirable locations for health care workers. Fifty percent of health care workers in Nicaragua work in the capital, Managua, although only 20% of the country's population lives there (Dussault & Franceschini, 2006). Some countries, like Peru, Colombia, Costa Rica, and Panama, have programs that require or incentivize rural service, but this can lead to unmotivated and unwilling health care workers. These programs often attract younger professionals who typically have less experience and exhibit a high rate of turnover, creating issues with continuity of care (Webb & Valencia, 2005). Rural providers also have difficulty coordinating referrals due to the lack of communication equipment and may have to provide care out of their scope of training. Due to a scarcity of available specialists, patients must often travel long distances and wait long periods for appointments, which can reduce trust in the health care system especially if the specialist makes a subsequent referral. Patients also struggle to complete referrals due to the high monetary and time costs of travel, particularly when they must arrange for the care of their crops, flocks, or children (Anticona Huaynate et al., 2015). Difficult climates, topography, and terrain pose further challenges for health care workers trying to reach isolated areas that typically also

lack technology, facilities, and other resources. The varied geography of Latin America includes dense vegetation in the Amazon basin to high altitude and steep terrain in the Andes Mountains. Rural areas also lack transportation infrastructure like paved roads, public transportation, and bridges, which creates further challenges to travel.

Telemedicine

One method of improving rural health and decreasing urban-rural health disparities is through telemedicine, which involves the use of technology such as mobile phone messaging, electronic transmissions of data or images, and video calling to provide care to patients remotely. As such, it has proven useful in treating patients in rural, often isolated, communities. This approach provides access to otherwise unavailable specialized care by allowing professionals to run tests and share results remotely. For example, an ultrasound specialist at a large health center can review digital images of fetuses sent electronically from a mobile ultrasound machine used by a rural health care worker. Alternately, rural health providers can receive recommendations, training, or advice from urban professionals. Mobile devices, like pulse-oximeters or blood glucose monitors, can provide current information to health care practitioners allowing them to track women's statuses and monitor risks from afar (Lavariega, Córdova, Gómez, & Avila, 2014). This technology can also provide additional training to physicians, nurses and community health workers, which can ameliorate a common complaint from rural providers about a lack of opportunity for career advancement and continued education. Additionally, access to health care colleagues through telemedicine can reduce feelings of isolation in practitioners in remote areas, another disincentive of rural practice (Martinez, Villarroel, Seoane, & Del Pozo, 2004). Access to technologically equipped rural health posts can reduce travel costs and other deterrents for rural patients, such as having to miss work and find childcare. Finally, as opposed to traveling

clinics and other care options for rural women, telemedicine facilitates continuous and consistent care with well-trained providers. Although the implementation of telemedicine does not address every barrier faced by rural populations, it can help overcome many key issues.

Telemedicine is a supply-side intervention meaning it aims to increase the availability of personnel, facilities and other resources. Other examples of supply-side interventions include incentivizing rural practice, building new clinics, or supplying equipment (Hurst, Semrau, Patna, Gawande, & Hirschhorn, 2015). Additionally, this category contains more targeted approaches such as maternity homes, where women with high-risk pregnancies can stay close to well-equipped medical centers, typically in urban areas, and receive care throughout their pregnancy. On the other hand, demand-side interventions attempt to increase the utilization of existing goods and services usually through incentives or education. These include providing cash or other incentives, like car seats or food supplies, to people who meet certain criteria such as attending doctors' appointments or receiving vaccinations. Another type of demand side intervention is educational promotion regarding what resources are available and when to use them in order to increase consumption.

The most common demand side programs in Latin America are conditional cash transfers, which are especially prevalent in Brazil and Mexico. Some of these interventions aim to improve maternal and infant health by providing cash to pregnant women who attend prenatal appointments (Gopalan, Das, & Mutasa 2014). These types of initiatives often lead to increased utilization of services but do not necessarily improve disease and mortality indicators. This is because the increased utilization may expose a lack of resources, facilities and staff unable to meet the new demand (Hurst et al., 2015). As such, planners must often combine them with supply side initiatives, increasing cost and labor. This being said, the educational component of

telemedicine incorporates demand side methodology with its supply side aims, making it an even more attractive option.

Methods

Sources

An initial search was performed of the PubMed database, a collection of biomedical literature, using the following search terms: telemedicine, e-health, "mobile health", telehealth, prenatal care, and antenatal care. A search was also done of the Google Scholar database using the search terms telemedicine, prenatal care, and each Latin American country's name. The first one hundred relevant matches were reviewed in each search. Google Scholar automatically looks for any synonyms of the given search terms so other sources were also identified beyond those containing the specific search terms. Additional sources were found using the references lists of relevant papers and links to lists of related articles on PubMed and Google Scholar.

A further search was executed of grey literature, which includes reports and other publications done by government agencies and other nongovernmental organizations, such as the United Nations, World Health Organization, Pan-American Health Organization, and World Bank. These publications are not included in academic databases because they are not typically peer reviewed. This examination was done through searches of the government websites of the included countries and the websites of the above listed organizations using the previously stated relevant search terms. An additional search used the GSMA mHealth Tracker to identify obstetrics-related telemedicine programs in Latin American countries. The GSMA is an international organization of over 800 mobile service providers and their mHealth tracker identifies and consolidates a collection of mobile health programs around the world. Subsequent searches in Google Scholar using the names of identified programs were performed to find

pertinent literature.

Criteria

Publications were included if they met the following criteria:

I. The study or report evaluated an intervention that focused on telemedicine, telehealth, e-health or mobile health. Studies were also included that generally addressed the use of technology, such as mobile phones or the Internet, to provide care to a population.

II. The study or report focused on, or at least addressed, the utilization of these interventions in rural or remote areas.

III. The study or report focused on, or at least addressed, the provision of prenatal care to pregnant women.

IV. The study or report was conducted in a Latin American country, excluding the Caribbean. This included Argentina, Bolivia, Brazil, Chile, Colombia, Costa Rica, Ecuador, El Salvador, Suriname, Guatemala, Honduras, Mexico, Nicaragua, Panama, Paraguay, Peru, Uruguay, and Venezuela. French Guiana was excluded although it is part of mainland South America because it is a territory of France.

V. The study or report was a peer-reviewed publication, a report by a governmental agency, or a report by a reputable nongovernmental organization.

VI. The study or report was published after January 1, 2000.

VII. The study or report was available in English or Spanish.

The topic criterion was included in the database search terms and also screened for manually. The location criterion was screened for by hand rather than in the search terms to prevent relevant papers from being excluded by the search engine. However, the language and

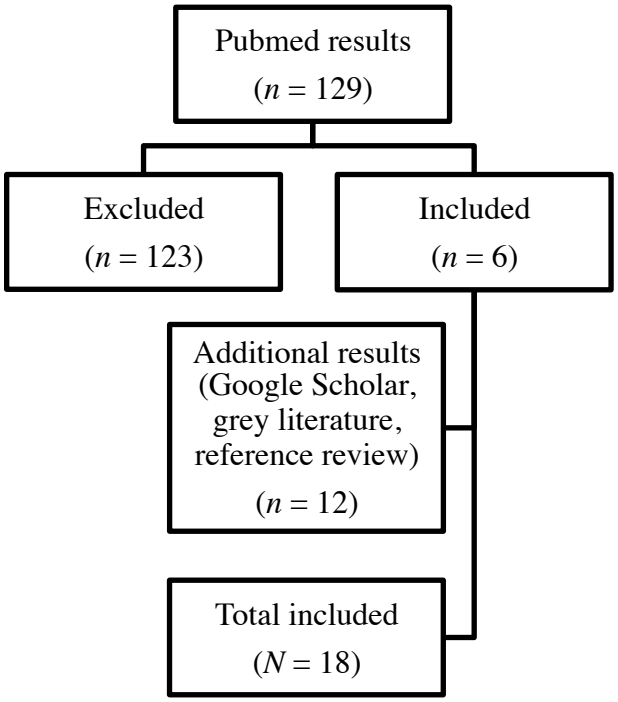
date criteria were added into the database search. The timeframe criterion was added because most modern information and communication technology was not widely available before 2000, especially in developing countries. The criterion of being peer-reviewed or published by a reputable organization was added to ensure a high quality of data and information and was screened for by hand or was implied by the source of the publication.

Results

Selections

An initial search of the PubMed database using the above search terms yielded 129 results. After screening the titles, abstracts, and/or bodies of these papers 111 studies were excluded because they occurred outside of Latin America. Two more studies were excluded because they were published only in Chinese and another one was excluded because it was published only in Portuguese. Another eight studies were omitted for not specifically addressing telemedicine and/or prenatal care in rural areas. This left six remaining results from PubMed (n = 6), three of which were studies performed in Latin American countries (n = 3). The remaining three were global review articles that considered at least one program in a Latin American country (n = 3). Reviewing the references of the above papers, Google Scholar, and grey literature sources resulted in the identification of twelve additional relevant results (n = 12). This included nine peer-reviewed study papers (n = 9), one peer-reviewed literature review paper (n = 1), and two grey literature reports (n = 2). The literature review process is illustrated by Figure 1.

Figure 1
Literature Review Results



In total, eighteen relevant sources were identified ($N = 18$). There were twelve total peer-reviewed study papers ($n = 12$), one from Argentina, one from Bolivia, one from Chile, two from Colombia, two from Guatemala, two from Mexico, two from Nicaragua, and one from Peru. Of these, eight were observational studies, three were quasi-experimental studies without random assignment of groups, and one was a true experimental study with random assignment of groups. There were also four total peer-reviewed literature review papers ($n = 4$), one that considered a program from Argentina, two that included programs in Peru, and one that considered a program in Colombia. Finally, there were two grey literature publications ($n = 2$), one that addressed a program in Mexico and the other a program in Peru. These eighteen publications studied a variety of different mediums of providing care and a wide variety of services that can be provided to patients. This information is displayed in Table 1.

Table 1
Literature Review Results

Study & Location	Medium	Services	Outcomes Measured	Results
Bravo et al., 2012 (Nicaragua)	Internet	Emergency alerts, status monitoring	N/A	N/A
Cormick et al., 2012 (Argentina)	Mobile phones (SMS messages)	Educational information	Interest in receiving messages	*n* = 147; 96% showed interest
Crispín Milart et al, 2012 (Guatemala)	Internet	Portable ultrasound, blood tests, health info system	Maternal mortality, neonatal mortality, anemia detection, referrals	*n* = 159; maternal mortality reduced, neonatal mortality reduced, anemia detection increased, referrals increased
Kolbe et al., 2014 (Nicaragua)	Internet	Point of care ultrasound	Categories of use, change in management	*n* = 132; most common use was prenatal exam, 2 pregnant women changed management
Lavariega et al., 2014 (Mexico)	Tablet with internet	Mobile sensors	System proposal	N/A
Leon et al., 2013 (Colombia)	Software	Collecting and sharing data	Usability of software	Lowest scores for consistency
Lewis et al., 2012 (Review – Peru)	Mobile phones or internet	Data sharing	N/A	N/A
Martínez-Fernández et al., 2015 (Guatemala)	Community facilitators with mobile phones	Data sharing, continuing education	Number of uses, child mortality, maternal mortality	*n* = 116,275; child mortality decreased, maternal mortality decreased
mHealth Alliance, 2012 (Review – Mexico)	Remote monitors	Risk management	N/A	N/A
Odibo et al., 2013 (Review – Colombia)	Website	Consultation	N/A	N/A

Pérez-Lu et al., 2015 (Peru)	N/A	N/A	State of maternal health information systems	Issues with horizontal and vertical transmission
Sondaal et al., 2016 (Review – Argentina)	Mobile phones (SMS messages)	Educational information	Interest in receiving messages	*n* = 147; 96% showed interest
Tamrat et al., 2011 (Review – Peru)	Smart phones for HC workers	Data sharing	N/A	N/A
Tapia-Conyer et al. 2015 (Mexico)	Sensors	Remote monitoring	Adherence to prenatal care schedule	*n* = 153; increased adherence
Valenzuela et al. 2007 (Colombia)	Website	Consultation	Number of users, categories of use	*n* = 270; ob/gyn most common category
Vargas et al., 2014 (Bolivia)	Internet	Ultrasound	Number of uses, categories of use	Obstetrics was third most common category
Viñals et al., 2005 (Chile)	Internet	4D ultrasound	Ability to execute and educate on ultrasound	*n* = 50; 86% and 95% successful cardiac exams from 2 operators
Vital Wave Consulting, 2009 (Review - Peru)	Smart phones for HC workers	Data sharing	N/A	N/A

Services

Provision of educational information for patients. Four publications examined the use of telemedicine to provide educational information or consultations to patients (*n* = 4). A study conducted in Argentina examined pregnant women's access to mobile devices and their interest in receiving educational information regarding pregnancy and infant care via their mobile phones (Cormick et al., 2012). Questionnaires were administered to women attending prenatal care visits

at two public hospitals in an urban area and at community health centers in an area including many rural women. Although 89% of participants reported living in urban areas, the mean travel time to the nearest hospital was 43.4 minutes, meaning rural women were an important component of the study cohort. They found that 96% of the women expressed interest in receiving educational SMS messages and 87% expressed interest in receiving informational phone calls. Some of the most common topics of interest were pregnancy dietary information, when to call a doctor during pregnancy, when to call a doctor for a newborn, and what to avoid while pregnant (Cormick et al., 2012). This study was included in the literature review "Assessing the Effect of mHealth Interventions in Improving Maternal and Neonatal Care in Low- and Middle-Income Countries: A Systematic Review." This review found that telemedicine, or mobile health, could be an effective way of improving maternal and neonatal health in developing countries (Sondaal et al., 2016). The second study evaluated a website called Doctor Chat, which is used in Colombia, Mexico, and Spain to provide remote health care consultations and answer patient questions. The researchers assessed its utilization and the categories of use. The majority of uses came from Colombia, with Mexico in third place. Obstetrics and gynecology was the most commonly requested specialty, with 26% of total uses (Valenzuela, Arguello, Cendales, & Rizo, 2007). This study was also included in a review article titled "Telemedicine in Obstetrics" which concluded that telemedicine could be an effective tool in providing care to pregnant women in remote areas (Odibo, Wendel, & Magann, 2013).

Although they are weakened by their small samples sizes and short durations due to the newness of this technology, all of these studies show the promise of the use of telemedicine in rural areas. Through already available technology, namely mobile phones and the Internet, rural women can receive valuable information regarding pregnancy the and care of their newborns, an

important component of prenatal care. This can help prevent many causes of maternal and infant death and improve the health status of rural women and children through providing information about nutrition and prevention. It also allows women to receive accurate information in answer to their questions. This technology could also inform women about resources they may not know are available to them and how they can access them in their communities. Finally, the same type of system could be used to provide continuing education to health care workers and allow them to have questions answered or access more information. These programs could potentially be expanded to be continuous and longitudinal, allowing women to have consistent counseling with trained professionals throughout their pregnancy and the beginning of their child's life. This could help rural women to create meaningful connections to the healthcare system and increase trust and utilization of resources.

Remote monitoring. Four publications addressed using technology to monitor pregnant women remotely ($n = 4$). A study conducted of 153 women with high-risk pregnancies in rural Mexico found that including a technologically equipped prenatal monitoring program, MiBebe, increased adherence to the recommended prenatal visit schedule to 94.3% compared to 45.1% in the control group. The maternal-fetal monitoring involved collecting samples and measurements, such as urine and weight, as well as thirty minute fetal monitoring sessions, including ultrasound of the fetal heartbeat and measuring uterine contractions. All of the data were sent to an obstetrics specialist who then made further recommendations (Tapia-Conyer et al., 2014). The mHealth Alliance, an organization of USAID, included this study in a publication called *Leveraging Mobile Technologies to Promote Maternal & Newborn Health*. This report used MiBebe as an example of how telemedicine can be an effective way of improving human resource capacity, better equipping health care workers to do their jobs (mHealth Alliance,

2012). Another paper from Mexico proposed a system, Mamicare, which would facilitate the monitoring of pregnant women using devices such as blood glucometers, portable ECG, and portable ultrasound. Risk assessment software would alert a social worker of any issues and all data would be stored and checked by a remote physician. The electronic records would be available in an emergency and would allow for detection of potential problems (Lavariega, Córdova, Gómez, & Avila, 2014). The final paper in this category described the development of a telemedicine system in Nicaragua. They addressed its ability to be used for prenatal monitoring, risk detection, and larger scale data collection to assess the health of communities. The researchers found telemedicine to be a promising and effective method of improving health outcomes, despite any challenges associated with its implementation (Bravo et al., 2012).

These publications are again limited by small sample sizes and short study durations. Additionally, there is a significant lack of research regarding the effectiveness of this monitoring technology in reducing complications before and after birth as well as increasing detection compared to standard methods. However, this branch of prenatal care could be greatly impacted by telemedicine and could have significant influence on maternal and infant health. The ability for lower level health care providers to monitor women and then have specialists confer could greatly improve health outcomes for women and infants. It could also improve the pregnancy experience of many women through symptom detection and treatment. Furthermore, knowing and understanding their vital signs could help women to have more ownership of their pregnancy experiences. This could give them more confidence and understanding of their health during and after pregnancy. Additionally, having accurate information would help providers to make well-informed decisions about future care for their patients, improving their overall experience, and allowing rural practitioners to have more confidence about the services they are providing.

Ultrasound. Four studies specifically assessed the provision of ultrasound through telemedicine, which could be considered a subset of remote monitoring ($n = 4$). One study of 1,500 women in rural Guatemala assessed women who received prenatal care from travelling nurses equipped with technology. This included a portable ultrasound, which could be charged by solar power, and a blood testing kit that was easy to store and transport. The nurses also had access to an online health information system where they uploaded records, including ultrasound images. Gynecologists in Spain then reviewed these images and gave feedback and instruction. There were fewer maternal and neonatal deaths in the experimental group compared to the control group as well as more hospital referrals for complications such as fetal malpresentation and multiple pregnancies (Crispín Milart, Diaz Molina, Prieto-Egido, & Martínez-Fernández, 2016). Another study in rural Nicaragua examined the effect of point-of-care ultrasound, or imaging at a patient's bedside, after training health care workers in a clinic to do the examinations. They found that out of 132 patients, the most common use was for prenatal exam, 23.5%, and a change in health management occurred in 2 of the cases of pregnant women (Kolbe et al., 2014). A third study in Chile tested if general obstetricians could be taught via email to obtain accurate images of fetal hearts. Further, the study investigated whether that information could be successfully transmitted for evaluation by specialists for signs of congenital heart defects. One operator was able to successfully complete a cardiac exam 86% of the time and the other operator was successful 95% of the time, meaning the training and transmission was effective. Several fetuses were diagnosed with heart defects, whose mothers were then counseled via email and videoconference (Viñals, Mandujano, Vargas, & Giuliano, 2004). The final study in Bolivia addressed the implementation of a new telemedicine program in a rural area, including ultrasound technology. Obstetric visits, specifically for prenatal check ups, were among the top

three uses of this technology. The authors concluded that telemedicine could be expanded in the country in collaboration with the government (Vargas, Ugalde, Vargas, Narvaez, & Geissbuhler, 2014).

While there were limitations with these studies due to small sample size or inability to randomly assign groups, they each demonstrate the viability of introducing telemedicine based ultrasound programs in rural Latin America. These four studies from four different countries demonstrate that it is not only possible, but also very effective to train rural health care providers to conduct ultrasounds and either to analyze them themselves or send them away for remote analysis. Ultrasound is a very important tool in prenatal care and can detect many risk factors in fetuses and mothers making its expansion a worthwhile goal. These scans help estimate gestational age, which allows women and health care workers plan to better during pregnancy, and increase the detection of multiple pregnancies and fetal anomalies (WHO, 2016). In the study addressed in the previous section conducted in Mexico, women who were given the opportunity to hear their baby's heartbeat through ultrasound considered it to be the most beneficial part of their monitoring experiences as they could gain insight into the health of their babies (Tapia-Conyer et al., 2014). This peace of mind and connection with their babies evidences the benefits of ultrasound access beyond those directly related to health. Additionally, in learning this new skill, rural health care workers are given an opportunity for continued education, which is often lacking in remote areas away from large medical centers and can help with the recruiting and retention of these workers.

Electronic data sharing. Although similar to the topic of remote monitoring, six papers focused more specifically on the sharing of data remotely ($n = 6$). One study in Guatemala assessed a program called TulaSalud in which community facilitators are given cell phones,

which allow them to upload epidemiological data that can be monitored remotely, ask questions or get help during an emergency, and continue to be trained. After five years and 116,275 consultations, the researchers found statistically significant reductions in maternal and child mortality in areas with this program (Martínez-Fernández, Lobos-Medina, Díaz-Molina, Chen-Cruz, & Prieto-Egido, 2015). Another study in Colombia designed and evaluated a software program to help facilitate the collection and sharing of data from prenatal care visits. TeleAIEPI helps the health care worker through the exam, suggests steps moving forward in light of the data collected, and sends the data to a physician for further analysis and recommendations. They found this software to be functional and effective (Leon, Aponte, Vega, & Romero, 2013). A project in Peru, WawaRed-Peru, assessed the current state of health information systems in Peru with hopes of making recommendations for improvements. They found serious deficiencies in infrastructure and issues with the vertical and horizontal transmission of information. Vertical transmission includes information sent from a local health care center to a regional hospital or other higher-level health facility. Horizontal transmission means information shared within a single health care center or between facilities of the same level. They recommended increases in training and in interoperability standards of health information systems (Pérez-Lu, Iguiñiz Romero, Bayer, & García, 2015). Finally, two peer-reviewed review papers and one grey literature publication addressed a Peruvian program, Nacer, which allows rural providers to share data via phone or Internet with specialists or hospitals. This helps rural health care workers and their urban counterparts to track patients, make referrals and recommendations, monitor disease outbreaks, and track supply usage (Lewis, Synowiec, Lagomarsino, & Schweitzer, 2012; Tamrat & Kachnowski, 2011; Vital Wave Consulting, 2009).

The study of TulaSaud is strong as it was conducted over several years with more than

116,000 exams completed. Though less thorough and without testing or data, the reviews of Peruvian programs, the assessment of the status in Peru, and the proposed TeleAIEPI software further showcase the potential of this branch of telemedicine in prenatal care (Lewis, Synowiec, Lagomarsino, & Schweitzer, 2012; Tamrat & Kachnowski, 2011; Vital Wave Consulting, 2009; Pérez-Lu, Iguiñiz Romero, Bayer, & García, 2015; Leon, Aponte, Vega, & Romero, 2013). With the ability to share data with specialists, not only do patients receive higher quality and more consistent care, but rural health care workers can also feel more connected to other professionals, thus reducing feelings of isolation and allowing for collaboration. Patients can receive analysis and advice from specialists without traveling long distances and having to make accommodations for their lives at home. Specialists could also care for more patients in less time because remote consultations would be more focused than traditional visits, which could help alleviate some of the bottlenecking that occurs due to high patient volume and a scarcity of specialists. Further research is needed over the long-term comparability of health outcomes for patients who receive remote care verses those who receive in person visits. However, this is not necessarily an equal comparison because many people who could benefit from remote care may have gone without care due to the barriers previously discussed.

Discussion

Overview

These four categories: education, ultrasound, remote monitoring, and electronic data sharing, meet many of the needs that are experienced in rural areas. Of the five major components of the WHO prenatal care recommendations: nutritional interventions, maternal and fetal assessment, preventative measures, interventions for common physiological symptoms, and health systems interventions (WHO, 2016), the provision of the four groups of services covers

many of their features. This is illustrated by Figure 2. For nutrition, the major point of counseling and education could be conducted with educational networks. However, there would need to be further increases in access to tangible resources such as folic acid or iron supplements. The major factors in maternal assessment, such as anemia testing, diabetes testing, and tobacco or substance use monitoring could also be conducted using telemedicine. The remote blood testing kits and glucometers provide practical testing services and remote counseling and education would help health care workers understanding of the women's substance habits. The only universally recommended fetal monitoring measure, ultrasound, can also be executed via telemedicine. With regards to prevention, telemedicine is likely less useful because vaccinations must be administered by hand and antibiotics must be provided physically. However, the impact telemedicine could have on the recruitment and education on rural health care workers could improve this. For symptom interventions, remote monitoring, education about treatment options, and long-term counseling could help women with their symptoms and help their practitioners care for them although there would need to be tangible interventions as well.

Figure 2.
WHO Recommendations Address by Telemedicine
Items marked in bold can be addressed with telemedicine

Nutrition	Maternal/Fetal Assessment	Prevention	Symptom Intervention	Health System Improvements
•**Education**	•**Substance Use Monitoring**	•Vaccination	•**Montoring**	•**Woman-Held Notes**
•Supplements	•**Testing**	•Antibiotics	•Treatment	•**Task Shifting**
	•**Ultrasound**			•**Community Engagement**

The implementation of telemedicine would also meet many of the goals of the health system intervention recommendations. Electronic health records would help with continuity and

quality of care. The ability to train providers remotely could increase the number of qualified health care workers would also help with both of those aims. Telemedicine could also be used to equip midwives, nurses, and community workers to perform some of the duties previously confined to doctors, which would allow more women to receive care. The specific goal of "recruitment and retention of staff in rural and remote areas" (WHO, 2016, xvi), could be improved by the education, collaboration, and career advancement opportunities provided by telemedicine programs. The final goal of increased prenatal contacts to eight visits during pregnancy could also be aided by the implementation of telemedicine as more women could receive care and would be more likely to access care.

Addressing Counterarguments

As stated previously, telemedicine is a supply side intervention. Some argue that demand side interventions are more efficient as they take advantage of existing resources rather than having to introduce new ones. These programs often increase utilization of services but often do not improve health because there is not enough supply to meet the new demand (Hurst et al., 2015). With that in mind, telemedicine can be a viable alternative because although it is considered to be a supply side intervention, the educational component that it involves could also allow it to increase demand. By providing women with general health education and information about available resources, such programs may increase their demand for health care for themselves and the rest of their families. As such, telemedicine is a better alternative to strictly demand side programs, like conditional cash transfers, because it also increases the availability of resources, access to specialists, and care in general. Telemedicine can also be an effective counterpart to demand side interventions as a means of increasing supply.

Another argument is that virtual interactions with health care practitioners are inferior to

in person visits. While this may be true, and it is likely there has not been enough research on the topic, the comparison here is not between receiving in person visits versus virtual visits. Instead, most of the time the comparison is between virtual visits and no visits at all. Since current efforts to increase availability of services for rural women have not been entirely successful as evidenced by the continuing disparities in the region, an alternative to in person visits must be found, at least for the short term. While increasing the number of facilities, practitioners, and other resources in rural areas should occur, telemedicine offers a viable alternative in the meantime. Additionally, telemedicine offers a long-term solution for extremely isolated area where building large facilities or employing specialists may not be cost-effective or realistic. Also, as technology continues to develop, virtual visits will likely become increasingly similar to in-person visits and any inferiority that may exists would diminish. No papers could be identified that specifically compared the effectiveness of in-person prenatal care versus virtual care, either in Latin America or in other areas of the world. As such, further research must be conducted of the health impacts and long-term systematic effects of virtual interactions with the health care system versus in person interactions.

Future Implementation Possibilities

In light of the data and results of this literature review, telemedicine programs in rural Latin America appear to be a promising medium to increase access to prenatal care. Despite the scarcity and limitations of existing studies and publications, telemedicine appears to be a viable option to increase access to care and increase quality of care for rural women. By giving women access to consistent, high quality care, it would make them more likely to seek out care in the future for themselves and the rest of their families. Telemedicine could not only impact the patients, but also improve the work and experience of rural health care practitioners, which could

increase their retention and recruitment. Governments and nongovernmental organizations must work closely with members of rural communities to ensure these programs are actually meeting the needs of their target populations and are fitting with the culture and systems that exist in these regions.

Although rural areas often lack access to technology, the Internet, and other resources necessary for the utilization of telemedicine (Martinez et al., 2004), many rural communities do have access to some existing infrastructure with potential for expansion. Ninety percent of Latin Americans have access to mobile broadband coverage, and while many of those without access are in rural areas, this evidences the feasibility of the expansion of services (GSMA Association, 2015). As of 2017, every mainland Latin American country except for Suriname had at least one telemedicine related program ("mHealth Deployment Tracker", 2017). Those that are not used to provide prenatal care could be expanded to deliver those services, and those not present in rural communities could be extended into those areas by expanding infrastructure. Although implementing such programs would require investments in training, infrastructure, and continued maintenance, they would generate significant savings for the health care system as a whole and for individuals in the community. The prevention of serious, often expensive, health issues would save the costs of further care for individuals and would reduce strain on health care facilities and programs (Orta & Sanabria, 2012). Telemedicine infrastructure and technology, such as Internet access and hardware, also could provide other types of care beyond obstetrics to benefit all members of the population. Additionally, communities could potentially use this infrastructure to conduct non-health related matters such as business, communications, and education, which could further improve the overall standard of living in the area.

Governments and accreditation organizations could implement a telemedicine

certification system that would encourage rural practitioners to receive training by allowing them to increase their credentials and have opportunities for career advancement. There are many of these types of certification programs in the United States and in other developed countries for providers of varying levels of education. For example, physicians in the United States can receive "Continuing Medical Education Units" from accredited telemedicine training programs ("Telehealth Resource Center", 2017). Certification could be incorporated into existing medical education programs, earned remotely, or made available through independent in person training programs. This would incentivize telemedicine training and hopefully attract more health care practitioners to the field. It would also encourage interest in telemedicine among students, researchers, and providers, which could increase awareness, research, and development.

Of the over one hundred sources excluded for not meeting the location criteria, the majority assessed obstetrics telemedicine programs in other parts of the world. Some considered programs in the United States, Australia, or other developed countries, but many evaluated programs in developing countries, from India, to Uganda, to Cambodia. This evidences that these programs not only exist in other parts of the world, but also are being evaluated and assessed for their efficacy and impact in their communities. A further search of grey literature would likely reveal more of the same. As such, the example of these programs should be adapted to meet the needs of Latin American communities and used as a model to start new programs and expand upon existing initiatives in the region. Additional studies were found relating to telemedicine programs in Latin America that were not being used to deliver prenatal care. These should be expanded to provide prenatal care, as it is an important service that greatly impacts the health of women and children. Collaborations should also be encouraged between countries, like the Doctor Chat program with Spanish doctors being involved in providing remote counseling

(Valenzuela et al., 2007). This allows the resources of developed countries to benefit the populations in developing countries. As the world continues to become more connected by technology, there will be ever increasing opportunities and need for collaboration.

Conclusion

Although there is relevant research being conducted in the field of telemedicine throughout the world, there is a lack of studies focused on rural Latin America and on the provision of prenatal care. The number of studies from developed countries, and from developing countries in other parts of the world, evidences the potential for this research and these programs in Latin America. Moreover, from the available research, telemedicine appears to be a promising method of increasing access to prenatal care in rural Latin America. As prenatal care is recognized internationally as an important contributing factor to maternal and infant health, this is a worthwhile goal. Additionally, as the health of rural women and children continues to fall behind that of urbanites in the region, any method of increasing health care access for this population must be considered. Telemedicine offers an efficient and effective solution that can utilize existing infrastructure and personnel while improving health outcomes. Such programs can also be expanded to serve other areas of rural populations and be used for other activities with the potential to improve quality of life.

Research must continue in the field of telemedicine and prenatal care regarding the effectiveness of these programs in improving maternal and infant health. Researchers must also evaluate their costs over time and their utilization in communities. Governments and nongovernmental organizations must assess the needs of rural women and children to ensure that programs are serving them as best as they can and that they are continuing to benefit from telemedicine. Additionally, they must devote resources to long-term maintenance and training to

ensure investments in infrastructure and preparation are not wasted with inevitable decay. As urban populations continue to swell and rural populations continue to shrink, rural communities will become increasingly vulnerable and easier to overlook when budgeting, creating programs, and conducting research. As such, it is incredibly important that the international community continues to advocate for and work to improve the health of rural populations, especially that of their most vulnerable subsets.

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