

Technology and Pregnant women: exploring pregnant women's perception of mobile app
design, utility, and information credibility

by

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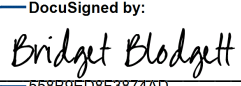
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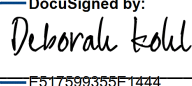
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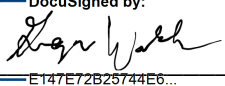
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Abstract

This study contributes to the research on pregnant women and their preferred use of mobile technology by exploring the perceptions of pregnant women of mobile app design, utility, and information technology. Explanatory sequential mixed methods research design was used. Quantitative data were collected from fifty-nine pregnancy women living in the United States between March and June 2021 using anonymous web surveys administered on social media platforms to pregnant women living in the United States. Qualitative data were, gathered using online multiple case study involving co-design techniques, were obtained from four pregnant women and one gynecologist.

Findings from the study demonstrate the relevance and adequacy of pregnancy apps in providing information access to pregnant patients. More than four-fifth of the participants had used pregnancy or health related apps in their current pregnancy. The results of study indicate that designers of pregnancy applications provide user friendly interfaces, information layout, fonts, information architecture, navigational aids, and menu because mobile app designs affect how pregnant patients perceive quality health information on pregnancy apps. The results also suggest that the involvement of stakeholders (i.e., people who will use the technology) in the design and development cycle is key for creating digital products and services that will meet user's needs and goals.

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Chapter 1: Introduction

The health care system plays an important role in the welfare and development of a nation. The United Nations (UN) Sustainable Development Goals (SDGs) prioritize health and well-being as the third development agenda to be achieved by 2030.

Achieving this will require substantial improvement in access to health care and provision of health information using technology. This study contributes by investigating the perceptions of pregnant women on mobile technology in the United States.

Understanding their views on mobile app design and information credibility can foster improving health information access using mobile technology to meet their growing health needs.

Technology and Health Care System

The United States operated a paternalistic health care system in the past, which limited patient's participation and involvement in health decisions. However, with the advent of internet technology, people's interest in health topics has increased, and newer technologies avail more people access to health information with or without physician's approval. Furthermore, there has been a swift shift in roles and responsibilities of physicians and patients. Unlike before, when physicians predominantly made health decisions for the patient, patients are now required to collaborate with their physicians in making health decisions (Honavar, 2018). Involvement of patients in health decisions is very important in health care delivery for better health outcomes (Shoshani & Kanat-

Maymon, 2018; Slattery, 2008). It is therefore vital to understand patient-physician relationships for improving health care delivery and patient compliance.

Patient-physician interaction is vital for achieving quality health care and better health outcomes. The patient-physician relationship is regarded as the second most important relationship after family relationships (Laugesen, Hassanein & Yuan, 2015). It is also the foundation on which medical care is built, simply because it can positively or negatively affect health outcomes (Johnson, 2019). Many studies have documented some negative health outcomes caused by poor patient-physician interactions, namely: poor patient satisfaction, protests, poor communication, lack of trust in physicians, unbalanced medical information and noncompliance to treatment protocols (Peng et al., 2020; Witzeman et al., 2020; Yelovich, 2016).

Technology is, however, changing the information asymmetry between patients and physicians. Physicians in the past did not see themselves as communicators and educators on health issues to their patients, but technology is changing this perception. This is because there is enormous online health information available to patients with varying degrees of accuracy (Peng et al., 2020; Nikiphorou & Berenbaum, 2018). Hence, understanding the patient-physician interaction can reveal some of the communication gaps. Notably, good patient-physician communication and patient compliance are central to effective patient-physician interaction.

Patient compliance is a major issue in the field of health sciences. Many studies have reported the impact of increased cases of non-adherence to treatment plans among patients globally (Yelovich, 2016; Laugesen, Hassanein & Yuan, 2015). Patient

compliance can be defined as decision of the patient to follow treatment regimens or plans recommended by a health care provider. Patient compliance is noticeable in adherence to medications, routine check-ups, healthy diets, and healthy lifestyle (Lu & Zhang, 2019; Malek et al., 2017). Advantageously, it promotes quicker recovery from diseases, self-management of health, and improved quality of life among patients (Zhang, Zhang, Lu & Zhu, 2018). For the purpose of this study, patient compliance is defined as the degree to which patient's behavior matches physician's instructions.

Conversely, patient noncompliance can be defined as the active and passive refusal to comply with instructions or treatment plans given by physicians (Yelovich, 2016). Noncompliance increases negative health outcomes and consequences among patients. Annually in the United States, an estimate of 125,000 deaths, more than US\$100,000 billion in additional health costs and a 10% increase in hospitalizations are caused by noncompliance to treatment plans (Kleinsinger, 2018; Laugesen, Hussanein & Yuan, 2015; Benjamin, 2012). Therefore, improving patient-physician communication with the use of newer technologies could improve patient satisfaction, trust, and compliance to treatment protocols. Technological advancement in health care is paving ways for use of mobile interventions to improve clinical care and patient compliance.

The use of mobile health applications can increase easy access to medical resources and health information in the United States. Recent studies have noted the positive impacts of mobile apps for promoting efficient and unobstructive interaction between patients and physicians (Nikolic et al., 2018). Health apps are also excellent at promoting easy communication (remote synchronous and asynchronous communication),

which could be a cure to alleviating the inequality growing in the health care system (Nikiphorou & Berenbaum, 2018; Jacobs et al., 2017). Thus, health mobile apps can increase and support patient compliance, thereby improving and saving lives (Lu & Zhang, 2019; Gan et al., 2016).

Background on Health Information Sources

The consultation model with physicians has evolved over the years. In the past, many patients received health care at home, with the physician traveling to the home of the patient to administer treatments. Today, many patients are required to visit their physician's office or hospital to receive health care. More patients prefer to visit their physicians at the hospital or health centers because of access to medical equipment, work efficiency among physicians and sanitized environment (Gan et al., 2016). Despite this shift, home-visits care still exists in some settings, both in developed and developing nations.

Advancement in internet technology is changing the medical landscape as well as other fields of human endeavors as more people depend on technology for making informed decisions regarding their health (Gan et al., 2016). This narrative is not different for people living in the United States: the Pew Internet and American Life project found that 80% of the population have used the internet for searching for health information (Ren et al., 2019). Furthermore, the internet is creating a valuable platform for delivering health interventions that can improve health behaviors and lifestyles. The potential of web-based interventions has been explored in topics such as alcohol intake, tobacco

cessation, weight gain, medication adherence and maternal and fetal health (Ryan, Bergin & Wells, 2017; Knight-Agarwal et al., 2015).

Patients utilize internet health information to learn about early diagnosis of health conditions, supplement physician's advice and compare treatment options (Zhang et al., 2019). Since more patients are heavily reliant on internet health information, mobile health applications can serve as good tools for delivering health interventions that can increase patient compliance to treatment protocols.

Many people use and rely on mobile technology to carry out their daily tasks and goals. This is not different in the health care sector, as technology-mediated health care is enhancing the way people receive care and access health information (DeNicola et al., 2020; Ren et al., 2019). Mobile technology is gradually changing the consultation model in clinics as patients can now receive health care from anywhere at any time at lesser costs using their mobile devices (Nikolic et al., 2018). This means of receiving care is breaking geographic boundaries as technology is allowing people to receive health contents and care from different parts of the world with just a touch of a button on a smartphone (Niela-Vilen et al., 2019).

Communication style or approach has also been affected by mobile technology. Mobile technology is expanding human communication beyond conversing over the phone by offering face-to-face real-time communication using mobile apps. In the health care sector, mobile applications are now ubiquitous as medical professionals and patients use this technology to connect, educate, motivate, and empower themselves on different topics related to general well-being (Nikolic et al., 2018). A review of mental and

physical mobile health apps revealed about 160,000 mobile health apps were available for download in apps stores (Sedrati et al., 2016).

Though mobile devices are patients' most preferred channel of receiving health information, physicians are still the most preferred source of health information (Laugesen, Hassanein and Yuan, 2015). These tools can be used to effectively promote patient-physician communication. Good patient-physician communication increases compliance to treatments (Lu & Zhang, 2019). Empowering patients to confidently engage in shared decision making about health outcomes, tracking of physiological and psychological biometrics to inform quicker health decisions are some of the advantages of mobile health applications (Jeffrey et al., 2019; Lu & Zhang, 2019).

Pregnant women are an important part of any society because the outcome of pregnancy affects lives and posterity. Even though pregnancy is a normal health condition, it requires adequate information, care, and medical resources to go through the phase successfully (Ghiasi, 2019; Javanmardi et al., 2019). Sadly, maternal deaths are still very high in the U.S. in comparison with other developed nations. Many of these deaths are caused by preventable causes (Collier & Molina, 2019).

Pregnant women use a variety of health information sources and channels ranging from print sources to electronic sources for staying healthy during pregnancy (Daly et al., 2017). Pregnant women also use social networks, mobile applications, search engines, and online health communities to seek for information, advice, reassurance, and emotional support. Connecting with other experienced mothers is one of the key benefits of these platforms to pregnant women (Thomas, Lupton & Pedersen, 2017). Pregnancy

brings about changes in the physiological and immunological makeup of the woman, causing them to consult different information sources and channels to reduce the level of uncertainty they have about pregnancy (Anggraini, Utami & Zairina, 2019). The use of mobile health applications has been associated with adherence to prenatal visits, decreased cases of low birth weight and improved monitoring and avoidance of obstetrics danger signals (Bush et al., 2017). Hence, use of mobile health applications may be useful to the health of pregnant women and fetuses.

Problem Statement

Pregnant women use a variety of information sources and channels for meeting their health needs during pregnancy and immediately after pregnancy (Lee and Moon, 2016). Mobile devices are ubiquitous in developed countries and generally incorporated into everyday life use. Proliferation of smartphones has given rise to numerous mobile applications. These health apps are efficient for managing health, educating patients, providing self-care information, setting and actualizing health goals, completing routine tasks efficiently, providing faster access to health information and permitting real-time communication from any part of the world at any time (Hussain et al., 2017; Osmá, Barrera & Ramphos, 2016).

Mobile health applications offer a flexible consultation model to patients by providing a portable, convenient, and accessible means of delivering and receiving health care. It also holds the capability of connecting patients with physicians in a short time. It offers easy and timely access to wealth of online health information, provides access to

personal experiences of other patients in similar health conditions and grant access to valuable enhanced high-resolution audio and video health contents (Daly et al., 2017; Lupton & Pedersen, 2016; Marko et al., 2016).

The primary source of health information to pregnant women is their healthcare providers. They rely on them for preventive health care and for meeting their health needs during pregnancy and immediately after pregnancy (Akanbi & Fourie, 2018). However, many studies suggests that most of these women still have unmet health information needs during pregnancy (Robinson et al., 2018; Kamali et al., 2018). The gap in knowledge about their health status encourages them to consult other information sources.

Prior to the internet age, pregnant women generally relied on traditional and print information sources such as physicians, health magazines, pamphlets at the doctor's office, books, and experienced family members for pregnancy-related information (Daly et al., 2017). With the advent of the internet and mobile technologies, the information-seeking behavior of pregnant women has shifted to rely on online resources for meeting their health needs (Kraschenewski et al., 2014). Many pregnant women prefer online sources using mobile devices for meeting their health needs during pregnancy.

However, there are serious concerns about the health information quality, accuracy, utility, and credibility of contents delivered on mobile health applications to pregnant women. A recent review and content analysis on mobile applications providing guidance on decreased fetal movement revealed that mobile applications failed as an antenatal tool for educating pregnant women on fetal movement information. It offered

inaccurate contents and unscientific advice on decreased fetal movements (Daly et al., 2019). Similarly, another study confirmed that health applications usage among pregnant women sometimes decreased their activation level i.e., patient's collaboration and engagement with physicians (Ledford et al., 2017). Thus, the success and adoption of a mobile interventions for pregnant women depends on different factors. App comprehensiveness, contents accuracy and utility are some notable factors to consider for users. Additionally, a study affirmed that apps interface features, such as navigational aids, font, and layout, are perceived by pregnant women to be quality metrics and motivators for adoption of pregnancy apps during pregnancy (Mao et al., 2018).

A significant and proposed means of improving patient compliance is through mobile interventions (Jeffrey et al., 2019; Lau et al., 2018). In contrast, Lee and Moon's (2016) study on utilization and content evaluation of mobile applications for pregnancy, birth and childcare noted that pregnancy-related applications could lead to patient noncompliance. Some pregnancy applications promote inadequate health information based on unscientific and unproven clinical knowledge. Some apps contain contradictory health information and recommendations.

Another challenge of health apps is poor app descriptions. The app descriptions designed to help users make informed choices on app downloads often does not provide detailed safety information pertinent to make informed decisions on app behaviors and utility. This often leads to user frustration. Users frequently end up in series of trial-and-error behavior evidenced in downloading and deleting different applications before

eventually finding a useful app suitable for their health needs. This may be the reason for poor adoption of mobile apps among users (Shaheen et al., 2018; Kuznetsov et al., 2016).

One major way to overcome some of the challenges identified with use of mobile health apps is the involvement of physicians. They can provide a list of credible health applications to their patients as well as increase consultation time to discuss what the patients might have learned online. Use of physician accredited apps can reduce the consumption and influence of poor online health contents. It can also promote better patient-physician relationships, thereby increasing patient compliance (Lau et al., 2018). Involvement of physicians in the design and development of health apps is vital for providing scientific and accuracy health contents.

Therefore, this study seeks to understand the perceptions of pregnant women on mobile app designs, utility, and information credibility. It also intends to investigate pregnant women's compliance to treatment plans using mobile health apps.

Purpose of the Study

The purpose of this study is to assess pregnant women's perceptions on mobile app design, utility, and credibility of health information provided on pregnancy apps for meeting their health needs during pregnancy. It also seeks to assess the effectiveness and adequacy of mobile app design for enhancing patient compliance, which is necessary for better health outcomes.

The increasing maternal mortality rates experienced in the United States (when compared with other developed countries), unequal access to health care services and

shortage of health care providers (specifically within obstetrics and gynecology) may be solved by improving access to quality health information and creating a more flexible consultation model to pregnant women. Unlike the unequal distribution of obstetrics and gynecological services, there is ubiquitous use of smartphones and health applications among women of reproductive age in the U.S.

Mobile technology can provide access to personalized health information and enhanced communication between physicians and patients. Thus, mobile technology has the potential of improving maternal and infant lives by creating more access to medical resources and care, as well as promoting healthy lifestyle choices, at little or no cost.

Against this background, this study will specifically focus on:

- App design interface and perceived quality of health information
- Adequacy and effectiveness of health information on apps against other health information modalities
- Relevance and influence of health applications on patient compliance.

This study will also add to existing knowledge on pregnant women and technology, patient compliance through app technology, and proffer scientific design recommendations that can impart mobile technology as useful antenatal tool for pregnant women.

Research Questions

This research will address these areas by answering several questions related to the intersection of mobile health apps, physician interaction and pregnant women:

- How does app design interface help with quality health information for pregnant women?
- How effective and adequate is health intervention through app technology for pregnant women?
- What design recommendations can be provided to improve health information for pregnant women: Participatory design approach.

Theoretical Framework

The conceptual framework for this study consists of constructs of self-efficacy of Bandura's social learning theory (Ghasemi et al., 2019; Bandura, 2004, 1977) and constructs of health belief model (Saghafi-Asi, Aliasgharzadeh, & Asghari-Jafarabadi, 2020).

The four identified sources of self-efficacy by Bandura (1977) (namely performance accomplishment, vicarious experience, verbal persuasion, and emotional arousal) as well as three constructs from the health belief model (namely perceived susceptibility, perceived severity, and cues to actions) will be considered. These seven constructs will help with understanding the effect of mobile app design on pregnant women.

Self-Efficacy Theory

Perceived self-efficacy refers to the ability or inability of a person to engage in a behavioral task. Personal efficacy is the cognitive process of engaging in a behavior based on perceived capability to successfully complete the behavior. It is seen in a

situation where a desired goal or behavior is accomplished even in the face of difficulty or aversive experience. It is the perceptual capability of expending control to achieve a specific goal or behavior. It could also be regarded as the personal confidence expressed by a person to achieve success in a task or behavior even in the face of persistent challenges (Ghasemi et al., 2019; Bandura, 2004, 1977). Similarly, Greiner, Croff, Wheeler and Miller (2018) defined self-efficacy as a belief required to accomplish a behavior.

Perceived self-efficacy is the belief of a person to perform specific required tasks or health goals or engage in some health measures successfully in the face of challenges. It is also the main motivator and predictor of achieving health goals or behavioral change (Myrick, 2017; 2019; Badura, 2004). It produces the motivation and action required to undertake a given task. Perceived self-efficacy of a patient is one of the key factors that can affect his or her adherence to treatment protocols (Motlagh et al., 2019; Ghasemi et al., 2019). Considering this, the perceived self-efficacy of a pregnant woman is her belief to take control of events that could affect her life during pregnancy and afterwards, and efforts expended to have a healthy pregnancy.

Perceived self-efficacy can strongly affect the way she follows advice and recommendations given by physicians, accomplishing health habits/goals even when they seem uncomfortable. Pregnancy is a unique health condition that requires self-sacrificing efforts and making healthier decisions that may be unnatural. Self-influence or motivation is thus needed by some pregnant women to adhere to their treatment protocols (Ghasemi et al., 2019; Badura, 2004). Perceived self-efficacy is a major determinant for

expending the effort to follow physicians' recommendations. Women with stronger personal efficacy tend to have increased adherence to treatment protocols and possess firmer commitments to achieve health goals (Motlagh et al., 2019; Ginja et al., 2018). Conversely, lower perceived self-efficacy may decrease adherence to treatment protocols (Ghasemi et al., 2019).

Additionally, perceived self-efficacy can also affect how a woman perceives a problem. Women with low personal efficacy tend to have lower motivation to engage in a behavior they perceive difficult and can easily give up at the slightest difficulty (Motlagh et al., 2019). A qualitative study on development of a healthy lifestyle mobile app for overweight pregnant women confirmed a relationship between obesity and adverse health outcomes (Lau et al., 2018). The study used the concept of social cognitive theory of self-regulation to design and develop a mobile app intervention for obese pregnant women. The study argues that importance of self-awareness and self-monitoring for promoting healthy diet in pregnancy and its possibility to improve maternal health. Self-awareness can be uncovered through mobile apps.

Perceived self-efficacy is influenced by four main sources that also apply to women in their reproductive years (Edwards, Ways & Hundley, 2019). The main sources of self-efficacy are performance accomplishment, vicarious experience, verbal persuasion, and emotion arousal (Badura, 1977).

Performance accomplishment is based on having repeated successes on a specific task or experience. It is formed on personal mastery experiences; this is obvious in the confidence level of women who have been pregnant before and first-time mothers. Lee

and Moon (2016) found a significant increase in the use of pregnancy-related apps by first-time mothers than women pregnant with second child. First-time women have low confidence levels about their pregnancy because they have not gone through pregnancy before. They usually have more questions about bodily changes than non-first-time women. First-time pregnant women are also more active health information-seekers than non-first-time mothers because they have no experience and are faced with uncertainty. Self-efficacy is a key psychological factor that positively affects pregnancy experience in first-time mothers (Edwards, Ways & Hundley, 2019).

Thus, access to high quality health information through mobile applications can increase women's confidence during pregnancy.

Given this, the following hypotheses are deduced:

H₁: Task accomplishment will positively affect patient compliance

Vicarious experience is the ability obtained from seeing someone else perform a behavior or achieve a goal that seems impossible for a person to achieve. This is evident in pregnant women's desire to learn from other mothers that might have gone through similar conditions. Perceived self-efficacy can be increased by exposure to success stories of other experienced mothers. Many pregnant women prefer advice given by other women who have had similar health situations than advice from health care providers (Fredriksen, Harris & Moland, 2016). Pregnant women show interest in connecting with other experienced women through newer technologies, such as online discussion forums, social network sites like Facebook, and engaging in real time face-to-face communication using mobile apps on phones (Daly et al., 2017). Pregnant women often seek reassurance

during pregnancy, which is usually received by connecting with other mothers physically or virtually (Harpel, 2018; Osma, Barrera & Ramphos, 2016).

H₂: Vicarious experience will positively affect patient compliance

Verbal persuasion is commonly used in many contexts to encourage a person to believe they can undertake a given behavior even if the person has previously failed or become overwhelmed. This is so because it is easy and always within the reach of the encourager (Bandura, 1977). Perceived self-efficacy can be increased in pregnant women through verbal persuasion. This influence is evident from women's interests to receive advice from care providers, family members and friends. Women who are far away from experienced relatives mostly depend on internet health information and advice from physicians (Thomas, Lupton & Pedersen, 2017).

H₃: Verbal persuasion will positively affect patient compliance

Emotional arousal can affect perceived self-efficacy of pregnant women (Myrick, 2017). Pregnancy can have both physiological and psychological effect on women. It can be stressful for many women, which could elicit emotional arousal. Some women experience maternal anxiety and depression which affects the confidence levels in pregnant women (Dol et al., 2019). Positive emotion would positively affect the perceived self-efficacy of pregnant women while negative emotions could affect them negatively. Newer technologies, especially mobile apps, can provide aesthetic pleasure to these women in form of comedies, horoscopes, and games (to mention a few options) to ease their stress levels.

H₄: Positive emotion will positively affect patient compliance

Health Belief Model (HBM)

The health belief model (HBM) was developed by Rosenstock and colleagues in the 1950s with a central focus on improving the use of preventive health services among patients. The HBM also seeks to understand people's motivation for embracing health programs and people who are not motivated (Moradi et al., 2020). The model consists of six constructs, however this study will adopt three of the constructs, namely perceived susceptibility, perceived severity, and cues to action. The HBM has been used in several health contexts to predict health behaviors (Saghafi-Asi, Aliasgharzadeh & Asghari-Jafarabadi, 2020). This model hypothesizes that the chance of a person acting out a behavior is predicted by the perceived threat to the disease in terms of the perceived susceptibility and perceived severity (Kahsay et al., 2019).

Perceived threat is the sum of perceived susceptibility and perceived severity to a health problem. Within the context of pregnancy, perceived susceptibility refers to the subjective perception of a pregnant woman's chance of developing an illness during pregnancy, while perceived severity refers to the subjective perception of having the severe illness during pregnancy and the consequence of the illness on the mother and baby. Knowledge of susceptibility and severity to a disease foster the desire for behavioral change.

H₅: Perceived susceptibility has a positive impact on patient compliance

H₆: Perceived severity has a positive impact on patient compliance

Cues to action refers to factors that motivate a person toward a desired behavior. Cues to action could be external or internal motivators needed to trigger an action (Saghafi-Asi, Aliasgharzadeh & Asghari-Jafarabadi, 2020). Cues to action in this context are external and internal motivators that influence a pregnant woman to achieve a desired health behavior or goal. For example, physiological and psychological trackers (features that routinely monitor, record, and provide automated alerts on mobile applications) allow users to self-track and self-manage their health. These features may lead to positive health outcomes and patient compliance (Ledford et al., 2017). Similarly, Sbaffi and Zhao (2020) and Johnson, Rowley and Sbaffi (2015) argue the influence of information characteristics (such as ease of use, credibility, content, usefulness, style, and brand) on user's perceptions of online information quality. These information characteristics could serve as external motivators that can trigger the use of a given health intervention.

H₇: Cues to action will positively affect patient compliance

H₈: Apps information quality has a positive impact on patient compliance

H₉: App design interface will increase patient compliance.

Conclusion

Access to health information is key to patient compliance and better health outcomes. Some of the identified ways of dealing with the inadequate access to health care and health information is use of newer technologies to disseminate quality information to patients. Even though internet and mobile technology is granting easy access to needful information, the conduit used for disseminating the information has a huge impact on how the information is perceived and used. Hence, this study seeks to

understand the perceptions of pregnant women on mobile app design, utility, and information credibility.

Division of Chapters

Chapter one provides a brief background on technology and the health care system, background on health information sources, problem statement, purpose of the study, research questions and theoretical framework.

Chapter two provides a literature analysis on the health care system in the United States, technology-mediated health care delivery, patient compliance, patient-physician interaction, patient physician communication, information behavior of pregnant women, utility of app information to pregnant women, influence of mobile app design on perceived information quality, current state of research by health organizations on apps used by pregnant women, evaluation of information quality regarding UX's best practices and implications of low quality health information on pregnant women.

Chapter three discusses the research methodology, research design, target population, sampling methods, recruitment and data collection techniques and triangulation of data.

Chapter four discusses the data analysis and empirical results.

Chapter five summarizes the conclusion of the study.

Chapter 2: Literature Review

The purpose of this study is to understand the perceptions of pregnant women on mobile app design, utility, and information credibility. It also seeks to explore the adequacy of mobile app design for promoting good maternal health outcomes. This chapter intends to provide a brief review of the literature on technology and pregnant women as background for a study on how mobile app design, information credibility and utility can increase patient compliance among pregnant women.

Health Care Delivery in the United States

Access to affordable health care is one of the fundamental needs of human to experience the totality of what life has to offer. According to the World Health Organization, health is defined as the “state of complete physical, mental, and social well-being” (Sommers, Gawande & Baicker, 2017). Health care, however, comes with a huge cost to governmental organizations, private establishments, and individuals. In the quest to meet the health needs of the people, many developed countries offer universal health care system to its residents. The health care system of the United States (U.S.) operates a more flexible health care system (Shi & Singh, 2019).

The U.S. health care system operates a complex system without a central governing agency. It is shaped by political, economic, cultural, technological, societal, environmental, and demographic factors, thereby making the system multifaceted (Shi & Singh, 2019). There is no universal health care provision in the country. Residents are solely responsible for securing a health care coverage plan or financing the health cost

(Shi & Singh, 2019). Millions of Americans depend on health insurance for the payment of their health costs. Health insurance is the most used means of financing health care expenses in the country (Berchick, Barnett & Upton, 2019).

The health care system in the U.S. is both privately and publicly funded. An estimate in 2018 found 67.3% of American residents used private health insurance while 34.4% used public coverage (Berchick, Barnett & Upton, 2019). Similarly, 176.6 million American residents below the age of 65 have privately funded health coverage while 110.7 million are covered by government funded health coverage (Shi & Singh, 2019). The government operates two main health programs called Medicare and Medicaid. The federal government manages Medicare, while Medicaid is managed by both the federal and state governments (Shi & Singh, 2019).

Employer-sponsored insurance, out-of-pocket payment, governmental health programs, safety-net facilities and securing insurance by self are the various means of financing health care in the States. Shi and Singh (2019) affirmed that 55% of the health care cost is financed by private health insurance while 45% is by the government. Even though many people in America secure their health insurance privately through their employers, many still lack adequate health coverage. The majority of people affected with poor health coverage are people who work on per-time basis, are jobless or unemployable. Since a large number of working-class residents depend on their employers to provide health coverage, those without fitting jobs are exempted from this privilege provided by employers, and thus lack access to health care when they need care.

Health coverage promotes improved access to primary health care, ambulatory care, and compliance to treatment protocols among patients (Sommers, Gawande & Baicker, 2017). Unfortunately, the current health care delivery system is shaped for economic gains and opportunities rather than a central design to meet the health needs of all residents. The Affordable Care Act (ACA) increased access to health care for uninsured residents, but ACA is not close to what universal health coverage offers (Shi & Singh, 2019; Knickman & Kovner, 2015). Millions of people still have inadequate access to health care due to lack of health insurance coverage and/or poor coverage for acute care among those who are insured (Knickman & Kovner, 2015). Health insurance coverage is advantageous for providing financial security, improved access to health care and better health outcomes, but the current health coverage modalities used in the country are still not sufficient to provide everyone with accessible health care. Hence, many people without insurance coverage lack access to affordable health care (Shi & Singh, 2019; Leone, 2016).

The huge financial cost dedicated to servicing the health care system is another vital element (Shi & Singh, 2019). The U.S. government spend nearly twice as much as other developed nations on health care services. Tikkanen and Abrams (2019) confirmed that the U.S. spent more than twice in per capital health spending than Australia, France, Canada, and the United Kingdom (U.K.). For example, in 2018, France and the U.K.'s total per capital on health cost were \$4,931 and \$3,943 respectively, while the U.S.'s total was \$10,207. The main cause was attributed to out-of-pocket and private spending as the public spending was similar to what patients paid in other developed countries.

Additionally, a Commonwealth Fund 2019 issue brief reported that, in 2018, France and the U.K. used 11.2% and 9.8% respectively of their gross domestic product (GDP) on health cost, whereas the US devoted 16.9% of GDP on health care yet has comparably mediocre health care outcomes (Tikkanen & Abrams, 2019).

The country spent 17% of its GDP on health care in the year 2013 and 2016 yet has the lowest life expectancy among the Organization for Economic Co-operation and Development (OECD) countries (Tikkanen & Abrams, 2019). The U.S. health costs in 2018 were \$3.6 trillion, 17.7% of its GDP, whereas the health costs in 1960 were \$27.2 billion, only 5% of the GDP. This implies an increase in health care cost per person. Amadeo and Boyle (2020) reported that the annual health cost per person in 2018 was \$11,172 while health cost per person in 1960 was only \$147. There is a need for policy makers to pay closer attention to the growing health costs in the country.

Furthermore, the cost of receiving health care is extremely high considering the country's minimum wage. The cost of receiving health care has soared more than the median annual income (Amadeo and Boyle, 2020). According to Health System Tracker (2020), the out-of-pocket payment for health care has increased from an average of \$115 per capita in 1970 to \$1,240 per capita in 2019. Despite the high expenditure dedicated to health care, many people who cannot pay for health care services or are uninsured wait at home until their health condition worsens to qualify for hospital emergency care (Shi & Singh, 2019). This health behavior may be part of the explanation for increased mortality rates among patients and lower life expectancy rates in the country.

A major part of the health care cost is spent on newer medical technology. Newer technology often increases the cost of receiving health care. Health care economists have suggested intensifying the use of older technologies or risk wasting 50% of annual health costs to newer technologies (Callahan, 2009). Medical technology has significantly and positively improved lives and health of people over the years, but not all technology is worth the price being paid (Van Baal et al., 2018; Cookson et al., 2017). Much of the health care expenditure is spent on acquiring expensive medical machines, such as magnetic resonance imaging (MRIs) and hip replacement procedures, when compared with other developed countries (Tikkanen & Abrams, 2019; Shi & Singh, 2019).

The effect of high-cost medical technology could discourage the extension of health coverage to part-time workers (Shi & Singh, 2019). Some researchers have suggested rebalancing hospital budgets by reducing expenses dedicated to pharmaceutical and diagnostic imaging companies for equipment upgrades, and instead dedicating a larger portion to promote an equitable health care system through greater coverage for those without insurance or needing financial support (Iriye et al., 2017; Cookson et al., 2017). Affirmatively, literatures in the health sciences and health organization have highlighted that increasing patient's adherence to treatment protocols is more beneficial than improving any medical treatment (Sanford & Rivers, 2019). Even though medical technology is very important in health care delivery for maximizing efficiency and producing better health outcomes, there ought to be a balanced financing of acquisition of high and low medical technologies to limit overuse and redundancy (Shi & Singh, 2019).

Racial disparity exists in the health care system in the U.S. (Mogos et al., 2020; Miller & Peck, 2020). Studies have reported that minority races experience prejudice from physicians. This is evident in the way treatments are administered to non-White patients (Yearby, 2018). Many White physicians have been reported to have racial prejudice against their non-White patients, thereby refusing to refer them for appropriate treatments. Physicians' stereotypical attitudes towards minority races make them sometimes favor White patients over Black patients (Yearby, 2018; Dahlem, Villarruel & Ronis, 2015).

Racial microaggression is another problem people of color experience from their White physicians. Miller and Peck (2020) noted the negative impact of racial microaggressions in health care contexts within the country. Racial microaggression is a conscious or unconscious negative treatment received by racial minority groups. People of color experience racial microaggressions at a higher volume than White patients when interacting with physicians of other ethnic groups. Microaggressions seen in medical context are usually more subtle than in other social contexts. It is sometimes expressed by physicians unconsciously because of the personal beliefs they have towards other ethnic groups (Miller and Peck, 2020). Level of education of patients affects the level of microaggression experienced. Educated patients tend to be more assertive when communicating with their physicians, whereas patients with low level of education experience more microaggressions, as well as discourteous and hasty interactions (Miller and Peck, 2020; Dahlem, Villarruel & Ronis, 2015).

Another important factor in the health care delivery system in the U.S. is physician burnout. Physician burnout is prevalent in the U.S. health care system. The system is faced with the challenge of burnout among medical practitioners (Reith, 2018; Rothenberger, 2017). More than 50% of physicians have showed signs of workplace burnout (Reith, 2018). Physicians' burnout can have negative impacts on the well-being of the physicians, patients, family members, colleagues, and health care institutions (West, Dyrbye & Shanafelt, 2018; Rothenberger, 2017). Physicians in the areas of family medicine, internal medicine and obstetrics and gynecology are at greater risks of experiencing burnout (Reith, 2018). Physicians' burnout is caused by systemic failure of the health care system and shortage of health care professionals in the country. This epidemic has adversely affected the number of hospital visits patients can have to see their physicians, further stressing patient-physician interactions (Tikkanen & Abrams, 2019). This is not the case in other developed countries; Germans and the Dutch, for example, visit their physicians at a rate two times higher than the average American (Tikkanen & Abrams, 2019).

Complicating the job of physicians and exacerbating the conditions leading to burnout is another element physicians in technological era deal with. Some physicians experience subjectively biased observations from patients online. Hall et al. (2020) investigated patient's perceptions of technical competence of White and Indian physicians based on photographs displayed on websites. Findings revealed that patients have biases against older male, less attractive and non-smiling Indian physicians as well as younger female physicians. Stereotypical perceptions among patients and physicians

can influence patient-physician interactions and compliance to treatment plans. The patient-physician relationship is not good enough in the country (Knickman & Kovner, 2015).

Thus, creating and developing mobile interventions that can promote positive patient-physician relationships may be vital for addressing some of the biases from patients and physicians.

Pregnancy and Health Care in the United States

Improving maternal health is one of the developmental goals of many countries and health organizations. Pregnancy is a delicate period in the life of any woman. It requires access to adequate health care and information to achieve positive health outcomes (Ghiasi et al., 2019; Javanmardi et al., 2019). Pregnancy comes with different changes, as it can affect the mother's immunological makeup, physiology and psychology. These changes often trigger the desire for a pregnant patient to know more about her well-being (Lee & Cho, 2019). Women often engage in self-sacrificing activities, and sometimes adopt new ways of living during pregnancy (Li, Ouyang & Shen, 2020; Lau et al., 2018). They therefore seek for health care and information from health care providers, internet health information, online forums, family members and traditional media to make sense of this period (Daly et al., 2018; Javanmardi et al., 2018).

Pregnant women are faced with different challenges when making efforts to stay healthy during pregnancy (Robinson et al., 2018). This period with its demands can be distressing for many women and families if the right health care and information are

inaccessible (Kamali et al., 2018). Studies have revealed that many pregnant women in the U.S. lack access to effective health care. This has attributed to the constant rise in maternal death rates experienced over the years in the country (Mogos et al., 2019; Iriye et al., 2017). Pregnancy-related deaths were 7.2 deaths per 100,000 livebirths in 1987 in comparison with 20.1 deaths per 100,000 live births in 2019 (Hoyert, 2021; Creanga et al., 2014). The World Health Organization (WHO) affirmed that the increase in maternal deaths reflects unequal access to quality health care services.

The WHO defines maternal death as “the death of a woman while pregnant or within 42 days of termination of pregnancy, irrespective of the duration and site of the pregnancy, from any cause related to or aggravated by pregnancy or its management but not from incidental or accidental causes” (Abboud, 2020). Maternal mortality rate (MMR) is one of the indicators used to assess the reproductive health of any nation. MMR can be defined as the death caused by pregnancy per 100,000 live births (Zelop, 2018). The MMR on a global scale has reduced by 30%. However, the MMR in the United States has risen by 56% from 16.9 in year 1990 to 26.4 in 2015 (Zelop, 2018).

Most women die from complications that arise during pregnancy and after delivery. A study by Mogos et al. (2019) confirmed a 150% increase in MMR between 1987 and 2014 in the U.S. Abboud (2020) opined the country as the most unsafe developed nation for any pregnant woman to delivery her baby, with the U.S. ranking 50th (among developed countries) for maternal mortality rates. Nearly 800 pregnant women die every year in the country (McLemore, 2019).

Studies on maternal health have identified racial disparity as one of the causes of ever-rising maternal deaths in the U.S. (McLemore, 2019; Vilda et al., 2019). The Center for Disease Control (2020) reported that non-Hispanic Black women have the highest pregnancy-related mortality rates (41.7 deaths per 100,000 live births), followed by non-Hispanic American Indian/Alaskan Native women (28.3 deaths per 100,000 live births), non-Hispanic Asian/Pacific women (13.8 deaths per 100,00 live birth), non-Hispanic White women (13.4 deaths per 100,000 live births) and Hispanic women (11.6 deaths per 100,000 live births). Maternal deaths among non-Hispanic Black mothers are three times higher than maternal deaths among non-Hispanic white mothers (Collier & Molina, 2019; Logsdon et al., 2019).

Inadequate access to health care services by non-white pregnant women has been discussed in literature to be associated with their deaths (McLemore, 2019). The Obstetric Care Consensus (2019) reports the closure of hospitals with low volume of obstetric services. Closure of hospitals could potentially increase health care disparity among pregnant women causing adverse maternal health outcomes. Additionally, lack of universal health insurance for pregnant women promotes inadequate access to health care services among uninsured pregnant women (Logsdon et al., 2019; Shi & Singh, 2019). The country does have excellent health care for pregnant women, but that care is not accessible to all (McLemore, 2019).

Negligence among health care providers is noted in literature to affect pregnancy experience. Many healthy pregnant women who showed no symptoms of sickness during pregnancy are suffering from post-delivery injuries (Abboud, 2020). More than 50,000

new mothers are inflicted with post-delivery injuries and 700 are lost because of negligence from health care providers (Abboud, 2020). With equal access to prenatal care, many of the maternal deaths can be significantly reduced; 59% of maternal deaths in the U.S. are preventable (Zelop, 2018). The Obstetric Care Consensus (2019) also confirmed that 60% of pregnant women died because of preventable health conditions between 2013 and 2017.

Maternal deaths are mostly caused by pre-eclampsia, eclampsia, infections, complications during delivery, and severe bleeding, together accounting for 75% of maternal deaths. Hemorrhage, cardiovascular diseases, cardiomyopathy, and infections are important causes of maternal deaths (Collier & Molina, 2019). Pre-eclampsia, eclampsia, and embolism are the main causes among non-Hispanic Black women, while mental health conditions are the leading cause of maternal deaths among non-Hispanic White women (Collier & Molina, 2019). These illnesses can be managed with an effective health care system. Improving access to quality health care by providing universal prenatal care to pregnant women, provisioning of standardized care for all in hospital settings, improving communication among health care teams, team training, and provisioning of risk-appropriate maternal care are a few identified solutions to improving maternal health outcomes in the U.S. (Collier & Molina, 2019; Logsdon et al., 2019; Marko et al., 2019).

Prenatal care is one of the most used preventative health care measures in the U.S., with an estimate of more than 4 million live births annually (Marko et al., 2019). Furthermore, categorizing pregnant women into either low-risk or high-risk pregnancy

can ensure that women carrying high-risk pregnancies are provided with the needed intensive care. Low-risk pregnant women tend to attend more prenatal visits than recommended by the American College of Obstetricians and Gynecologists (ACOG) thereby limiting the time available to high-risk women. Monitoring of blood sugar levels and weight are some of the medical routines done during prenatal visits. Access to the required prenatal care can be enhanced using health apps that can provide the functionality of remote monitoring of blood sugar level and weight, which can be of particular benefit to high-risk pregnant women. Hence, creating prenatal care models that allow high-risk mothers access to the required care is key to reducing maternal deaths.

It is appalling that, despite the expensive medical technology and high financing by the government in health care, the rates of maternal mortality have been steadily rising in the country. The rate of maternal deaths in year 1986 was seven women for every 100,000 live births but has soared to 17.4 per 100,000 livebirths in 2018. Sadly, 50,000 women are still faced with pregnancy and delivery-related complications (Gingrey, 2020).

Integration of mobile technology into prenatal care may be useful for improving maternal health outcomes. Most women of reproductive age have smartphones, making integration of this technology into prenatal care cheap and easily available, allowing patients access to health information and connecting patients with physicians at the touch of a button. The next section will discuss the impact of technology-dependent health care delivery on maternal health outcomes.

Technology-Mediated Health Care Delivery

Generally, health care is administered at either the patient's home or at physician's offices (Gan et al., 2016). Both health care delivery methods are still currently in use; however, patients in many parts of the world receive health care by going to the hospital or medical practice. This is so because hospitals provide access to medical equipment, medical professionals from different specialties and a sanitized environment (Gan et al., 2016). Nevertheless, hospital and home visits have their merits and demerits. Inadequate medical equipment and a contaminated environment are the danger of home visits, whereas the long waiting time for appointments can be frustrating in hospital visits (Gan et al., 2016).

The health care sector is experiencing a gradual shift in roles and responsibilities of physicians and patients. Previous studies in medical sciences have reported the change from paternalistic-centered care to patient-centered care. In the former, physicians handled all health decisions with little or no involvement of the patients (Khurana et al., 2019; Osei-Frimpong, Wilson & Lemke, 2018). This shift in roles has effect on the care delivery patient-physician relationship. Patients are now required to be actively involved in making decisions regarding their health, treatments, and collaborating with physicians for the best health outcomes (Cannon, 2018; Jusoh, 2017; Lu & Zhang, 2019).

Technology-mediated health care delivery supports the use of online health communities, emails, text messages, web, and mobile technologies in health care. Technology enhances flexible means of delivery and receiving health care at a cheaper cost (Lu & Zhang, 2019). Technology-mediated health care delivery using mobile

technology can also overcome some of the challenges pertinent to hospital and home care delivery. Improvement of patient-physician interaction and communication through virtual consultations can be provided using technology thereby reducing implicit biases in health care.

Easy patient-physician communication, remote monitoring, access to medical resources, and receiving diagnoses and test results instantly can be achieved using mobile technology. This is especially valuable for pregnant women (Cannon, 2018; Lehnert et al., 2017).

Impact of Technology-Mediated Healthcare on Maternal Health Outcomes

Advancement in internet and mobile technologies is providing more patients with flexible means of receiving health care and connecting with any physician from anywhere in the world at any time (Wexler et al., 2020; Dalton et al., 2018). More dependence on technology by women of reproductive age is increasing partly because of the influx of newer technologies. These technologies include wearable devices, social media, instant messaging, virtual audio and video communication in real time and integration of medical devices to mobile applications (DeNicola et al., 2020; Cannon, 2018). More women can easily self-examine themselves now before making an appointment as well as immediately after appointments with physicians to learn more about their health conditions (DeNicola et al., 2020; Marko et al., 2016). Technology-dependent health care delivery is advantageous to pregnant women because of its flexibility and convenience. It reduces the waiting time required to receive care, supports personalized messaging and

alerts of obstetrics danger signals. Mobile technology supports tracking of ultrasound recording and monitoring of physiological and psychological biometrics without traveling to the hospital (Li, Ouyang & Shen, 2020; Lau et al., 2018).

Pregnancy demands lifestyle changes, particularly for women with underlying health conditions, to reduce adverse health outcomes for the mother and fetus (Li, Ouyang & Shen, 2020). Studies on pregnant women have reported the positive impact of mobile technology for improving maternal outcomes in the areas of smoking cessation and breastfeeding (DeNicola et al., 2020). Furthermore, the effectiveness of this technology has also been reported in the contexts of postnatal depression (Dyurich & Oliver, 2020), gestational diabetes mellitus (Li, Ouyang & Shen, 2020) and personal efficacy in prenatal care (Ginja et al., 2018).

A study reported the use of a mobile phone intervention, Wired Mothers, to improve maternal health. This study found a relationship between mobile phone intervention and reduced maternal mortality in settings with limited resources (Lund et al., 2014). More studies have shown promising results in low- and middle-income countries on the use of mobile intervention for improving maternal health outcomes (Gbadamosi et al., 2018; Lund et al., 2014).

Another study conducted on the effectiveness of technology-supported lifestyle intervention for women living with gestational diabetes in Wuhan, China revealed that the lifestyle intervention helped the women reduce gestational weight gain (Li, Ouyang & Shen, 2020).

Similarly, a randomized trial study on the effect of technology-enhanced prenatal diet and lifestyle intervention on pregnant women in the U.S. found significant differences in gestational weight gain between the research subjects in the intervention group and those in the control group. Women in the intervention group lost more weight than women in the control group without any adverse health outcomes on mother and child (Van Horn et al., 2018). Since pregnant women are required to make personal health choices and decisions, technology can offer patient empowerment to make informed decisions with their physicians. (Lee & Cho, 2019; Ledford et al., 2017).

The impact of mobile health interventions on maternal psychological health in developed countries, however, remains unclear (Dol et al., 2020). This may be because of the significant dearth of evidence-based reviews on existing mobile software. There is more mobile software than evidence-based findings (DeNicola et al., 2020; Jusoh, 2017; Gan et al., 2016). Patients including pregnant women rely on web and app technology to manage their health conditions (Duan et al., 2020; Morrison et al., 2018). Since pregnant women are consumers of internet health information and contents, it is vital to understand their use of web and app technologies during pregnancy. The next sub-sections will discuss health information delivery through web and app technologies.

Health Information Delivery through Web Technology. One of the means of accessing internet information is through web technology. The prevalent use of websites for searching for information is fostered by advancement in internet technology. Most public, private, and governmental health organizations have an online presence through

websites. Health websites are meeting the growing health needs of the people as they are good sources of health information for patients (Lu et al., 2018; Fredriksen, Harris & Moland, 2016). Web health information is generally used by people to learn about their health conditions (Ren et al., 2019), search for health information, connect patients with physicians (Liu, Zhang & Lu, 2019), discuss health conditions with physicians, share personal experiences with people having similar health conditions, and exchange information (Yi & Hu, 2020; Lu and Zhang, 2019).

Web health information is beneficial to patients for providing reassurance to those experiencing negative emotions caused by health conditions. Patients tend to experience fears when they must undergo surgical procedures or harsh treatments. Past studies revealed that some health care providers offer their patients lists of relevant websites as supplementary means of learning more about their health conditions (Liu, Zhang & Lu, 2019; Fredriksen, Moland & Harris, 2018).

However, most health institutions under-utilize this information source for meeting the needs of their patients. An investigation on the use of obstetrics practice websites for disseminating health information to pregnant women during the Zika virus outbreak in the U.S. revealed that, at baseline, only 25% of the websites disseminated information on Zika virus (Lehnert et al., 2017). The use of the website for dissemination of Zika virus information however increased to 36% over a period of seven months. Despite the awareness of the adverse health outcomes of Zika virus to pregnant women in the U.S, obstetrics practices under-utilized their websites for spreading valuable health

information on Zika virus to pregnant women. It could have provided answers to the worrying needs of patients (Lehnert et al., 2017).

A major concern about web health information is the trustworthiness of the contents and information quality (Fredriksen, Harris & Moland, 2016). A content analysis on online nutrition information for pregnant women in Australia revealed that 39.7% of website contents were accurate, 22.8% contained varied information and 37.5% contained inaccurate information. In addition, the readability of the information contents for users was considered difficult, with only 0.5% of the websites meeting the reading level of at or below grade 6 guidelines (Storr, Maher & Swanepoel, 2016).

Health Information Delivery through App Technology. The World Health Organization's Global Observatory for eHealth (2017) defines mobile health as “medical and public health practice supported by mobile devices, such as mobile phones, patient monitoring devices, personal digital assistants, and other wireless devices” (Morse, 2017). Health information delivery through app technology refers to the use of computer software designed for mobile devices to improve health management, health care services and health research (Daly et al., 2017; Morse et al., 2017). Advancement in mobile health application is improving lives by providing faster access to health information on different health topics. More patients rely on app health information for making informed decisions on their health as well as for engaging in shared decision making with their physicians (Vandenberk et al., 2019; Daly et al., 2017).

The prevalence of smartphones and mobile applications is on the rise in developed and developing countries (Wang et al., 2019; Nikolic et al., 2018). As of 2018, global

smartphone ownership is estimated to be 66%, with more than 175 billion mobile applications downloads in 2017 (Mo et al., 2018). The rise in use of mobile applications is noticeable globally. Deloitte Australia reported a 5% increase in smartphone penetration in Australia since 2016 and a 50% increase in time spent on mobile applications between 2016 and 2018 (Khurram & Sardar, 2020). On a global scale, a nearly 35% increase was recorded in application downloads between 2016 and 2018. Specifically, the U.S., U.K., France, and Brazil have noted a 35% increase in mobile health applications downloads. India and Indonesia have noted a 65% and 110% increase respectively (Khurram & Sardar, 2020).

Recent studies have documented mobile applications as the newest means of accessing health information among pregnant women. They access, store, share, and track pregnancy-related information on mobile applications (DeNicola et al., 2020; Dalton et al., 2018; Hussain et al., 2017). Mobile applications offer a more convenient, cheaper, efficient, and portable means of communicating in health care settings (Daniel et al., 2018). Mobile applications are valuable for identifying and preventing maternal risks factors, thereby reducing adverse maternal and fetal health outcomes.

Different studies have explored the use of mobile interventions for managing maternal risks factors such as obesity (Lau et al., 2018), diabetes (Tumminia et al., 2019; Carolan-Olah et al., 2017), diet/nutrition (Storr, Maher & Swanepoel, 2016), mood disorder (Faherty et al., 2017) and stress management (Jallo et al., 2017). Notably, pregnant women prefer mobile applications because they permit quicker access to health information, management of health and diseases, adoption of behavioral changes which

could lead to healthier lifestyles, and adhering to medications (DeNicola et al., 2020; Cannon, 2018). They also prefer health applications to other information sources because applications support remote monitoring of their well-being and virtual prenatal care (Marko et al., 2019; Marko et al., 2016), support interactive patient education (Dalton et al., 2018), support tracking of physiological and psychological well-being (Mo et al., 2018), possess features that support alerting and aesthetic pleasure (Deka, 2016) and features to connect pregnant women with other women with the same health needs for reassurance (Daniel et al., 2018). Many of the functionalities on mobile health applications promote personal monitoring of health biometrics that would otherwise be noticed only in the clinician's office. Mobile health apps might be useful for promoting health and patient compliance to treatment plans.

Patient compliance and Positive Health Outcomes through App Technology

Patient compliance refers to patient adherence to instructions or treatment plans recommended by their physicians. It is a major concern in the field of health sciences as many patients actively or passively fail to adhere to medical instructions and advice. Treatment plans are usually recommended to speed up recovery from illnesses, manage diseases and reduce worsening of diseases (Lu et al., 2018). Treatment plans include medications, follow-up appointments, diet, exercise, utilizing health devices, and health interventions (Sanford & Rivers, 2020; Lu & Zhang, 2019).

Patient noncompliance has been a major concern for over half a century. It has a great effect on health care costs and quality of lives. The World Health Organization

stated that only 50% of people living with chronic diseases in developed nations adhere to treatment plans. In the U.S, 60% of adults are living with chronic diseases, meaning 6 in 10 American adults are likely to be undergoing treatment plans to manage their health conditions (CDC, 2021; Audrain-Pontevia, Menvielle & Ertz, 2019). Alas, patient noncompliance to treatment plans is common. Patient noncompliance leads to negative health outcomes.

Medication adherence is key for achieving positive health outcomes among pregnant women, particularly women with underlying diseases. Women are generally advised to take supplements during pregnancy to prevent fetal developmental challenges (Chandyo et al., 2017). Globally, about 80%-90% of pregnant women use over the counter or prescribed medications during pregnancy (Roldan Munoz et al., 2020). Nevertheless, many women do not adhere to their medication plans. Some cases of noncompliance to medication plans among pregnant women is out of genuine concern about the safety of medication for their unborn (Dathe & Schaefer, 2019). Another recent study reiterated low adherence to medication among pregnant women living with chronic diseases (Roldan Munoz et al., 2020). Patient education and provision of right information using mobile health applications may increase adherence to medications. Apps offer a unique platform for educating and informing millions of pregnant women on safety measures during pregnancy. Affirmatively, many studies have reported the use of mobile health applications by pregnant women for dealing with different health conditions such as gestational diabetes, hypertension, and depression (Tumminia et al.,

2019; Miah, Gammack & Hasan, 2017). Hence, app technology is valuable for medication management.

Patient compliance is a complex and dynamic process involving shared responsibilities between patients and physicians for obtaining desired health outcomes. It is also crucial for disease and health management (Laugesen, Hassanein & Yuan, 2015). Patient empowerment cannot be over-emphasized considering the current patient-centric care approach in health care which demands the involvement of patients with physicians to make decisions relating to treatment plans (Audrain-Pontevia, Menvielle & Ertz, 2019; Zhang et al., 2019). Mobile health application is very useful for supporting patient empowerment.

Furthermore, patient compliance is central to the patient-physician relationship. Patient commitment (decision to follow physician's instructions) directly and indirectly supports patient compliance. Compliance to physician's advice and recommendations also depends partly on good patient-physician communication. It is an essential component of patient compliance (Khurana et al., 2019; Lu & Zhang, 2019; Lu et al., 2018). Abayomi et al. (2020) affirmed the relevance of good communication between pregnant women and their primary health care providers for improving maternal health outcomes. App technology can enhance the communication between patients and physicians for achieving positive health outcomes (Laugesen, Hassanein & Yuan, 2015).

A study carried out in Wyoming revealed that use of mobile health applications increased user engagement and adherence to prenatal care (Bush et al., 2017). Prenatal care is a preventive care given to women to go through pregnancy successfully. It is a

recommended treatment plan to all pregnant women by the American College of Obstetricians and Gynecologists (Marko et al., 2019). Nonetheless, some pregnant women miss their prenatal visits. A few factors have been identified in literature to promote non-adherence to prenatal visits. Poor patient-physician communication, busy work schedules, inability to secure appointment time, long distance, unequal access to health care, shortage of physicians, and poverty hinder women from prenatal visits (Abraham, 2020; Wheeler et al., 2020; Dahlem et al., 2015).

Mobile applications offer intuitive and interactive features that allow patients to set and actualize health goals. They frequently provide updates to users on the progression of set goals. The personal efficacy to be in control of and adhere to treatment plans for positive health outcomes is supported by app technology. App technology thus offers an excellent platform to disseminate health information to pregnant women as well as communicate with physicians (Buzzi et al., 2019; Lu & Zhang, 2019).

App technology is useful for providing easy access to medical resources, such as making appointments to see physicians from anywhere at any time and getting cheaper access to health care. Mobile health offers a unique opportunity to midwives and gynecologists to provide prenatal care beyond onsite care. Aggregation of data points from various sensors (made possible by mobile apps) can easily alert all relevant stakeholders to take real-time actions, thereby promoting patient health outcome (Miah, Gammack & Hasan, 2017).

Patient-Physician Interaction

Patient-physician interaction is the foundation of effective health care delivery. It is the relationship between physicians and patients for the purpose of meeting medical needs. Patient-centric care demands the need to equip patients with adequate knowledge and skills to engage with physicians. There is also a need for physicians to understand the needs of their patients during consultations to achieve good interaction which promotes patient compliance and better health outcomes.

Effective patient-physician interaction engenders clear diagnosis, patient compliance, proper monitoring of health conditions and unambiguous interpretation of clinical results (Lu & Zhang, 2019; Gan et al., 2016). Patient-physician interaction affects patient satisfaction. Poor patient satisfaction can lead to potential risk of being sued for malpractice (Tasso & Behar-Horenstein, 2008). Poor patient-physician relationships have been noted over the years in literature. Implicit racial bias, disagreement on treatment plans, poor communication, bureaucracy, cost containment, and language difference are some of the identified factors that promotes poor patient-physician interaction (O'Hara & Shue, 2018; Hariwara & Dent 2016).

There appears to be a mismatch in perceptions of physicians and patients on the concept of patient-physician interaction. Patients believe physicians are supposed to provide technical and emotional expertise, but physicians do not share the same views. A recent investigation on patient-physician relationship from physician's perspectives found that physicians concentrate on their technical skill and disregard interpersonal skills like empathy and friendliness in their interaction with patients (Berger et al., 2020). Similarly,

Lu et al.'s (2018) study confirmed that patients develop trust in their physicians based on cognitive (technical skills and performance) and affective (emotional connection developed based on the empathy and care shown by the physician) actions. Patients perceive both technical and interpersonal skills as important in patient-physician interaction. Conversely, physicians rated social interaction and being friendly with patients unimportant (Lu et al., 2018). Hence, there is a gap in the expectations of patients and physicians toward each other. This may contribute to poor patient-physician interaction, patient noncompliance, and poor health outcomes.

Patient-physician asymmetry (knowledge hierarchy between patient and physician) can also hamper patient-physician interactions (Yelovich, 2016). The imbalance in power structure between patients and physicians has placed patients in a vulnerable position over the years. However, with the emergence of the internet and mobile technologies, the personal efficacy of more patients is increasing to engage in shared decision making about their health with their physicians (Laugesen, Hassanein & Yuan, 2015).

Understanding of the perception patients have of the condition being treated plays an important role in the adhering to treatment plans. Patients are more likely to be reassured with physicians who provide enough information on the health condition than those who do not. Patients tend to follow the instructions of physicians who meet their information needs. Good patient-physician interaction is healing, and it is as important as the recommended treatment plan (O'Hara & Shue, 2018; Tasso & Behar-Horenstein, 2008).

Impact of Technology on Patient-Physician Interaction

Patient-physician interaction in the past involved face-to-face contact between the physician and patient in a hospital or home setting (Gan et al., 2016). Patients knew about their health conditions based on the information provided by the physician. Physicians only provided a little information considered relevant to the wellbeing of the patient (Timmermans, 2020; Yelovich, 2016). Now, patient-physician interaction is changing with patient-centered care and mobile technology.

Disparities in health care are associated with poor patient-physician interaction. The country is still plagued with the challenge of unequal access to health care and availability of physicians (Assari 2019; Dahlem et al., 2015). Technology-mediated health care has, however, been proven to improve the distribution of medical resources in countries overwhelmed with large populations. The impact of online health communities is increasing patients' access to health care in China, thereby reducing burnout experienced by physicians and enhancing patient satisfaction (Peng et al., 2020; Lu & Zhang, 2020). Since the U.S. is faced with unequal access to health care, technology-mediated health care can increase marginalized patients access to relevant medical resources (Lyford & Lash, 2019). Technology also promotes more convenient means of receiving health care from anywhere at any time, thus breaking systemic, geographic, and distance barriers hindering equitable care (Lu & Zhang, 2019; Niela-Vilen et al., 2019).

Information access supported by newer technology is empowering patients during consultations. Studies have shown that not all patients have access to adequate health information (Assari 2020; Kamali et al., 2018), but more patients are becoming more

informed on relevant health information through mobile devices and meeting their health needs (DeNicola et al., 2020). Reliable and adequate health information empower and educate patients to ask the right questions and make informed health choices. Health information also promotes health literacy and reduces uncertainty. Internet and mobile technologies thus offer unparalleled access to health information in different formats that interest users. It is important to stress that internet health information comes with both positive and negative outcomes. These effects can affect patient-physician interaction (Lu & Zhang, 2019; Laugesen, Hassanein & Yuan, 2015).

A recent study reported the possibility of incomplete understanding of patient's diseases due to lacking an in-person examination of the physiology of the patient (Lu & Zhang, 2019). Some health cases require physical contact to properly examine the patient. On the contrary, Marko et al. (2019, 2016) asserted the relevance and efficacy of integrating connecting devices with mobile applications for efficient monitoring of patient biometrics. Sensors on smartphones and supported applications have the capability of easy tracking of biometric data and provides instant test results needed to make informed decisions. Additionally, complex medical reports like electrocardiogram (ECG) and X-rays can now be easily sent and viewed on mobile devices. Video conferencing supporting live chats is also supported by mobile technology. These features and functionalities can positively affect patient-physician interaction (DeNicola et al., 2020; Gan et al., 2016).

Good patient-physician interaction is vital for meeting the patient's personal/sensitive health needs. Peng et al. (2020) noted that some patients need health

counseling but feel embarrassed to discuss the issue with their physicians in-person.

Technology provides a personalized platform to interact with physicians anonymously.

Use of mobile health applications can adequately meet the varying health needs of patients. Some patients may prefer to discuss sensitive health issues they feel shy about with physicians virtually because their privacy is protected (Witzeman et al., 2020).

Consequently, technology-enhanced health care offers access to a wealth of medical resources and information (Lu et al., 2018; Lau et al., 2018), promotes reassurance needed to meet emotional needs (Dol et al., 2019), and supports quicker access to physicians to obtain needful health information (Lu & Zhang, 2019). It also promotes flexibility in health care delivery making scarce medical help available to more people, promotes appointment tracking, saves time, and allows anonymous interaction with physicians to discuss sensitive health concerns (Liu & Zhang, 2019; Laugesen, Hassanein & Yuan, 2015). These are all advantageous for promoting patient-physician interaction and adherence to treatment plans.

Patient-Physician Communication

Central to effective health care and patient-physician interaction is patient-physician communication (Khurana et al., 2019; Zhao, Kessler & Guo, 2018). Research has shown that communication is crucial for effective patient-physician interactions and treatment efficiency (Lu et al., 2018; Nikolic et al., 2018). Patient-physician communication is the process of sending and receiving health information between patients and physicians to ensure proper diagnosis and adequate treatment (Labaf et al.,

2019). Effective health care delivery involves the collaborative roles of patients and physicians for shared decision making about treatment plans. Proper communication is necessary to reduce uncertainty on any health concern among patients, as well as help physicians make correct diagnoses (Ghofranipour et al., 2018). Thus, good patient-physician communication is important for patient compliance and patient engagement with physicians (Unal, Akbolat & Amarat, 2018).

Methods of communication is vital to patients. Verbal communication is very common in all health care settings, but many physicians seem to lack good communication skills (Honavar, 2018). Patients pay close attention to both verbal and non-verbal behaviors of physicians. Ghofranipour et al. (2018) confirmed that patients are still expressing dissatisfaction on how physicians communicate despite undergoing training. The researchers believe that physicians need better communication skills and increased personal efficacy to effectively communicate with patients. Physicians need improved communication skills for face-to-face interaction and non-verbal qualities for online communication. Non-verbal communication behavior is equally as important as verbal communication in health care contexts. It is important to pay closer attention to both verbal and non-verbal clues of patients for effective delivery of health care (Labaf et al., 2019).

It is important for physicians to pay close attention to both the physical and online presence. There is a new trend among patients of using the online photos and non-verbal attributes of physicians to judge their technical competence and emotional intelligence.

Patients create first impressions of a physician based on their verbal or nonverbal cues (e.g., attire and cleanliness) (Hall et al., 2020; La Rosa et al., 2018).

A patient's trust in their physician is important for effective communication, and effective communication promotes trust (Lu et al., 2018). Trust is crucial in patient-physician communication because it determines the extent to which patients feel comfortable about sharing health concerns with the physicians (Zhang et al., 2019). Lack of trust often leads to poor patient-physician interaction, increased complaints, negligence claims and nonadherence to treatment (Honavar, 2018). Patients who trust their physicians are better satisfied with the service delivery than those who have little or no trust (Honavar, 2018; La Rosa et al., 2018).

Shared decision making is central in patient-physician communication to achieve effective health care (Peimani et al., 2020; Levit et al., 2019). Effective communication promotes good rapport between patients and physicians. Patients tend to perceive some level of closeness with their physician based on the use of words. Physicians who use first-person pronouns (e.g., we) during conversation have better rapport with the patients (Falkenstein et al., 2016). Choice of words of physicians during consultation can make or mar patient-physician communication.

Low health literacy, education level and language barrier can hinder good patient-physician communication (Greenberg et al., 2019; Labaf et al., 2019). Language barrier is a major challenge that stresses patient-physician communication particularly for patients from different cultural backgrounds (Labaf et al., 2019). A study on determinants of patient-physician communication found that education and language proficiency are

important factors in patient-physician communication. Patients who were well-educated had better patient-physician communication than those with a low educational level. Additionally, patients with poor language proficiency had an increased chance of experiencing negative patient-physician interaction (Aelbrecht et al., 2019). In situations where the patients were not fluent in the official language of the country, being well-educated helped them cope better with the physician than those with a lower level of education. Hence, effective patient-physician communication rests on language comprehension and the educational level of the patient (Aelbrecht et al., 2019; Levit et al., 2019).

Ineffective patient-physician communication can lead to noncompliance to treatment plans, which is detrimental to patient wellbeing (Peimani et al., 2020; Lu et al., 2018). Physicians, on the other hand, are exposed to reputational damage from poor online reviews and ratings (Laugesen, Hassanein & Yuan, 2015). Patient satisfaction is perceived as a pointer to health care quality (Ng & Luk, 2019). Good patient-physician communication lessens psychosocial stress, financial loss, poor life quality, and poor patient satisfaction. These factors have adverse health outcomes on patients (La Rosa et al., 2018; Falkenstein et al., 2016).

Impact of Technology on Patient-Physician Communication

As mentioned in the above section, patient-physician communication is a requirement for effective patient-physician interaction and good patient satisfaction (La Rosa et al., 2018). Communication pattern is changing in all sectors of human endeavors, including health care, because of the prevalence of newer communication technologies.

Mobile technology and online health communities can support patient-physician communication (DeNicola et al., 2020; Lu & Zhang, 2019). Virtual communication is possible and easier with mobile applications, text messaging, phone calls, emails, and websites (Daniel et al., 2018; Lu et al., 2018).

Daniel et al. (2018) noted that email is presently the most used means of communicating among medical colleagues, followed by WhatsApp. Evidently, many health organizations are incorporating mobile applications at a faster rate for facilitating communications among colleagues and patients (Nikolic et al., 2018).

Since racial discordance, language barriers, low educational levels and low health literacy are inhibitors of patient-physician communication, mobile applications can address some of these problems. For example, some health applications offer a language feature which allows users to change the main language to their preferred language or offer language translation. Additionally, it supports textual means of communication for patients who may be unable to communicate verbally (Cannon, 2018).

Use of online communication channels hold the potential of improving patient education, patient empowerment, adherence to treatment plans, and efficient patient care (Danak et al., 2019; Jeffrey et al., 2019). It can also reduce potential conflicts between patients and physicians, thereby strengthening the relationship and increasing patient satisfaction and trust (Daniel et al., 2018; Lu & Zhang, 2019). A study confirmed the use of smartphones, text messages and emails for improving communication between diabetes patients and their physicians. A survey of 102 Type 2 diabetes patients revealed

that the participants had interest in using health communication technology for communicating with their physicians between visits (Khurana et al., 2019).

Chronically sick patients find it extremely difficult to comprehend, recall and adhere to all the instructions given to them by their physicians. The use of a mobile health application is very useful for reminding and educating them on health information, as well as offer personalized messages, appointment tracking, health behavioral tracking, and community engagement (Marko et al., 2019; Mehralizade et al., 2017).

Nevertheless, the incorporation of health technology into health care delivery has its drawbacks. DeNicola et al. (2020) reported that many of the newer technologies adopted into the health care system still lack sufficient evidence-based reviews for clinical use. Most are adopted subjectively based on few promising feasibility studies conducted on them. There is need for more accurate scientific investigations and evaluations on these technologies to diminish potential health hazards and costs that can result from understudied technology. It may also hinder future adoption of potentially effective technology into the health care system (Dalton et al., 2018; Jusoh, 2017).

Another drawback is patients' over-reliance on internet health information. Some patients develop strong opinions from the health information sought online before consulting the physicians, and when alternative opinions are offered, they become defensive and sometimes rude to physicians (Fredriksen, Moland & Harris, 2018). This can negatively affect patient-physician relationship (Fredriksen, Harris & Moland, 2016). Frequent questioning of physician recommendations also threatens the physician's professionalism and authority. This behavior can be repulsive to physicians and affect

patient-physician relationships (Honavar, 2018; Osei-Frimpong, Wilson & Lemke, 2018). Additionally, the internet promotes consumerism in health care because patients have more access to health information (Osei-Frimpong, Wilson & Lemke, 2018). Patients are viewed as consumers with ever-increasing demands and expectations from physicians.

The Impact of Technology on Physician's Workload and Experience of Physicians

The impact of adopting technology into the health care services have been explored in many health literatures (Morse et al., 2017; Osei-Frimpong, Wilson & Lemke, 2018). The health care system in the country uses electronic health records for organizing health data and information of patients (Pelland, Baier & Gardner, 2017). Electronic health records decrease medical errors, improve quality of care, and promote accuracy of patient's health information, however utilizing electronic health records often leads to work overload for physicians (Danak et al., 2019; Arndt et al., 2017).

A study by Pelland, Baier and Gardner (2017) noted that electronic health records are very valuable in health care delivery, however their findings reveal some negative effects of using electronic health records on patient-physician interaction. Hospital-based physicians spend lesser time with patients because they must input patient data into the computer system, which often creates some silent moments of the physician gazing on the screens or typing on the keyboard while the patient watches. This little distraction has a potential of reducing the quality of patient-physician interaction and communication. Physicians use almost two hours of their limited time to collate electronic health records of their patients (Arndt et al., 2017).

Another study reiterated that physicians spend 2.6 hours of their workday on clerical tasks, 1.4 hours on mail, and nearly 6 hours interacting with electronic health records (Danak et al., 2019). Danak et al. (2019) suggested the use of scribes (unlicensed paraprofessionals) to assist physicians with clerical tasks in real time.

Work burnout can negatively affect physician's performance and quality of care (Squiers et al., 2017). Feelings of exhaustion, medical errors, lack of fulfillment and increased mortality rates are associated with physician burnout (West, Dyrbe & Shanafelt, 2018; Reith, 2018). The benefit of online health communities for dealing with hospital congestion and physicians' burnout have been mentioned in literature (Lu and Zhang, 2019).

A study on the computerization and future of primary care based on general practitioners' views in the U.K. revealed that 68% of physicians believed that technology cannot replace them in patient diagnoses, 61% believed technology cannot make specialist referrals and offer personalized treatment plans, while 94% thought technology cannot offer empathic care. In contrast, almost 80% supported the possibility of technology replacing them in documentation (Blease et al., 2018). Providing support staff for the purpose of documenting patient information may be useful in health care settings to encourage more physician focus on administering care to patients. Alternatively, design of better technology that promotes quicker and easier documentation of patient data e.g., voice command may be useful for reducing the level of stress that comes from updating patient records.

Mobile health technology can serve as a new model for providing improved care quality to patients as well as improve physicians' work experience (Rodriguez et al, 2020). Mobile applications are being incorporated to deliver a range of different health care services. Cao et al. (2018) confirmed increased referral rates supports the use of medical health applications for clinic-seeking care. Rodríguez et al. (2020) confirmed the usefulness of mobile applications for detecting and reporting vector-borne disease in Colombia.

Mobile applications are also reported to help physicians make informed diagnostic and therapeutic decisions among respiratory allergic diseased patients (Tripodi et al., 2020). Furthermore, a study investigated the use of medical applications among physicians for administering sexually transmitted disease (STD) treatments and for offering consultations to patients. Findings showed that 54.9% of physicians have recommended STD testing and 43.9% have offered treatment plans to web-based patients. A majority of the physicians (85%) used medical mobile applications to provide follow-up consultations to STD patients while 21.6% used medical mobile applications for patient evaluation more than one time a week (Cao et al., 2018).

In the U.S. nearly 4 million children are born every year, making prenatal care one of the most used preventive health care services in the country (Marko et al., 2019). Mobile technology has the potential of improving pregnant women-physician interaction and pregnant women-physician communication. It can also promote more access to health information and prenatal care. Health policy makers ought to consider the use of

mobile technology for dealing with inequality in receiving prenatal care which may boost maternal health and promote infant health.

Information Behavior of Pregnant Women

Pregnant women often engage in online information seeking to supplement the information provided by their health care providers. Pregnancy is a unique period in the life of every mother as the outcome affects lives (Javanmardi et al., 2018; Ghaiasi, 2018). Many studies have described pregnancy to be a period that demands change (Corno et al., 2017), development (Kamali et al., 2018) and sensitivity (Sharifi et al., 2020). Pregnancy comes with physiological, psychological, and immunological changes in women. The changes trigger the need for information to make sense of all the new developments they experience. Although pregnancy is a common health condition, there are still some gaps in the knowledge of women as most experience uncertainties during this period (Ghiasi, 2019; Holroyd et al., 2017).

Information Needs of Pregnant Women

Information needs of pregnant women is a state of incomplete knowledge on pregnancy-related information (Ford, 2015). It means there is a need to solve an information problem (Robinson et al., 2018). Information needs can be expressed or unexpressed (Mnieszak et al., 2020; Volpe, 2010). Pregnant women experience both expressed and unexpressed information needs (Akanbi & Fourie, 2018). Expressed information need is an articulated need by a person, expressed by articulating the need and taking actions to resolve the need (Akanbi, 2016). It is a need a person is conscious

about (e.g., a need for nutrition information and checking the internet to retrieve relevant information on nutrition). Conversely, unexpressed information need is an unconscious need with no resultant action. It is also a person's decision to ignore a need (Akanbi, 2016; Volpe, 2010).

Unexpressed needs can however be triggered by an external factor such as information monitoring, reminders, notification, and alerts (Akanbi & Fourie, 2018; Ford, 2015). Unexpressed needs are sometimes trapped in the cognitive space of a person that requires an external force to bring it to the recipient's consciousness. This is in line with the "cue to action" construct identified in the health belief model. Cues to action can trigger an unexpressed information need (Saghafi-Asi, Aliasgharzadeh & Asghari-Jafarabadi, 2020). Likewise, Anggraini, Utami and Zairina (2019) referred cues to action as internal or external factors that can stimulate a desired behavior or influence a person to act out specific behaviors. In short, cues to action can expose the reality of unexpressed needs in pregnant women (Kahsay et al., 2019; Masoi & Kibusi, 2019). Technology with the capability of meeting both the expressed and unexpressed information needs of pregnant women is crucial for improving maternal and infant health outcomes.

Pregnancy is a developmental period that activates the desire for more information to cope with all the different stages of pregnancy (Kamali et al., 2018). Pregnancy-related information needs are caused by bodily and emotional changes (Ramphos et al., 2019), inadequate access to quality health information (Lee & Moon, 2016), absence of experienced family members (Thomas, Lupton & Perderson, 2017),

inaccurate and unscientific online health information (Dalton et al., 2018), poor mobile app design and quality (Mao et al., 2018), and insufficient time with healthcare providers (Halili et al., 2018). Information needs among pregnant women also depend on number of pregnancies (first-time pregnant mothers seek information more than non-first-time pregnant mothers), age and external factors (Perez-Lu, Bayer & Iguñiz-Romero, 2018). Recent studies on pregnant women have made it clear that they have unmet information needs during pregnancy (Wexler et al., 2020; Kamali et al., 2018; Robinson et al., 2018). Unmet information needs among pregnant women can limit what they know about pregnancy, thereby causing them to make poor choices that can affect them and the fetus. Incomplete state of knowledge can also lead to preventable diseases and deaths (Kamali et al., 2018; Jallo et al., 2018). Women's need for information sometimes changes as pregnancy progresses. This makes pregnancy information needs not a once-off event but an ongoing need. Hence, there is a need for technology that provides information on an ongoing basis.

Literatures on pregnant women have noted pregnant women's information needs. They have needs regarding prenatal care (Wexler et al., 2020), vaccination information (Clarke, Sirota & Paterson, 2019), medications (Dathe & Schaefer, 2019), mental health care (Chung et al., 2020; Faherty et al., 2017), nutrition (Snyder, Neufeld & Forbes, 2020; Storr, Maher & Swanepoel, 2017), physical activity (Choi et al., 2016), body weight (Lau et al., 2018), dental care (Liu et al., 2019; Bahramian et al., 2018), supplements (Arcia, Stonbraker & Warner, 2019), breastfeeding information (McKenzie, Rasmussen & Garner, 2018), genetic counseling (Tsai et al., 2017), fetal development

(Daly et al., 2019), stress management (Jallo et al., 2017), information monitoring (Santur, Santur & Karakose, 2020), personal support (Wexler et al., 2020; Javanmardi et al., 2018), employment opportunities and government support (Arcia, Stonbraker and Warner, 2019).

A recent study focused on predicting information-seeking behaviors and health-related needs of pregnant women and care givers revealed that a total of 1,014 health needs were noted by 95 participants. An estimate of 10.7 health needs were noted per person, 11.8 for pregnant women and 7.9 for care givers. The findings showed that 66% were interested in informational needs, 30% were interested in disease-related information, 8.6% needed medical information, 16% needed support for logistical issues, and 8.9 % needed support for social issues (Holroyd et al., 2018). This shows a great need for relevant information on pregnancy topics. The need among pregnant women may differ by culture and language. How technology impacts women from different cultural and linguistic backgrounds remains unclear (Hughson et al., 2018).

The first and most important step in helping a woman have a safe pregnancy and delivery is to provide relevant information to make informed decisions and communicate effectively with health care providers (Kamali et al., 2018; Javanmardi et al., 2018). Adequate information is required for women to go through pregnancy, delivery, and the postnatal period (Kamali et al., 2018; Hamzehei et al., 2018). Health information promotes patient education, patient empowerment, and disease management (Nooriani et al., 2019; Kamali et al., 2018). It fosters preventive health care measures and raises self-care abilities (Javanmardi et al., 2019). Health information is also beneficial for

increasing the patient's health literacy, patient-physician interaction, patient-physician communication, patient compliance, and detection of health risks and dangers, as well as for decreasing maternal and infant mortality and morbidity (Daly et al., 2017; Guendelman et al., 2017).

Health information is associated with increased health knowledge, which is vital for detecting obstetrics danger signs and thus reducing complications and health risks. The quantity and quality of health-related information provided to expectant mothers determines the quality of their pregnancy experience and impacts the degree of care she gives to herself and the unborn (Sharifi et al., 2020; Lawrentschuk et al., 2016).

Access to quality health information is necessary to make informed health decisions (Ghiasi et al., 2019; Kamali et al., 2018). Health behaviors embraced during this period affect the health of the mother and the unborn. Therefore, providing quality health information is valuable for meeting the information needs of pregnant women.

Access to affordable health care is also crucial for reducing uncertainty associated with pregnancy (Arcia, Stonbraker & Warner, 2019). Maternal health care is one of the most used care services in the U.S, with nearly 6.5 million pregnancies and 4 million live births every year (Marko et al., 2019; Holroyd et al., 2017). Pregnant women (especially those who lack health coverage) need affordable health care to prevent adverse health outcomes for themselves and the fetus (Javamardi et al., 2018; Kamali et al., 2018). Hospital-generated health information resources are important for meeting the information needs of pregnant women (Wang et al., 2019). Hence, health care providers

ought to provide patient-centered health information to pregnant women through both traditional and newer communication technologies.

Advancement in technology is increasing the use of internet and mobile applications in the delivery of health care (DeNicola et al., 2020; Zhu et al., 2019). The International Telecommunication Union in 2016 confirmed there are more than 7 billion mobile cellular subscriptions globally (Halili et al., 2018). More than 90% of millennial pregnant women in the U.S., Canada, U.K., and China are owners of mobile phones (Sherifali et al., 2017). This suggests that many younger pregnant women rely on mobile technology for meeting their pregnancy-related needs (Sherifali et al., 2017). Women of reproductive age are generally consumers of health technology (Halili et al., 2018).

Internet technology is the most popular source of information used by pregnant women regardless of social or economic class (Javanmardi et al., 2018; Fredriksen, Harris & Moland, 2016). Women of different socioeconomic classes use the internet as their major information source. Javanmardi et al. (2018) mentioned that the use of internet among pregnant women is triggered by unmet information needs, ease of use, and access to timely information. It also provides an avenue to learn and connect with people with similar health conditions. Advancement in internet and mobile technologies is availing more people to use more than one computer device for their online information seeking (Fredriksen, Harris & Moland, 2016). Ceulemans et al. (2019) confirmed that pregnant women use many online sources to meet their pregnancy-related needs. The internet thus plays a vital role in the meeting information needs and

understanding the information-seeking behaviors of pregnant women (Javanmardi et al., 2019).

However, the usefulness of internet information for improving maternal health outcomes remain inconsistent in literatures (Arcia, Stonbraker & Warner, 2019; Hughson et al., 2018). Pregnant women also do not discuss their online information activities during consultation with physicians (Fredriksen, Harris & Moland, 2018). It is important for physicians to allocate some time to understand the online sources used by their patients to correct any misinformation and erroneous beliefs. Providing women with evidence-based online sources is vital for promoting maternal health.

Understanding of pregnant women's information needs is very important for providing the right health interventions to meet their needs, overcome informational challenges they face, and improve the effectiveness and efficiency of their preferred sources of information (Ghiassi et al., 2019). Effective health intervention is vital for promoting patient compliance and saving lives. Research suggests that health behavioral interventions developed for pregnant women must be based on valid theoretical models (Hazavehie et al., 2018) and user-centered design (Lau et al., 2018). The adequacy of health interventions for pregnant women is crucial for achieving health goals and outcomes.

Since pregnancy affects the knowledge state of women and brings need for information, providing answers to burgeoning questions of pregnant women is one of the effective ways of combating maternal and infant mortality rates in the U.S. (Maurer et al., 2017; Holroyd et al., 2018; Logsdon et al., 2019). Use of internet and mobile

technologies can provide the right and cheapest platform to provide answers to women's information needs.

Information Seeking Behavior of Pregnant Women

Information seeking entails all the various activities a person engages in to fill the gap in knowledge state, resolve uncertainty and make informed decisions (So et al., 2019; Sbaffi & Zhao, 2019). Online information seeking can be referred to as information search, using online sources to meet an information need. It involves the right application of the online information to specific needs (Hamzehei et al., 2018). The internet is popularly used for searching and seeking information because it is convenient, affordable, and readily available to everyone with internet access (Nikolic et al., 2018; Ryan, 2018). Information-seeking behavior is seen as a psychological phenomenon influenced by personal, situational, and environmental factors (Zare-Farashbandi et al., 2016).

One of the benefits of online information seeking is for meeting the growing health information needs of people (Myrick & Willoughby, 2019; Holroyd et al., 2017). Health information seeking refers to all actions taken to inquire about health topics and engage in healthy behaviors (Sbaffi & Zhao, 2019). Studies have shown that more people depend on online sources for learning more about their health conditions (Audrain-Pontevia, Menvielle & Ertz, 2019; Tan & Gooawardene, 2017). About three-quarters of Americans have used the internet for searching for health-related information in the past year (Myrick & Willoughby, 2019).

Some factors have been noted in literature to affect online health information seeking. These factors include education (Myrick & Willoughby, 2019), emotions (So, Kuang & Cho, 2019), age (Sharifi et al., 2020), health information type, credibility, and reliability of information source (Zare-Farashbandi et al., 2016). People with a higher level of education tend to seek health information online and adhere to physician's instructions than those with a lower level of education (Sharifi et al., 2020; Myrick & Willoughby, 2019). Perceived susceptibility and severity to a health condition is another factor that can motivate online health information seeking (Cangol et al., 2020; So, Kuang & Cho, 2019).

Firstly, online information seeking is important for increasing the health literacy level of patients. Health literacy can stimulate patients to be more actively involved with their physicians in making decisions about their health (Greenberg et al., 2019; Ledford et al., 2017). Secondly, it has the potential of increasing the confidence level of patients, thereby empowering them to take control of their health (Coglianese et al., 2020). Thirdly, it supports unparalleled access to relevant health information to make sense of uncertainty about different health conditions (Fredriksen, Harris & Moland, 2016). Therefore, online health information seeking can meet some of the information needs of pregnant women and reduce adverse maternal health outcomes (Javanmardi et al., 2019; Harpel, 2018).

Seeking for information is one of the ways pregnant women deal with pregnancy and make sense of the different bodily and immunological changes they experience (Ghiasi, 2019; Pijpers et al., 2016). Many pregnant women engage in online information

seeking because of the popularity of internet and mobile technologies (Liu, Zhang & Lu, 2019; Zhu et al., 2019). Research on pregnant women have reported that they are active and passive seekers of health information during pregnancy (Lau et al., 2018; Clarke, Sirota & Paterson, 2019). They use different information sources to meet their needs. They consult physicians (Holroyd et al., 2017), family members (Thomas, Lupton & Pedersen, 2017), websites (Fredriksen, Harris & Moland, 2018; Lehnert et al., 2017), search engines, (Javanmardi et al., 2019), online discussion groups (Fredriksen, Harris & Moland, 2016), social networks (Harpel, 2018) and use mobile health applications (Hughson et al., 2018; Jallo et al., 2017).

Online information seeking among pregnant women has been reported to improve adherence to treatment (Nooriani et al., 2019), patient-physician communication (Liu, Zhang & Lu, 2019), mental health (Ramphos et al., 2019) and support system (Dorst et al., 2019). Hence, it is important for healthcare providers to discuss the most preferred information-seeking methods with pregnant women to meet their health needs (Javanmardi et al., 2018).

Utility of App Health Information to Pregnant Women

Maternal health remains a public health issue considering the increasing maternal mortality and morbidity rates, unequal access to health care, and unfiltered online health information to deal with pregnancy (Abboud, 2020; Collier & Molina, 2019). Mobile and app technologies can promote access to medical resources that may be otherwise difficult to access due to inequalities in health care and shortage of obstetrics and gynecologists.

However, little research exists on the usefulness and validity of these technologies for addressing maternal health outcomes in the U.S. (DeNicola et al., 2020; Shi & Singh, 2019).

Mobile applications refer to software that runs on mobile devices. This mobile software permits efficient completion of different tasks on mobile devices (Mehralizade et al., 2017). It can also be regarded as a set of computer instructions that run on a mobile device for achieving a specific goal (Daly et al., 2017). The use of mobile technology for accessing health information is prevalent in both developed and developing countries. More people have more access to health information through their smartphones than before because of the penetration of mobile devices worldwide (Harpel 2018; Osma, Barrera & Ramphos, 2016). More than 70% of the world's population own a smartphone (Santur, Santur and Karakose, 2020).

Increased users of mobile technology are clear in the number of app downloads from app stores and the amount of time devoted to using mobile applications. Time spent online using mobile apps has increased, as 89% of users were reported to spend time online using mobile apps while 11% used mobile web (Osma, Barrera & Ramphos, 2016). The Institute for Health Care Informatics noted more than 160,000 mobile health apps were available on both Android and iOS stores the previous year, of which 7% were classified as health and pregnancy apps (DeNicola et al., 2020; Sedrati et al., 2016). In the U.S. almost 85% of adults own a mobile phone, with 53% having used their devices for searching different health topics and 19% having downloaded mobile applications (Kim, Paige Powell & Bhuyan, 2017).

Recent studies have reported some significant milestones of mobile health applications. This technology is improving patient lives by ensuring better health management (Niela-Vilen et al., 2019; Mehralizade et al., 2017). The validity and utility of mobile apps is also evident in its ability to provide personalized patient education which supports patient empowerment (Dalton et al., 2018; Ledford et al., 2017). It also promotes healthier lifestyles, adherence to treatment plans, easier access to health information, better patient-physician communication and interaction, and monitoring of health biometrics, which is impossible with other communication modalities (Lyford & Lash, 2019; Osma, Barrera & Ramphos, 2016).

A practical way to deal with the staggering increase in maternal deaths in the U.S. is mandatory involvement of patients in health decisions (Moore, 2016). Shared decision making on prenatal choices can be fostered with mobile apps. Mobile apps as a communication modality can increase activation and engagement levels of pregnant women (Ledford et al., 2017). Portability of mobile devices support convenient access to health information, as access to information is a click away and can be easily included in daily routine. It also allows the running of several applications at the same time on a single device (Santur, Santur & Karakose, 2020; Jallo et al., 2017; Mehralizade et al., 2017).

Considering the cost implication associated with doctor's visits and scarcity of reliable health information, mobile applications can offer a cost-effective means of obtaining health information from any part of the world at any time, overcoming geographical and systemic barriers (Silva et al., 2015). A study on the Health-e Babies

app, a mobile application providing antenatal education for socially disadvantaged pregnant women, noted that women from low socioeconomic backgrounds can utilize health apps for behavioral change and staying healthy and informed (Dalton et al., 2018).

Smartphone sensors can monitor and make known some physiological and psychological data, such as blood pressure level, blood sugar level, and mood, that patients would otherwise have had to spend more time traveling to see a doctor for before having such sensitive information (Dol et al., 2019; Gan et al., 2016). It also facilitates easy booking of appointments, quicker professional consultation, easy access to test results, personalized messages and remote monitoring of mother and fetus (Ginja et al., 2018; Lu & Zhang, 2018; Gan et al., 2016). Mobile apps hence have the strength of improving efficiency and quality of care given to patients.

Pregnancy apps are excellent at early detection of abnormality and obstetric danger signals (Ginja et al., 2018). Apps dedicated to maternal health can easily detect fetal abnormalities that would have taken a large amount of time to detect in the hospital and impossible to detect with web technology (Huang, Han & Fan, 2019). The usefulness of apps dedicated to maternal health has been noted in literature. The functionality of mobile apps supports detection of gestational depression (Faherty et al., 2017), gestational diabetes (Tumminia et al., 2019), hypertension, diet (Van Horn et al., 2018), gestational weight gain (Lau et al., 2018), remote monitoring of high-risk pregnancies (Niela-Vilen et al., 2019) and fetal movement (Daly et al., 2019).

Maternal health behaviors directly affect the pregnancy experience (Van Horn et al., 2018). Unhealthy lifestyles and behaviors have been associated with adverse health

outcomes such as fetal alcohol spectrum disorder (FASD) and infant morbidity (Gibson et al., 2020; Lau et al., 2018). App technology allows its users to set and actualize personal health goals (Santur, Santur & Karakose, 2020). Mobile applications offer a unique platform to help people set behavioral goals and change accordingly (Lau et al., 2018). Maternal gestational weight gain for example is a serious health issue confronted by many pregnant women. About 50% of pregnant women struggle with gestational weight gain (Lau et al., 2018).

The health care system is limited in resources to address this problem, and physicians sometimes shy away from discussing this topic in full because it is regarded as a sensitive topic to women (Knight-Agarwal et al., 2015). Many resource-intensive interventions have been used to tackle obesity in pregnancy but have produce limited results. Maternal obesity could increase the risk of developing hypoglycemia and macrosomia, which are linked with adverse health outcomes for the mother and the unborn in the present and future (Lau et al., 2018; Knight-Agarwal et al., 2015). Hence, app technology can help pregnant women to set goals (such as eating healthy diets and engaging in regular physical exercises) to reduce gestational weight gain.

Recent studies have documented the usefulness of mobile applications for improving maternal health in areas of providing health information to resolve uncertainties, but the credibility and accuracy of content is still a concern from a physician's standpoint (Wommack, Anderson & Ledford, 2018; Dalton et al., 2018). Lee & Moon's (2016) review on the characteristics, contents, and credibility of mobile applications used for pregnancy, birth and childcare stated that apps are effective for

providing answers to women's questions on health and accessing physicians' quick opinions, however 39% of the respondents noted that the apps they used lacked credibility.

A content analysis done in 2018 suggested the effectiveness of mobile apps dedicated to maternal care as a supplemental source of health information but found that the apps contained inconsistent risk recommendations lacking clinical research to support their contents (Wommack, Anderson & Ledford, 2018). Even among the most used apps, contradictory recommendations were found in subtle ways. The researchers, however, stated that the contradictions may be because of differences in the apps' countries of origin, as only 57% of the apps were developed in the U.S. The rest of the apps were from other countries with different cultures and guidelines for maternal care. However, half of the apps mentioned the sources of their recommendations.

A study on drinking choices among pregnant women in Australia found that women's information sources influenced their choice of alcohol intake during pregnancy (Gibson et al., 2020). Women of reproductive ages preferred mobile apps as information sources (Harpel, 2018). The potential of app technology has not been fully explored in research. Only a few studies have been conducted to support the utility of mobile applications for addressing maternal health outcomes (Jusoh, 2017; Mehralizade et al., 2017). There is a significant dearth of evidence-based research on the efficacy of mobile health applications used by pregnant women (DeNicola et al., 2020; Daly et al., 2017; Sedrati et al., 2016).

Additionally, there is need for standardization from the U.S. Food and Drug Administration authority on mobile app contents. Currently, there is no standard regulation for guiding and informing the design of apps targeted at health topics. This may be creating more burden on the users as they must deal with varying information quality and recommendations provided on health apps on their health conditions. It can also affect the patient's perception of the risk associated with a health condition, which may lead to noncompliance to treatment plans (Wommack, Anderson & Ledford, 2018; Lupton & Pedersen, 2016).

It is therefore important for physicians treating pregnant women to be aware of the potential risks these women are exposed to and be willing to discuss other approved online sources with them during consultation.

Influence of Mobile App Design on Perceived Information Quality

Advancement in mobile technology is increasing the use of mobile devices and applications (Cannon, 2018). Mobile devices have become important personal asset included in our everyday life because of its portability, capability, features and functionalities (Feng et al., 2019; Hussain et al., 2017). Smartphones and mobile applications have also changed the machine-human interaction, making the interaction seem natural and innate. This is evident in how toddlers handle their parent's mobile devices (Meranda, 2020; Buzzi et al., 2019; Sosa-Tzec, 2019). Mobile app design is an element to be considered in the field of Human-Computer Interaction (HCI) considering the movement from large screen computers to mobile devices for carrying out normal everyday life tasks. More users than before can access the internet using their mobile

devices. The influx of mobile devices is increasing the development of and widespread access to mobile applications in diverse areas of human endeavors. Mobile app adoptions and information retention by users are shaped by the inherent design of the interfaces through which information is relayed.

Mobile App Design

Mobile devices and applications have greatly influenced the way people carry out their daily activities, perform tasks, think, and live (Hussain et al., 2017). Studies have reported the use and benefits of mobile applications for enhancing different behavioral changes (Lau et al., 2018; Dol et al., 2020). App design interface has the capacity of influencing users' online choices, behaviors, and decision making (Schneider, Weinmann & Brocke, 2018). Buzzi et al. (2019) referred to the app interface as a digital coach in a digital choice environment. Well-designed interfaces are powerful tools for empowering users to create and accomplish personal and health goals, such as physical exercise to lose body weight.

App design interface is an important component of mobile devices which enhances the interaction between humans and computers. It is the mobile space that allows human-computer interaction for the purpose of completing a specific task and achieving a specific goal. It also displays to users everything they need to see on the screens of mobile devices (Buzzi et al., 2019; Kuznetsov et al., 2016; Hu et al., 2019). App design interface also acts as a nudge that aids users to effectively find their way when performing a task on mobile devices. Therefore, the design of user interface is considered the most crucial element when designing digital products. as it determines the

ease of use, efficiency, visual attractiveness, and usability of the product (Kureerung & Ramingwong, 2019; Wallwiener et al., 2016).

Furthermore, app design interface is an important determining factor for app adoption, success in marketplaces and retention by users (Hamzah, Persada & Hidayatullah, 2018; Deka, 2016). Mobile app design is made up of static and dynamic components. Static components are the user interface layouts and visual elements, while dynamic components are the user flows and navigation parts of the interface of the app (Deka, 2016). Much attention has been given to intuitive elements like buttons, checkboxes, menus, and icons to convey messages and explain functionality to users (Kuznetsov et al., 2016).

The usability and good user experience of a mobile application depends on the app design interface elements. Users are quick to create first impressions about an app by the first glance at the interface. It is vital for app design to be intuitive, self-explanatory, user-friendly and behave the way users anticipate it to perform (Kuznetsov et al., 2016; Silvennoinen, Vogel & Kujala, 2014). It can also determine the perceived trust users have for an app. For instance, when users encounter difficulty while navigating on an app, they are quick to abandon the app. This can affect user perception of the information content relayed through the app. Health-seekers are more interested in easy-to-use technology that would not add to the burden of their health condition (Khurram & Sardar, 2020). Similarly, task-oriented apps seem attractive to users when the interface is simple and easy to use (Silvennoinen, Vogel & Kujala, 2014). Since app interface design determines its adoption and engagement level of users, as well as determines perceptions users have

of the quality of health information, it is noteworthy to design interfaces that support easy navigation, efficient and effective performance of goals and meet the needs of the user (Todi et al., 2019; Lachner, Nguyen & Butz, 2018).

Quality Health Information

Quality health information is the desire of every health information-seeker, but not all seekers find the right information (Al-Jefri et al. 2018; Pang et al., 2015). Health information quality is a public health concern considering the high user involvement in online health information seeking (Al-Jefri et al. 2018). The internet contains health information of varying quality from professionals to non-professionals without any censoring from regulatory bodies or public health authorities, including the U.S. Food and Drug Administration (FDA).

Health information available online contains unfiltered and unregulated information contents (Al-Jefri et al. 2018). Health-seekers are given the responsibility to ascertain the quality of health information they encounter online. This may be bewildering for some people considering the varying cognitive capabilities, educational and socioeconomic backgrounds of users of online sources who wants to meet their health needs. It is imperative for health care providers and health organizations to acknowledge the urgency and need for quality online health information for patients, especially pregnant women.

Trustworthiness of online health contents is very crucial to patients because many patients have noted that they encounter unclear and contradictory information online.

Johnson, Rowley and Sbaffi (2015) stated that users base their trust for online contents on the peripheral cues and information contents. Information cues are likened to design elements, such as ease of use of an app. Trust formation in online environments however depends on the context. The utility of information source influences trust formation in online contexts. Information quality is usually based on the user's judgment of the information in the context of the needed information (Johnson, Rowley & Sbaffi, 2015). In health contexts, for instance, it is based on how the content relates to the health need. The likelihood of trusting an information source is based on the possibility of the contents meeting the need of the patient (Basnyat et al., 2018). Information source attributes and behavior also promotes trust.

The characteristics of the information source such as credibility, usefulness, accuracy, and topicality influences patient decision to use the health information. Interestingly, users sometimes base their quality metrics on the peripheral cues (i.e., design elements) instead of the informational contents. They base the assessment of an information source on the peripheral cues especially when the information contents require much mental effort to understand the message (Sbaffi & Zhao, 2020; Silvennoinen, Vogel & Kujala, 2014). Thus, well-designed apps are perceived to convey quality health information (Mao et al., 2018). Conversely, apps containing evidence-based information without good design will potentially be neglected by users. There is need for quality health information and well-designed apps to meet the needs of patients.

Credibility of health information can influence the user's perception of quality of health information on apps (Johnson, Rowley & Sbaffi, 2015). Credibility of online

sources are very important to patients. It is also crucial for user engagement with the app, however little research exists on how app design interface shapes user perception of the credibility of health information (Oyibo, Ali & Vassileva, 2016). A study focused on the relationship between aesthetics, usability and credibility in mobile websites reported that aesthetics primarily influenced users' judgement of credibility at both global level and smaller group level (Oyibo & Vassileva, 2016).

Scientific completeness is another quality metric that influences user perception of health information quality on websites (Al-Jefri et al. 2018), which is also true for mobile applications (Daly et al., 2017). Knowledgeable source and expert knowledge are trust indicators of health websites for users. Similarly, app users are interested in evidence-based and accurate description of disease symptoms, treatments, and potential side effects of disease condition (Daly et al., 2017). Comprehensiveness, accuracy, and practicality of knowledge shapes perceptions of users toward quality health information (Mao et al., 2018).

Patient age also influences user perceptions of health information quality. Health information quality is perceived differently by different age groups (Shaheen et al.,2018). Liao and Fu (2012) noted that older adults are less concerned with user interface elements when compared with younger users. Younger users prefer dynamic and pictorial interfaces whereas older users prefer numeric (Shaheen et al.,2018). Similarly, a study on online health information-seeking processes of university students in the U.K. revealed that younger users attached trustworthiness with design features than the actual informational contents (Sbaffi & Zhao, 2020).

Display of contents on computer screens affect how users perceive quality health information. Mobile devices usually display shorter answers than desktop, which may be comforting for some users. The linearity of information influences how users perceive the quality of information displayed on apps. The way user interface features adapt to various sizes of device screens influences user perception of health information quality and success of adoption (Hamzah, Persada & Hidayatullah, 2018). For instance, a person may decide to kick off a specific task using a mobile device with the intent of completing the task on laptop or vice versa. The way the information is relayed on both computers is key for future usage of the app. The behavior of the app on different devices is vital to how users perceive the quality of content. Phone elements such as touch screen capability, storage and bandwidth can also affect the design of mobile applications and how app information is perceived by users (Hamzah, Persada & Hidayatullah, 2018).

Emotions, past experiences, gender, cultural backgrounds, and user expectations are factors that can influence user perception of app design interface and information quality (Lachner, Nguyen and Butz 2018; Lee & Moon, 2016). Visual elements can trigger affective and emotional responses from users. Emotion arousal is one of the sources of personal efficacy developed in the social cognitive learning theory (Bandura, 1977). Emotional arousal stimulated by the design of an app can affects the user's efficacy to perform and complete a specific task. Mostly, users perceive app interfaces that elicit good emotional experience, dynamic user flow, appealing visuals, well-designed interface layout and information architecture as apps conveying quality

information (Lachner, Nguyen & Butz, 2018; Deka, 2016; Silvennoinen, Vogel & Kujala, 2014).

Mobile applications support easy access to health information, but mobile technology has its limitations which can potentially affect user perception of app information quality (Hamzah, Persada & Hidayatullah, 2018). Many mobile health applications are poorly designed and lack good usability (Mao et al., 2018; Hussain et al., 2017). A study on UX of a pregnancy app revealed that the participants in the usability study encountered difficulty in locating and re-locating the needed information, and navigating through the app (Hussain et al., 2017).

With the millions of mobile health applications available in both Android and iOS app stores for pregnant women, only a few have been evaluated and scrutinized to determine usability and accuracy with obstetrics guidelines and recommendations (Dalton et al., 2018; Hussain et al., 2017).

Current State of Research by Health Organizations on Apps Used by Pregnant Women

Research on app technology has reported that more people use this technology for health reasons because of its popularity, biometric functionality, efficiency, ease of use and portability (DeNicola et al., 2020; Nikolic et al., 2018; Hussain et al., 2017). The World Health Organization is focused on extending universal health coverage to people who are unable to get affordable care because of low finances. Mobile technology is one of the means to achieve health care access. Health organizations are open to emerging technologies that can improve patient care quality, especially in low resource settings, but

they advocate for technologies in line with the skills of the users (WHO, 2016). There is, however, paucity of research done by health organizations and institutions on pregnancy-related health apps. Most research on mobile health applications are developer-driven, individual projects and academic-oriented projects. Thus, the accuracy and credibility of these applications may be a concern as most are developed by non-medical professionals and institutions (Biviji et al., 2020; Miah, Gammack & Hasan, 2017).

There is increasing demand for mobile health applications by users. This is clear from the high numbers of app downloads seen in app stores (Santur, Santur & Karakose, 2020). Many private companies such as Apple and Samsung are investing significant finances and resources into the research and development of mobile technology (Santur, Santur & Karakose, 2020; Miah, Gammack & Hasan, 2017). Nevertheless, the designs of most pregnancy-related applications lack of theoretical contents (Duan et al., 2020; Lau et al., 2018). Theoretical-based applications would be more impactful in guiding design teams to design and develop better features that can improve health behavior of users (Lau et al., 2018).

There is a significant dearth on research and evidence concerning the use of mobile apps to improve maternal health in the U.S. (Mehralizade et al., 2017). Beyond the U.S, studies in China and Malaysia affirmed the paucity of research on the effectiveness of pregnancy-related apps (Mo et al., 2018; Hussain et al., 2017).

Insufficient evidence based on clinical research is viewed to affect information quality of apps provided for pregnant women. There is underrepresentation of pregnant women in

research. This limits the extent of studies that can be done on pregnant women (Radin et al., 2018).

Evaluation of Information Quality Regarding UX's Best Practices

Literature in the field of HCI has identified interoperability, usability, credibility, safety, privacy, navigational layout and aesthetics as important elements in the design and development of mobile health applications (Shaheen et al., 2018; Hamzah, Persada & Hidayatullah, 2018). It is vital for designers to give close attention to these elements when designing digital products.

As mentioned previously, user interface layout and navigational aids influence the perception of users regarding quality health information (Shaheen et al., 2018; Pang et al., 2015). Clean user interface and clear navigational aid are expedient for good user experience. Furthermore, Johnson, Rowley and Sbaffi (2015) confirmed design factors, such as clear interface layout, navigational aids, and intuitive features, as contributors to user perception of quality health information. In the context of pregnancy, Mao et al. (2018) mentioned that pregnant women regard layouts, fonts, medical background in app descriptions and regular updating of app as quality metrics in pregnancy-related apps for meeting their pregnancy-related needs.

The aesthetics of app design have a great influence on how the content is perceived by users. Attractive visual elements arouse emotions and cognition of users. The aesthetic appearance and feel of the user interface features determine the perceived utility of the app by users, as well as the information contents. Since this study is focused on technology for pregnant women, it is important for designers of women technology to be

aware of how they perceive app interface because app design is perceived differently by gender (Oyibo, Ali & Vassileva, 2016). A study reported that females are more conscious and sensitive to user interface elements. Research has shown women to be more detailed-oriented than men, and they notice changes in user interface elements more than men (Oyibo, Ali & Vassileva, 2016). Thus, the aesthetics of app design interface is important for pregnant women considering they are all females.

Studies have shown that some functional designs of health apps are unsuccessful in meeting the needs of intended patients (Duan et al., 2020; Mao et al., 2018). Poor design often leads to low user engagement or loss of interest in the apps. Low engagement with health applications may be due to ineffectiveness in delivery or onboarding process (e.g., some apps require that patients log-in unnecessary information before use). There is a need for more health applications to be more encouraging to users (Ledford et al., 2017). Additionally, Kuznetsov et al. (2016) found discrepancies between app descriptions and behavior of apps when displayed on mobile screens of users. Little is known about the influence of inaccurate descriptions of apps on perceived quality of health information.

An investigation conducted in Australia on the rise in use of pregnancy apps among culturally and linguistically diverse women found low usage and adoption of pregnancy-related apps among non-English speaking and poor pregnant women (Hughson et al., 2018). Diverse cultural backgrounds may influence the adoption of mobile applications. For example, use of color is symbolic in different countries and cultures, and the interpretation of colors used in app design might determine its adoption in another

cultural context (Silvennoinen, Vogel & Kujala, 2014). Designers must be aware of how colors are perceived in different cultures.

Furthermore, user needs should determine the design of any product. Women have different needs during pregnancy and those needs change as pregnancy progresses. For example, fetal movement may not be important to a woman who just found out she is pregnant. Designers of pregnancy technology should not use a “one size fits all” approach. Wang et al. (2019) noted the reduction in use of pregnancy apps as pregnancy progressed among Chinese pregnant women from 70% in first trimester to 41% in third trimester. Another study in the U.S. reported a decrease in patient activation level regarding use of mobile applications over time among pregnant women (Ledford et al., 2017). The cause of app disengagement is unclear. Disengagement with apps can be linked to the fluidity of women’s needs, i.e., needs changing as pregnancy progresses. Women can also lose interest in an app because of poor design of the app and infrequent updating of contents relayed in the app.

Correct use of icons and imagery is very valuable in the design of app interfaces (Hussain et al., 2017). Good iconography can create a good user experience for pregnant women and affirm what they feel (emotions) when using the application. A usability study of the Amila pregnancy app carried out in Malaysia noted that the pregnant women in the study could not interpret some of the displayed icons (Hussain et al., 2017). Hence, poor icon design hindered good user experience of the Amila app.

It is important to design app interfaces based on the needs and goals of users because variation exist across different demographics and cultures. Importantly, women

of reproductive ages prefer mobile health applications to other communication modalities for meeting their health information needs (Dalton et al., 2018; Daly et al., 2018).

Implications of Low-Quality Health Information on Pregnant Women?

Provision of quality health information to pregnant women is key for having a successful pregnancy. According to Robinson et al. (2018), “obtaining information is one of the most basic actions a person can do to be engaged in health and make informed decisions about care.” Hence, one of the quickest means of helping and empowering women to engage meaningfully with their physicians is to be informed. Lee and Moon (2016) noted that the most pressing need pregnant women seek from pregnancy apps is information. Pregnancy apps are regarded as information conduits (Radin et al., 2018). It is vital to pay close attention to the informational contents generated on mobile applications. The pregnancy period demands adherence to different treatment plans such as taking medications and supplements and attending routine prenatal care. Pregnancy also requires healthy behaviors such as adhering to healthy diets, physical activities, and refraining from alcoholic drinks and hard substances to prevent fetal alcohol syndrome (FAS) (Snyder, Neufeld & Forbes, 2020; Dathe & Schaefer, 2019; Lau et al., 2018; Jallo et al., 2017). Remarkably, much information published online on different pregnancy topics exist in varying quality. Therefore, poor quality health information is a serious public health concern for pregnant women, physicians, and health organizations combating maternal deaths.

Poor quality health information can increase noncompliance among pregnant women. Noncompliance to treatment protocols or plans is already a global and common

practice among patients (Dolinski, Dolinska & Bar-Tal, 2018). The impact of noncompliance to treatments not only adversely affects the patients, but it also directly or indirectly affects societies, physicians, pharmaceutical companies, health care expenditure, financial systems, workplaces, insurance companies, and family members (Audrain-Pontevia, Menvielle & Ertz, 2019; Lu et al., 2018; Laugesen, Hassanein & Yuan, 2015). Lives, resources, and money are lost to patient noncompliance annually.

Poor quality health information can lead to ineffective treatment and lack of confidence in the physicians (Liu et al., 2019; Joury et al., 2016). Many studies have shown the influence of internet health information on patient-physician relationships in health care settings (Lu & Zhang, 2019; Lu et al., 2018). When physicians' recommendations are inconsistent with what some patients have read online, friction can occur between them and the physicians. Little time allocated to wellness discussions ends up being lost to debating subjective issues. Unreliable health information leads to poor patient-physician interaction and noncompliance. In the case of pregnant women, it is more dangerous because it can lead to maternal and infant morbidities and mortality.

Poor quality information also contributes to poor health literacy, which may then lead to lack of understanding and ineffective application of acquired health information (Arts, Lemetyinen & Edge, 2019; Dalton et al., 2018). Another challenge of online health information is the sophisticated nature of the language used to convey the messages. Yi and Hu (2020) indicate that many medical resources available online are written at a high school reading level and may be challenging for an average reader to comprehend.

Poor quality health information is associated with increased stress and anxiety levels among patients (Lu et al., 2018). Processing of online health resources can be cognitively tasking and overwhelming for some users. Much exposure to poor quality health information can increase negative emotions, which can lead to adverse health outcomes (So, Kuang & Cho, 2019). Finally, poor quality information can ultimately lead to disability and unwarranted loss of patient life. Failure to adhere to treatment plans alone causes 125,000 deaths annually in the U.S. As such, poor quality health information plays a huge role in misleading and endangering lives of patients (Biviji et al., 2020; Dol et al., 2020; Laugesen et al., 2015).

Relationship Between App Developers, Physicians, and Medical Institutions

Most mobile health applications are designed and developed by non-medical institutions and professionals. They are developer-driven with mostly no input from physicians to scrutinize the accuracy of the product and ensure it is in accordance with obstetrics guidelines (Dalton et al., 2018; Miah, Gammack & Hasan, 2017). Pregnancy applications are supposed to be designed and developed based on evidence-based clinical recommendations provided by medical professionals, but this is not the case (Mao et al., 2018; Daly et al., 2017). Lee and Moon (2016) advocate for the integration of input from health care providers into the design and development of pregnancy apps.

Inclusion of app developers with medical background is lacking among the design team. Mao et al. (2018) opined the importance of inclusion of app developers with medical background in the app development team. A review on mental and physical mobile health apps found that most applications designed and developed for diagnostic

and treatment purposes were done without the inclusion of any medical professionals (Sedrati et al., 2016). Tech-giant companies and individuals are the ones leading mobile health research and innovations with little to no input from medical organizations (Al-Jefri et al., 2018; Miah, Gammack & Hasan, 2017). Additionally, there is no regulatory body scrutinizing app health information (Kamal et al., 2014). Most of the health information online also lack peer-review assessments (Yi & Hu, 2020). There is need for health institutions and professionals to get involved with information curation in online scenes.

Conclusion

This chapter highlights the reality of health care delivery available to pregnant women in the U.S. and the impact of patient communication and patient-physician interaction on patient compliance. Studies have shown the need to respond to the annual increasing rates of maternal deaths recorded in the country in the face of a complex health care system. With the advent and prevalence of internet and mobile technology, more women can access health information and resources through health apps. However, understanding the design, utility and information credibility of app technology is vital for its acceptance in health care settings.

Since more women irrespective of socioeconomic and ethnic backgrounds use pregnancy-related apps, it is important to understand how they perceive the technology.

Chapter 3: Methodology

Introduction

This chapter covers the methodology of the study and describes the research design and procedures used for conducting the study. It also highlights survey research method, target population and sampling method, recruitment, data collection techniques, validity and reliability, ethical consideration, data analysis and triangulation of data.

Purpose of the Study

The purpose of this study is to assess pregnant women's perceptions on mobile app design, utility, and credibility of health information provided on pregnancy apps for meeting their health needs during their current pregnancy. It also seeks to assess the effectiveness and adequacy of mobile app design for enhancing patient compliance, which is necessary for better health outcomes.

Research Questions

As noted in Chapter 1, the problem statement for this study was to determine the perceptions of pregnant women on mobile app designs, utility, and information credibility, and explore the utility of pregnancy apps for meeting their needs during their current pregnancy.

Hence, the following research questions were explored:

1. How does app design interface help with quality health information for pregnant women?
2. How effective and adequate is health intervention through app technology for pregnant women?

3. What design recommendations can be provided to improve health information for pregnant women? (Participatory design approach.)

Research Design

Mixed methods design involves the combining of both quantitative and qualitative research approaches in the same study (Roberts & Hyatt, 2019). According to Creswell and Creswell (2018), mixed methods research is an approach which combines both quantitative and qualitative data, integrates the two forms of data, and use different research designs in a single study. Interestingly, both quantitative and qualitative approaches have its biases and weaknesses. Hence, the integration of both approaches generates more comprehensive and robust insights that either quantitative or qualitative could generate individually. Additionally, inclusion of both approaches neutralizes the weaknesses of both while harnessing the strengths of both quantitative and qualitative research.

Mixed methods research offers the strengths of both quantitative and qualitative in answering the research questions. Therefore, this study used an explanatory sequential mixed methods design for investigating the perceptions of pregnant women of mobile app design, utility, and information credibility. Explanatory sequential mixed methods involve the collection and analyzing of the quantitative data first, and then followed by collection of the qualitative data. The quantitative results are further buttressed and better understood with insights from the qualitative analysis (Creswell & Creswell, 2018).

This research design is preferred firstly because of its capacity to collect a more robust and comprehensive data. Secondly, it supports the integration of two different research approaches to answer complex research questions. Thirdly, the quantitative results purposively inform the type of participants to be included in the qualitative phase, and lastly, the qualitative results help to provide deeper and more detailed explanation to the quantitative results analyzed initially, thereby providing a better picture of and solution to the research questions.

The researcher first conducted quantitative research using anonymous surveys gathered through SurveyMonkey software to elicit responses from research participants. Afterwards, online case studies using co-designing technique were used to gather the qualitative data from the research participants. The quantitative data gathered in the first phase were analyzed first, and the quantitative results were used to plan the second qualitative phase.

Survey as a Research Method

Survey research is a research approach or tool used for gathering both qualitative and quantitative data from a large sample (Lin & Van Ryzin, 2012; Lavrakas, 2008). Surveys are a well-defined and well-written set of questions presented to people in a study to provide information about themselves. Surveys are one of the foremost research methods used in the field of human-computer interaction (Lazar, Feng and Hochheiser 2017; Cozby, 2001). Surveys are also useful for collecting attitudinal data from population samples that may be difficult to reach in a single location, especially those in geographically dispersed situations. It also measures behaviors, beliefs, demographics,

awareness, and feedback on user experiences. It is also advantageous for easy collection of responses from large audiences at a low cost (Lazar, Feng & Hochheiser; Sauro & Lewis, 2016). They are prominent for studying relationships between variables and measuring past and future human behaviors (Cozby, 2001).

Survey research uses different data collection techniques for gathering personal information from people. This study used web surveys and online case studies to ask pregnant women to provide information about their experiences with pregnancy apps.

Case study is a research strategy which “investigates a contemporary phenomenon within its real-life context, especially when the boundaries between phenomenon and context are not clearly evident” (Yin, 2003). It could be single-case or multiple-case studies.

This study used multiple-case studies because of its ability to provide more robust and compelling findings on the topic being studied. Yin (2003) noted the value embedded in two or more cases in comparison to single-case, particularly regarding the analytical conclusion.

Case study is an empirical inquiry for the purpose of describing, understanding, and predicting the person being studied in real-life context. This method is an in-depth study of a specific phenomenon within a real-life context (Lazar, Feng and Hochheiser, 2017).

Target Population and Sampling Methods

The exclusion criteria were women who were not pregnant and living outside the United States. The researcher was interested in exploring the perceptions of pregnant

women on mobile app designs, utility, and information credibility of contents from pregnancy health applications.

Convenience and purposeful sampling techniques were used for the study.

Convenience sampling entails selecting a set of people for a particular study in a convenient location or internet service (Edgar & Manz, 2017). It is also regarded as a sampling technique which involves collecting of responses from people who are willing to participate in a research study at a time the researcher needs them (Fink, 2009).

Purposeful sampling involves the identifying and selecting of people who have the characteristics, knowledge, and experience of the phenomenon of interest being studied for the research purpose (Palinkas et al., 2015). The samples were conveniently and purposefully chosen from online social media pregnancy groups, particularly Twitter and Facebook pregnancy groups and through word of mouth. The quantitative data were collected using an anonymous web survey from 59 pregnant women.

Recruitment & Data Collection Techniques

Upon the approval of the research instruments from the Institutional Review Board (IRB), the researcher joined different online social media pregnancy support groups to find interested pregnant women. The research participants in the study were mainly recruited from Facebook pregnancy support groups and through word of mouth. The web survey (see Appendix) link was shared on different pregnancy support groups to interested pregnant women and shared with close contacts who knew anyone pregnant in the U.S. Data were collected between March and June 2021.

The researcher used online social groups for recruitment due to the COVID-19 pandemic, during which human interaction was limited and risky, thus making it difficult to reach the target population in person. The data collection for the study were completed in two phases. The first phase involved the use of web surveys for gathering the quantitative data. The survey link was posted on different social media platforms, particularly Facebook pregnancy groups for U.S residents.

The second phase involved gathering of qualitative data from fewer pregnant women. To achieve this, a research invitation (see Appendix) was shared through WhatsApp with close contacts who knew any pregnant women in the U.S. The research invitation was also posted on Facebook pregnancy support groups. The invitation provided interested participants a web link to fill in their contact information. The researcher retrieved details of interested participants and contacted them through email to schedule suitable days and dates for the online case studies/co-designing sessions. A total of four pregnant women and one gynecologist showed interest in the online case studies. The study awarded a sum of \$50 to each pregnant woman and \$100 to the gynecologist for participating in the study.

Data Collection

The researcher gathered participants' responses from the survey on the SurveyMonkey software while the qualitative data were gathered using Zoom software. The researcher used a semi-structured interview guide during the online case studies sessions (see Appendix). Additionally, the researcher used co-designing technique for

involving the research participants in a design session. A total of five participants were included in the qualitative phase, namely four pregnant women and one gynecologist.

The researcher collected both video and audio recordings of the sessions and took notes to document vital facts discovered during the design sessions. Each of the sessions with the pregnant women lasted 30 minutes, whereas the session with the gynecologist lasted 45 minutes.

The study offered research incentives to participants who participated in the qualitative research. All four pregnant women were given \$50 Amazon gift cards and a \$100 Amazon gift card was given to the gynecologist.

Validity and Reliability

Validity refers to the truthfulness of the findings purported from a study. It is also the degree to which the research instrument measures what it is intended to measure in a study (Cozby, 2001). The survey and online case study questions for the study were able to measure perceptions of pregnant women on mobile app design, utility, and information credibility.

Reliability is defined as the degree to which a research instrument consistently measures what it intends to measure. It is a consistent measure of a given behavior (Cozby, 2001).

To ensure reliability and validity, the study adopted previously validated instruments from Laugesen et al.'s (2015) study for the survey questions. Patient compliance and perceived internet health information quality (in the context of mobile apps) were

measured using a 7-point Likert scale ranging from strongly agree to strongly disagree (see Appendix). Furthermore, the study instruments underwent thorough scrutiny of the dissertation advisors and IRB of the University of Baltimore, and the study underwent triangulation i.e., comparing sources (Sbaffi & Zhao, 2018).

Ethical Considerations

The researcher ensured that all the participants signed a copy of the informed consent form approved by the IRB of the University of Baltimore before the research sessions. The informed consent for the survey was included on the first page of the survey since it was an anonymous and electronic submission.

All the participants were assured of anonymity, confidentiality, and that participation was voluntary. Participants were informed the collected data were kept safe in the researcher's encrypted passworded laptop, and all the participants were briefed the title and purpose of the study before the online sessions commenced.

Data Analysis

The study used descriptive statistics for analyzing the quantitative data gathered from the web survey. Descriptive statistics are statistical procedures used to convert raw scores into meaningful and manageable data. Descriptive statistics simplify complex data scores into tables or graphs from which the researcher can draw conclusions from the sample about the population (Gravetter & Wallnau, 2017).

Thematic analysis was used for analyzing the qualitative data gathered from the online case studies. Thematic analysis is a “method for identifying, analyzing, and reporting patterns (themes) within data” (Braun & Clarke 2016). It is a research analysis

qualitative method which identifies themes or patterns from the qualitative data and are reported as researcher-generated codes or themes (Lochmiller, 2021). The output of thematic analysis is usually longer sentences rather than shorter codes (Saldaña, 2016).

Triangulation of Data

Data triangulation involves using different data sources/research methods to validate research questions and empirical results in a study, as well as involves collection of more knowledge to corroborate findings in research study (Flick, 2018). Likewise, Saldanha and O'Brien (2013) described triangulation as “cross-checking the results of one set of data provides with results from another set of data.”

Past literature confirmed the shift to newer technologies for accessing medical information among pregnant patients. New studies on pregnant women have also reported the use of pregnancy apps among pregnant women in developed countries (DeNicola et al., 2020; Dalton et al., 2018). Use of pregnancy apps among women in their reproductive ages is driven by the internet and mobile technology advancement. Pregnant women prefer to source health information from their physicians (Holroyd et al., 2017), the internet (Javanmardi et al., 2018), websites, (Fredriksen, Harris & Moland 2018; Fredriksen, Harris & Moland, 2016) and pregnancy apps (DeNicola et al., 2020; Daly et al., 2017). These were confirmed from the web survey and online case studies responses.

Conclusion

This chapter highlighted a detailed explanation of the research design, target population, sampling techniques, recruitments, data collection techniques, ethical considerations, data analysis and data triangulation. The next chapter will discuss the overall data analysis and results.

Chapter 4: Data Analysis and Results

Introduction

This chapter will explain the data analysis for the study and interpretation of the findings from the empirical components of the study on perceptions of pregnant women on mobile app design, utility, and information credibility.

This chapter will also summarize findings from the quantitative and qualitative data. It also highlights triangulation of findings, which is central to mixed methods research design.

Overview

The purpose of this mixed methods research was to explore the perceptions of pregnant women resident in the United States on mobile app design, utility, and information credibility. A self-report survey developed particularly for assessing patient compliance and perceived quality of internet health information (Laugesen et al., 2015) was used to gather the descriptive data from the participants. The qualitative data was gathered with the use of co-designing during online case study sessions. The qualitative questions were developed to help explain in detail how pregnant women view pregnancy-related app designs, utility, and the credibility of the contents displayed on the apps. The aim of this study is to assess the perceptions of pregnant women on mobile app design, utility and credibility of health information provided on pregnancy-related apps they use during their current pregnancy. It also seeks to understand the effectiveness and adequacy of pregnancy apps for promoting patient compliance, which is key for maternal health in the U.S.

The following research questions were established to discover the perceptions of pregnant women on mobile app designs, utility, and information credibility. These questions were established to confront the significant dearth of research on the usefulness of pregnancy-related apps and pregnancy apps for increasing patient compliance in the U.S. Therefore, the research questions are:

1. How does app design interface help with quality health information for pregnant women?
2. How effective and adequate is health intervention through app technology for pregnant women?
3. What design recommendations can be provided to improve health information for pregnant women? (Participatory design approach.)

Research participation in accordance with methods of data collection

The target population for this study are pregnant women resident in the U.S. This study used a sequential explanatory mixed methods research design to understand the perceptions of pregnant women on mobile app design, utility, and information credibility. Convenience and purposive sampling techniques were used to identify a sample from the target population. The quantitative data were collected using an anonymous web survey from 59 pregnant women. The link to the survey was shared via social media, mainly on American Facebook pregnancy support groups and Twitter. The researcher also used WhatsApp to share the web link with close contacts who knew any pregnant women in the U.S.

Furthermore, an e-invitation was posted on American Facebook pregnancy support groups to solicit for interested pregnant women to participate in the online case studies using the co-designing method. Women interested in the study could provide their contact details on the e-invitation. The researcher responded to the women through email to finalize the scheduling of the Zoom meetings. The Zoom meetings were scheduled, and the link to the meeting room and informed consent form were shared through the researcher's email to all the participants prior to the day of the meeting. A total of four pregnant women and one gynecologist responded and participated in the online case studies involving co-designing. Data were collected between March and June 2021. Zoom software was used for the co-designing sessions with the pregnant women.

Table 1. Summary of Participants according to the method of data collection

	Web survey	Online case study
Total number of participants	89	5
Number of returns: Incomplete	31	5
Usable	58	

The table above shows the profile of participants who were included in the data analysis.

Finding and analysis from the web survey

The web survey contained 31 questions. The questions covered demographic information, information related to pregnancy, pregnancy and patient compliance, and app health information quality.

Characteristics of the Study Population

Demographic characteristics of the sample are displayed in Table 2 below.

Age. This question was asked to know the ages of women who participated in the study (n=57). A total of 57 out of 89 women responded to this question. The majority of pregnant women who responded were ages 25-34 (64.91%), followed by ages 35-44 (24.56%). A minority of them were ages 18-24 (8.77%) and 45-54 (1.75%). None of the women were 55 and above.

Ethnic Background. This question revealed the diverse ethnic backgrounds of the participants (n=58). Only 58 out of 89 women responded. The majority of the pregnant women were White or Caucasian and Black or African American, 29 (50%), and 24 (41.38%) respectively. Other women were Hispanic or Latino 2 (3.45%), and Asian or Asian American 2 (3.45%). The question specified for other ethnic backgrounds to be listed; only one woman responded to be White and Black.

Marital Status. This question was asked to determine the marital status of the participants (n=58). The majority of the women were married 46 (79.31%) and a few were unmarried 8 (13.79%). The participants had the option to specify other terms that described their marital status. Two women specified being engaged 2 (3.45%), one specified divorced 1 (1.72%) and one specified domestic partnership 1 (1.72%).

Highest educational level. This question was asked to determine the highest education level of the participants (n=58). The highest identified level of education was master's degree 19 (32.76%), followed by bachelor's degree 14 (24.14%), doctoral degree 11 (18.97%), associate degree 6 (10.34%) and 5 (8.62%) had completed high school. Only 2 (3.45%) had not completed high school. The question offered other

options; one participant (1.72%) responded with “completed one year college, no degree.”

Employment status. The intention of this question was to determine the employment status of the participants (n=59). More than half of the women were employed, working full-time 39 (66.10%) and 6 (10.17%) were also employed, working part-time. However, 5 (8.47%) were not employed, looking for work, 7 (11.86%) were not employed, not looking for work, and 2 (3.39%) identified as disabled, not able to work.

Table 2. Sample demographics
(N=89)

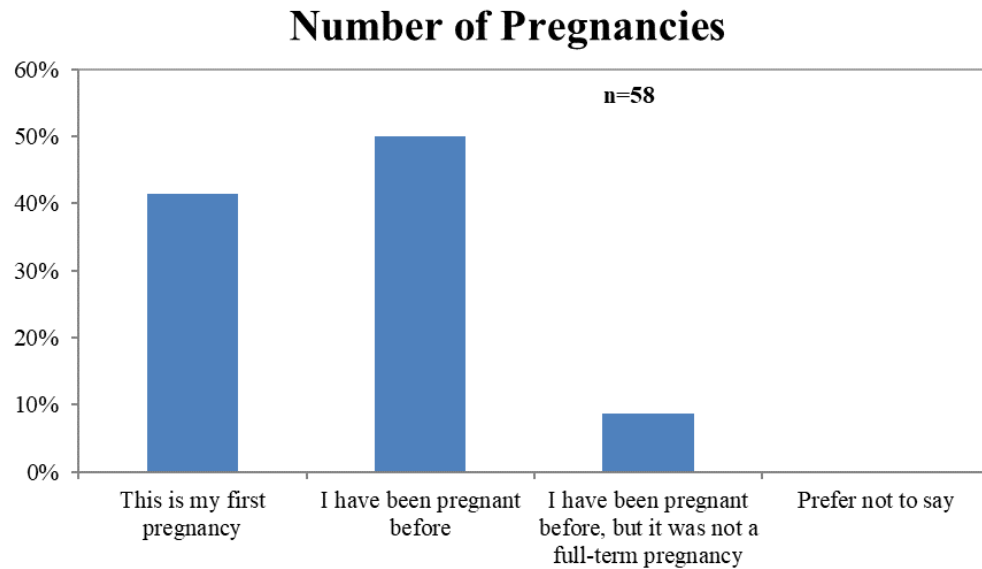
Demographic Characteristics	n%
Age	n=57
18-24	5(8.77%)
25-34	37(64.91%)
35-44	14(24.56%)
45-54	1(1.75%)
55+	0(0%)
Ethnic Backgrounds	n=58
White or Caucasian	29(50.00%)
Black or African American	24(41.38%)
Hispanic or Latino	2(3.45%)
Asian or Asia American	2(3.45%)
American Indian or Alaska Native	0(0%)
Other	1(1.72%)
Marital Status	n=58
Married	46(79.31%)
Not married	8(13.79%)
Other	4(6.90%)

Education (highest level)	n=58
Have not completed high school	2(3.45%)
Completed high school	5(8.62%)
Associate degree	6(10.34%)
Bachelor's degree	14(24.14%)
Master's degree	19(32.76%)
Doctoral degree	11(18.97%)
Other	1(1.72%)
Employment Status	n=59
Employed, working full-time	39(66.10%)
Employed, working part-time	6(10.17%)
Not employed, looking for work	5(8.47%)
Not employed, NOT looking for work	7(11.86%)
Retired	0(0%)
Disabled, not able to work	2(3.39%)

Information-related to Pregnancy

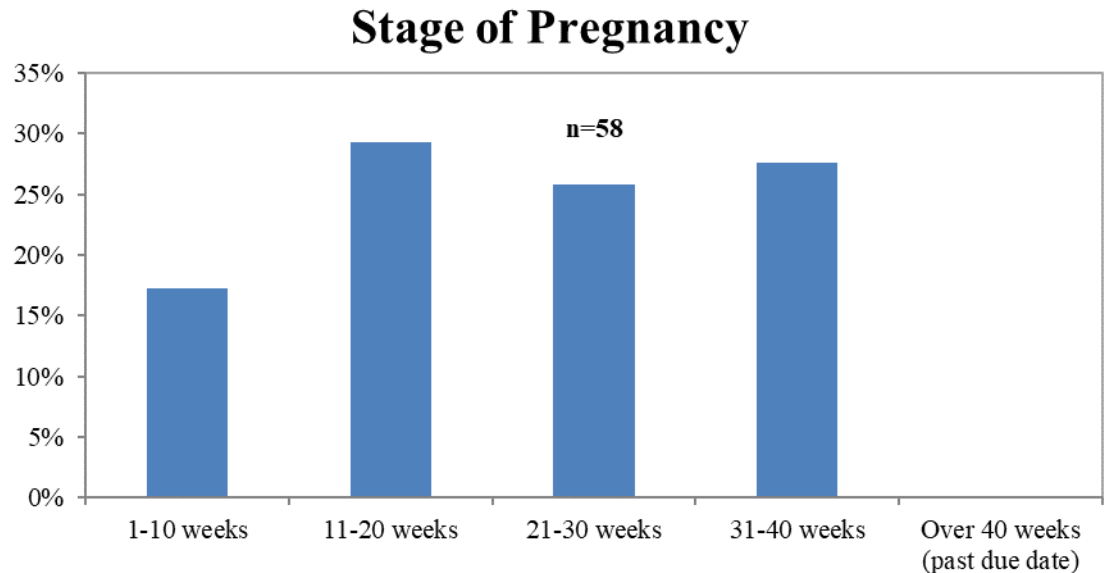
Number of Pregnancies. This question was asked to ascertain whether the current pregnancy is the first or if the participant had been pregnant before. Only 58 out of 89 women responded to this question. 24 (41.38%) indicated that the current pregnancy was their first, 29 (50%) identified that they have been pregnant before. Only 5 (8.62%) indicated that they had been pregnant before, but it was not a full-term pregnancy.

Figure 1. Number of Pregnancies



Stage of Pregnancy. Question two was asked to determine the stage of pregnancy of the participants. Only 58 out of 89 women responded to this question. Responses showed that 17 (29.31%) were in 11-20 weeks, 16 (27.59%) were in 31-40 weeks, 15 (25.86%) were 21-30 weeks and 10 (17.24%) were in 1-10 weeks of pregnancy.

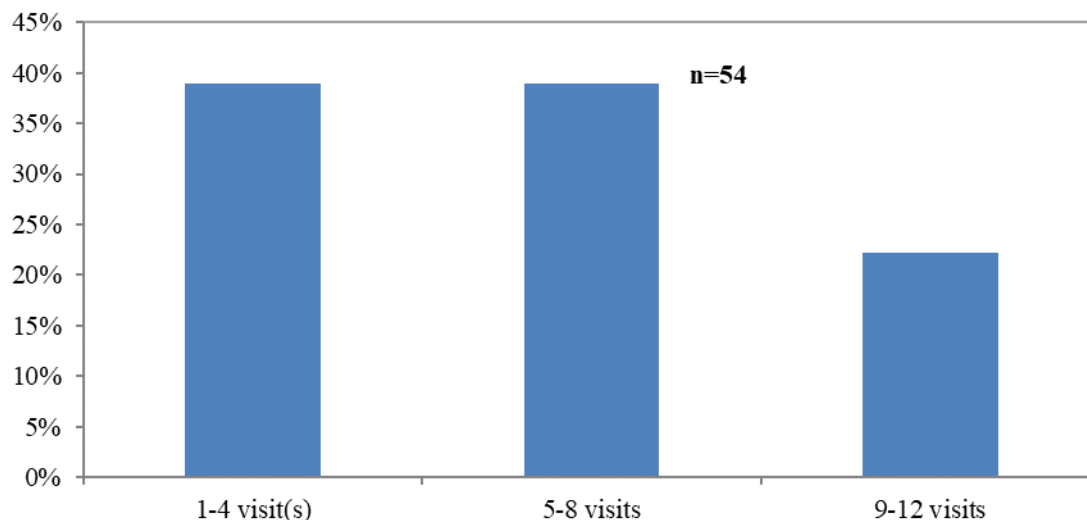
Figure 2. Stage of Pregnancy



Number of prenatal visits for the current pregnancy. This question uncovered the approximate number of prenatal visits of the participants in their current pregnancy. Only 54 out of the 89 women responded to this question. The majority of the participants indicated 1-4 visit(s) and 5-8 visits, 21 (38.89%) and 21 (38.89%) respectively, while 12 (22.22%) indicated 9-12 prenatal visits. This question asked the participants to specify other prenatal visits beyond twelfth visits. The additional responses included two participants who responded, “not yet,” one noted 9-12 visits by the end of her pregnancy, one participant indicated 19 visits, and one participant noted 12 OB (obstetrics) visits and eight MFM (maternal-fetal medicine specialist) visits.

Figure 3. Approximate Number of Prenatal Visits

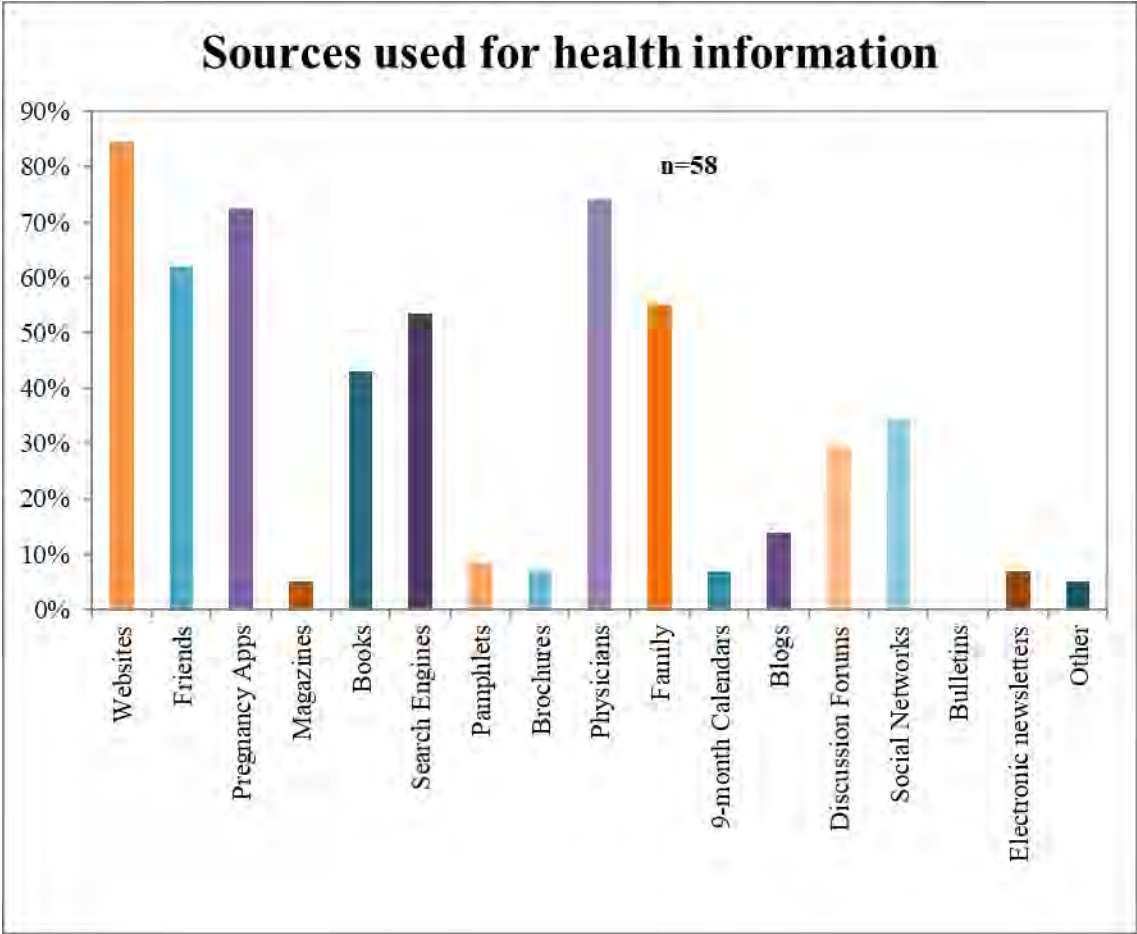
Approximate number of prenatal visits



Information sources used for looking for health information during the current pregnancy. This question was asked to understand the various information sources used by the participants during their current pregnancy. Only 58 out of the 89 women responded to this question. The most sought health information sources were websites 49 (84.48%), followed by physicians 43 (74.14%), pregnancy applications (apps) 42 (72.41%) and friends 36 (62.07%).

The least sought health information sources were magazines 3 (5.17%), electronic newsletter 4 (6.90%), brochures 4 (6.90%) and nine-month calendars 4 (6.90%). This question asked the participants to specify “other” information sources used but not mentioned in the survey. Three participants responded, and their responses were doulas, Reddit, the app The Bump, and YouTube.

Figure 4. Sources used for Health Information

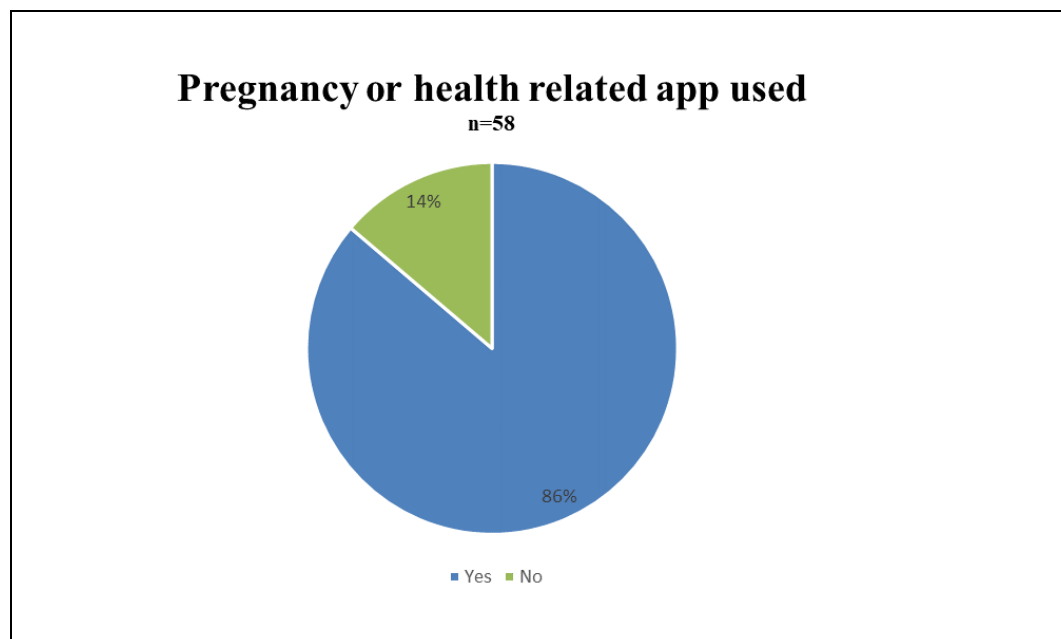


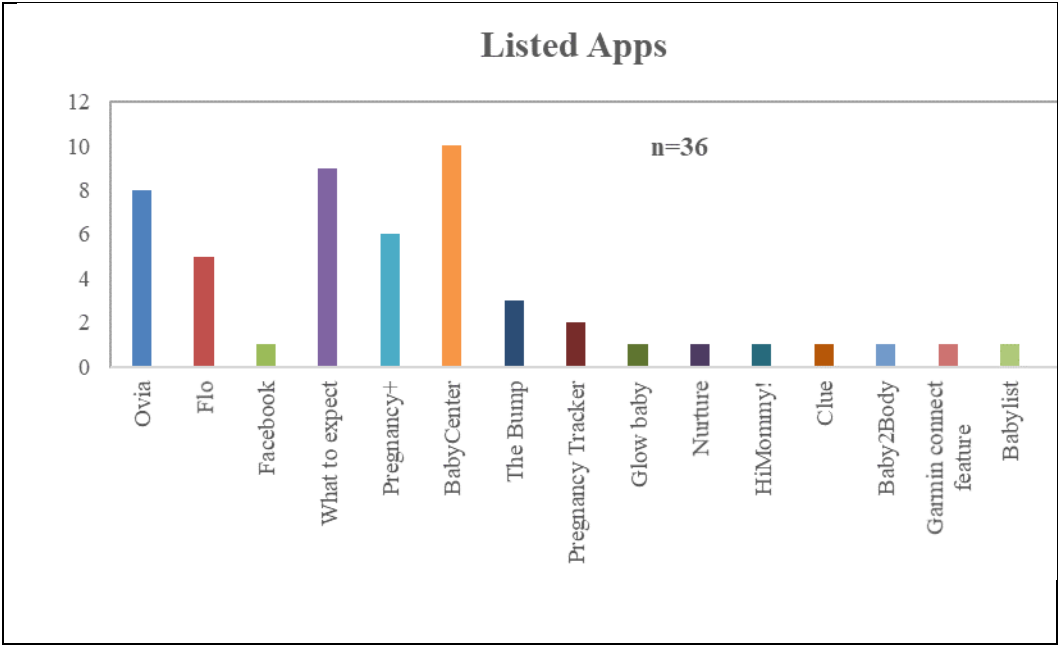
Pregnancy or Health Related App used during the Current Pregnancy. This question asked if participants used a pregnancy or health-related app during their current pregnancy. Only 58 out of the 89 women responded to this question. A total of 50 (86.21%) said Yes, while 8 (13.79%) said No. The question also provided the option of

listing the specific health-related apps used by the participants. 36 women provided answers to listing specific apps, indicating 16 apps.

The listed health apps were: **Ovia, Flo, Facebook, What to Expect, Pregnancy+, BabyCenter, The Bump, Pregnancy Tracker, Glow Baby, Nurture, HiMommy!, Clue (ovulation tracking), Baby2Body, Garmin Connect Feature, Babylist and Kaiser.**

Figure 5. Pregnancy or Health Related App used





Pregnancy and Patient Compliance

Compliance refers to patients’ decision to follow the treatment plans and instructions provided by a physician (Lu & Zhang, 2019; Laugesen et al., 2015). The following section focuses on compliance to physician’s instructions, medications, lifestyle, suggested treatment, and follow-up tests for treatment.

Table 3 below summarizes and ranks all the compliances pertinent to pregnant women.

The option “I have returned or plan to return to the physician on the schedule he or she suggested for treatment” ranked highest, followed by the option “I have had or plan to have the follow-up tests for treatment, as recommended by the physician,” and “I

am following or did follow the physician's recommendations on use of medication and supplements" was ranked in third place. The least ranked patient compliance item was "I am following or did follow the physician's orders on healthier lifestyle, such as diet and exercise."

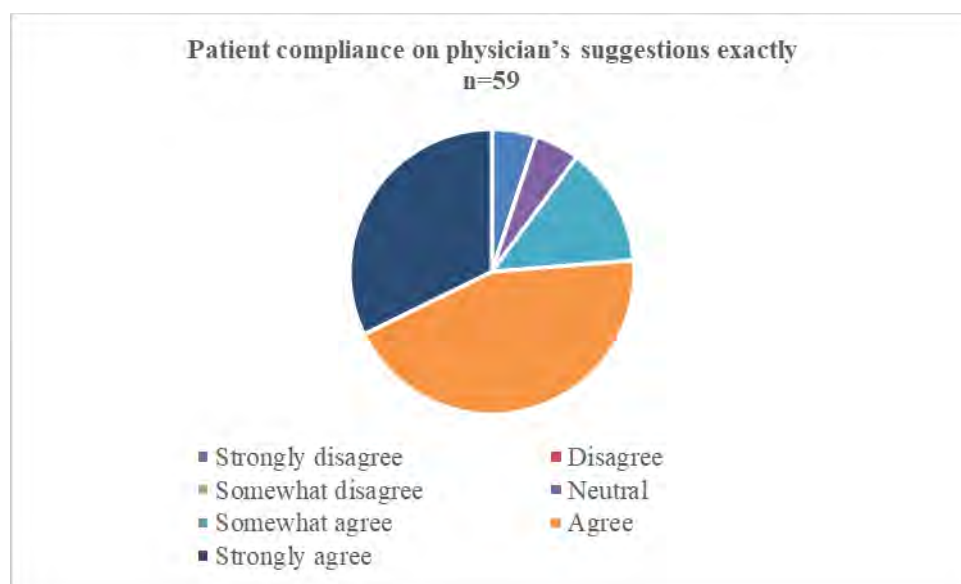
Table 3. Patient Compliance and Pregnancy

n=59	Strongly disagree	Disagree	Somewhat disagree	Neutral	Somewhat agree	Agree	Strongly agree	Total	Weighted Average	Rank
Patient compliance on physician's suggestion exactly	5.08%	0.00%	0.00%	5.08%	13.56%	44.07%	32.20%	59	5.83	4
Patient compliance on use of medication and supplements	5.08%	0.00%	0.00%	3.39%	11.86%	22.03%	57.63%	59	6.14	3
Patient compliance on healthier lifestyle, such as diet and exercise	5.08%	3.39%	1.69%	8.47%	22.03%	42.37%	16.95%	59	5.34	5
Patient compliance on suggested treatment	1.72%	0.00%	3.45%	6.90%	5.17%	25.86%	56.90%	58	6.19	1
Patient compliance on follow-up tests for treatment	3.39%	0.00%	1.69%	5.08%	8.47%	25.42%	55.93%	59	6.15	2

Patient Compliance on Adherence to Physician's Suggestions exactly. This question concerns the degree to which pregnant women follow or adhere to physician's suggestion exactly during their current pregnancy (n=59). This question used a seven-point Likert scale, the options being strongly disagree, disagree, somewhat disagree, neutral, somewhat agree, agree, and strongly agree. A higher weighting was attached to strongly agree and agree.

Based on the responses from the participants, answers to "I am following or did follow the physician's suggestions exactly" revealed that a high number 26 (44.07%) agree with following or did follow the physician suggestions exactly, followed by 19 (32.20%) who indicated "strongly agree" and 8 (13.56%) who indicated "somewhat agree." A total of 53 (89.83%) strongly agreed, agreed, or somewhat agreed to adhering to physician's suggestions exactly. Conversely, 3 (5.08%) were neutral and 3 (5.08%) strongly disagreed with the statement.

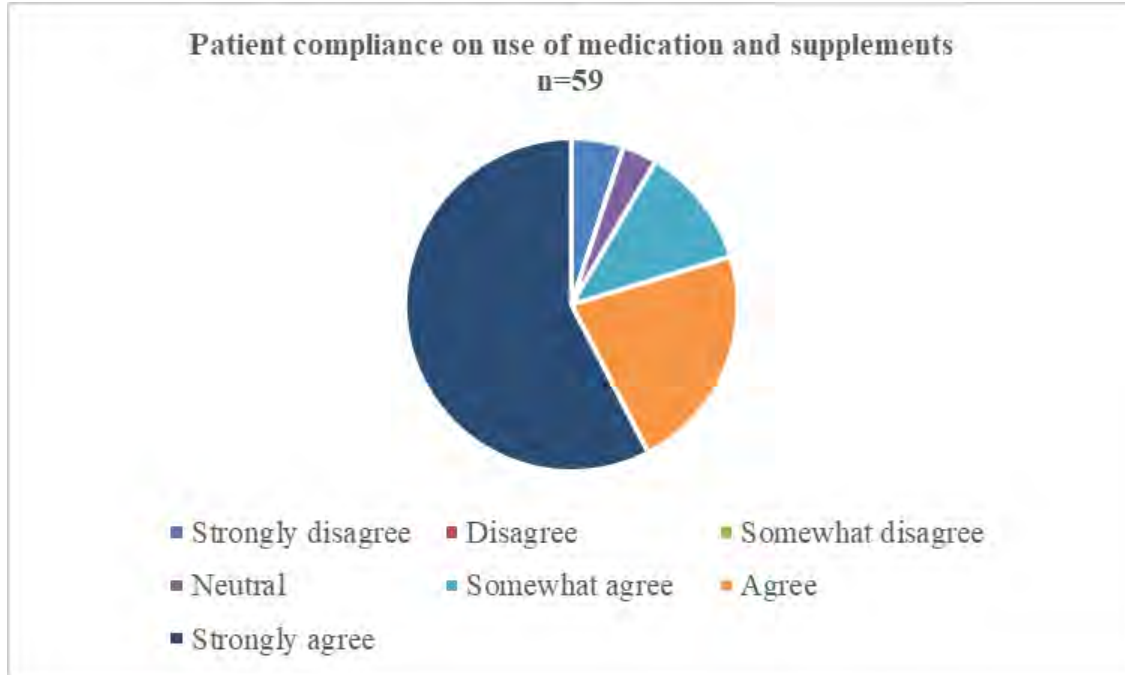
Figure 6. Patient Compliance on Physician's Suggestions exactly



Patient Compliance on Use of Medication and Supplements. Compliance can be assessed from patient's adherence to medicine (Lu & Zhang, 2019). Use of prenatal vitamins is a major requirement for women during pregnancy for fetal growth and development. The aim of this question is to determine whether the participants adhere to their physician's recommendations on medications and supplements (n=59). This question used a seven-point Likert scale, the options being strongly disagree, disagree, somewhat disagree, neutral, somewhat agree, agree, and strongly agree. A higher weighting was attached to strongly agree and agree.

Responses to "I am following or did follow the physician's recommendations on use of medication and supplements" show that 34 (57.63%) strongly agree, 13 (22.03%) agree and 7 (11.86%) somewhat agree. Thus, a total of 54 (91.52%) strongly agreed, agreed, or somewhat agreed with their physicians on medication and supplements, while 2 (3.39%) were neutral and 3 (5.08%) strongly disagreed.

Figure 7. Patient compliance on use of Medication and Supplements



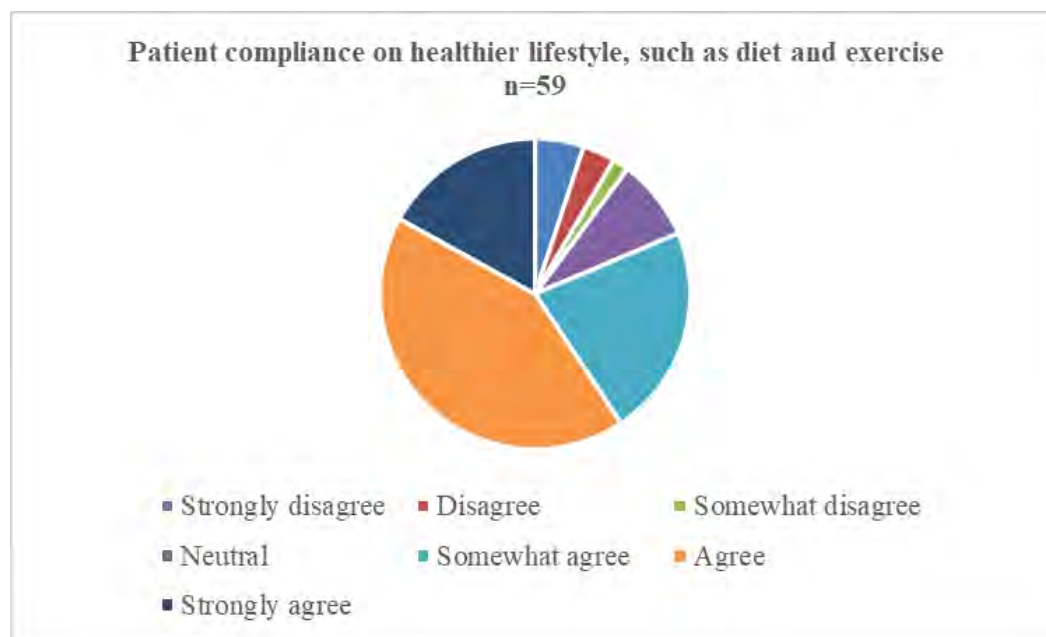
Patient Compliance on Healthier Lifestyle. Compliance can also be determined from maintaining a healthy lifestyle (Lu & Zhang, 2019). This question used a seven-point Likert scale, the options being strongly disagree, disagree, somewhat disagree, neutral, somewhat agree, agree, and strongly agree. A higher weighting was attached to strongly agree and agree (n=59).

Responses to “I am following or did follow the physician’s orders on healthier lifestyle, such as diet and exercise” indicate that the majority of the participants agree, strongly agree, and somewhat agree, 25 (42.37%), 10 (16.95%) and 13 (22.03%) respectively. Thus, 48 (81.35%) strongly agreed, agreed, or somewhat agreed to advice on healthier lifestyle from the physicians. Only a few of the participants were neutral 5

(8.47%), strongly disagreed 3 (5.08%), disagreed 2 (3.39%) and somewhat disagreed 1 (1.69%).

Interestingly, 11 (18.63%) of the participants were either neutral or had some level of disagreement.

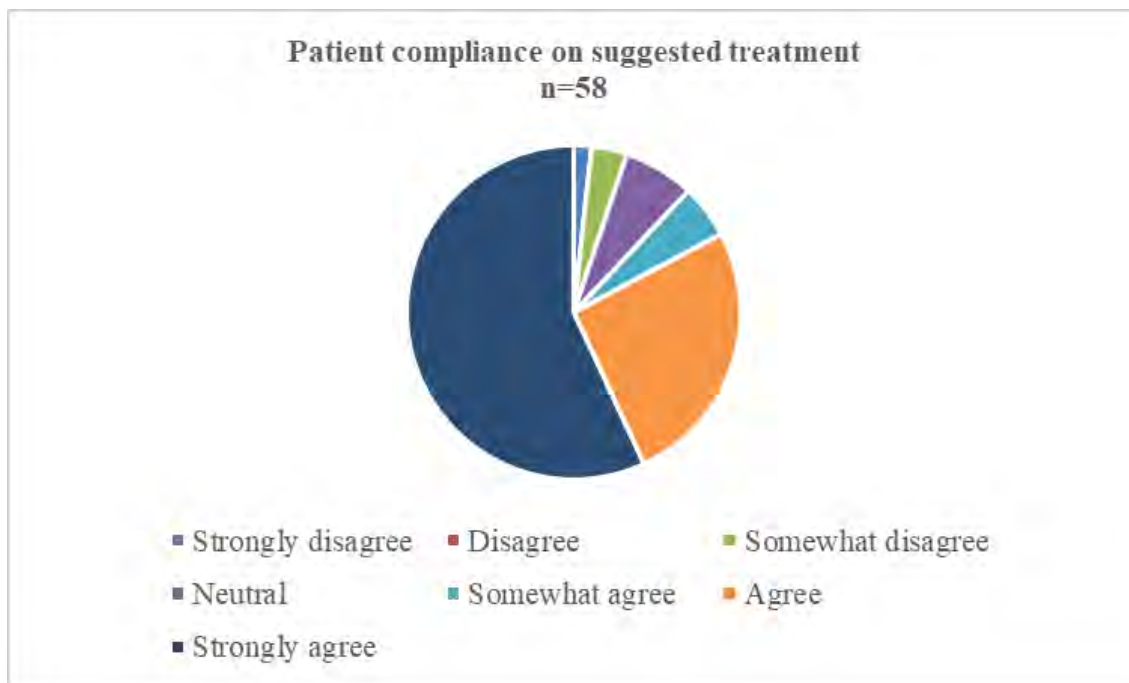
Figure 8. Patient Compliance on Healthier Lifestyle



Patient Compliance on Suggested Treatment. The question “I have returned or plan to return to the physician on the schedule he or she suggested for treatment” uncovers an important aspect of patient compliance which is paramount to better health outcomes. This question used a seven-point Likert scale, the options being strongly disagree, disagree, somewhat disagree, neutral, somewhat agree, agree, and strongly agree. A higher weighting was attached to strongly agree and agree (n=58).

Of the 58 responses, 33 (56.90%) expressed “strongly agree,” 15 (25.86%) “agree” and 3 (5.17%) indicated “somewhat agree.” Hence, majority 51 out of 58 have returned or plan to return to the physician on the suggested treatment plan. Conversely, a total of 7 (12.07%) either strongly disagreed, somewhat disagreed, or were neutral.

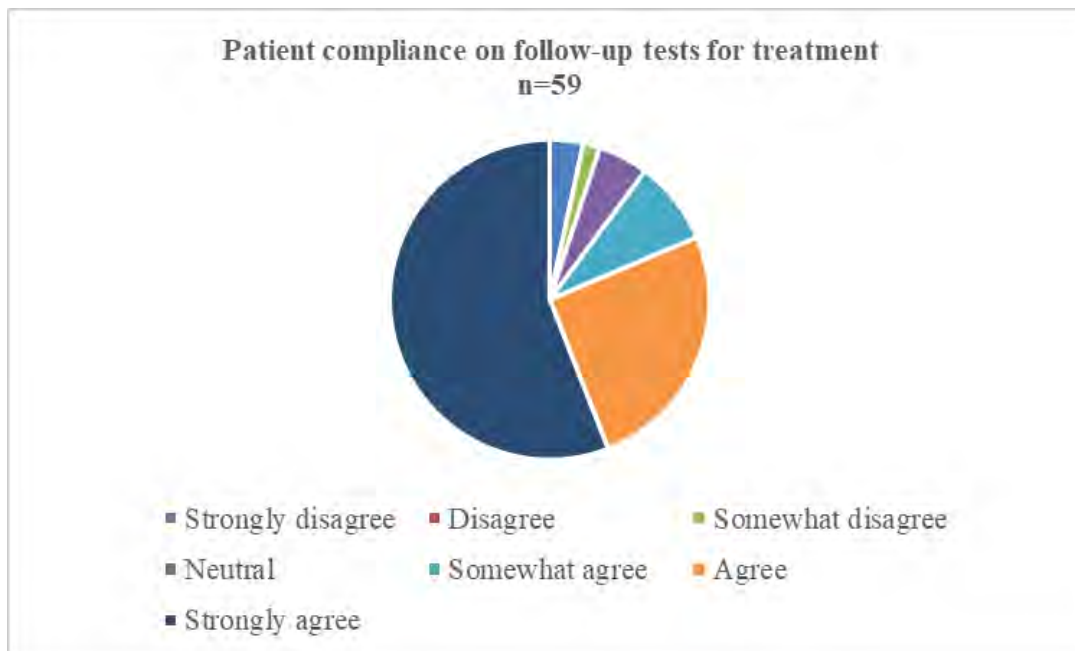
Figure 9. Patient Compliance on Suggested Treatment



Patient Compliance on Follow-up tests for Treatment. Question fifteen “I have had or plan to have the follow-up tests for treatments, as recommended by the physician” unveils the intents of the women to their physicians’ treatment plans. The majority of the participants 53 (89.82%) either strongly agreed, agreed, or somewhat agreed to adhere to follow-up tests for treatment by their physicians. On the other hand, 3 (5.08%) were

neutral, while 2 (3.39%) and 1 (1.69%) strongly disagreed and somewhat disagreed respectively.

Figure 10. Patient Compliance on Follow-up Tests for Treatment



Relevance of App Health Information Quality

This section covers the views and perceptions of pregnant women on the relevance of information contents offered on the pregnancy apps they have used during their current pregnancy.

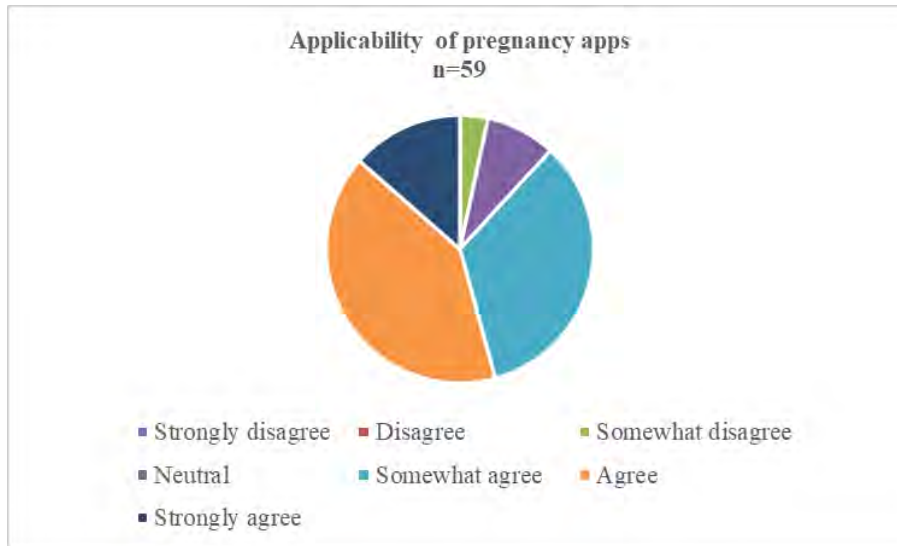
The option, “For my health needs, I believe the internet health information provided by pregnancy app(s) was applicable to health needs” ranked highest. In second place, “For my health needs, I believe internet health information provided by pregnancy

app(s) was pertinent to my needs,” and the option “For my health needs, I believe internet health information provided by pregnancy app(s) was relevant to my needs” ranked in third place.

Table 4. Relevance of app health information quality

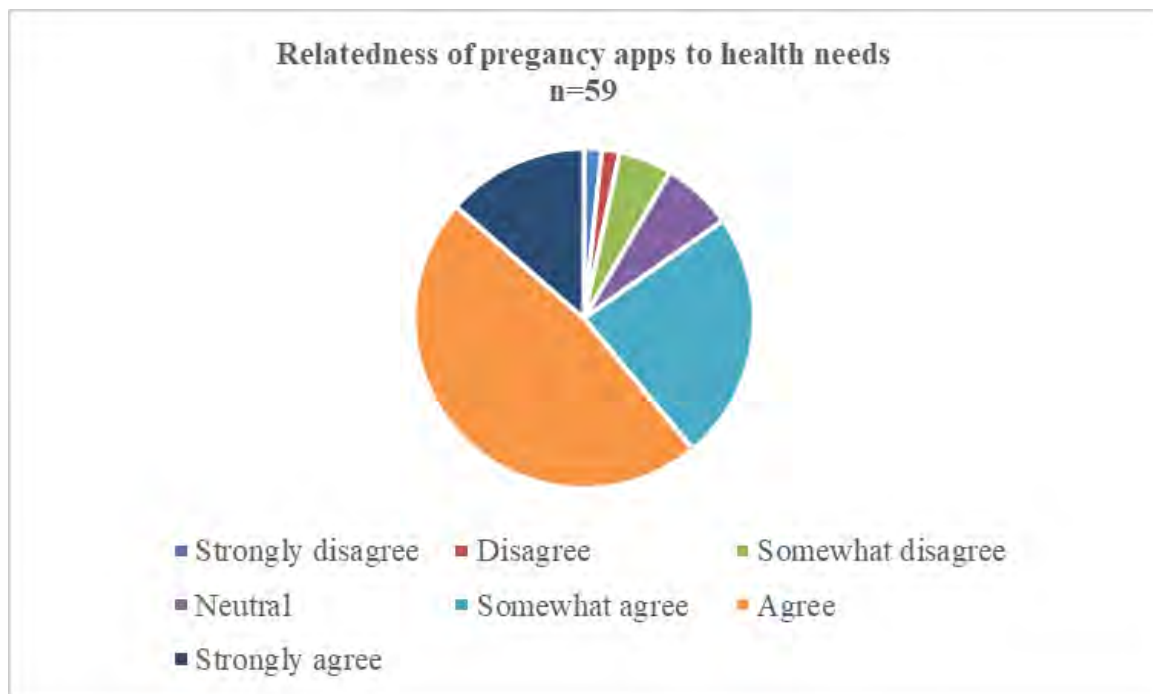
n=59	Strongly disagree	Disagree	Somewhat disagree	Neutral	Somewhat agree	Agree	Strongly agree	Total	Weighted Average	Rank
Applicability	0.00%	0.00%	3.39%	8.47%	33.90%	40.68%	13.56%	59	5.53	1
Relatedness	1.69%	1.69%	5.08%	6.78%	23.73%	47.46%	13.56%	59	5.46	4
Pertinency	1.72%	0.00%	5.17%	8.62%	24.14%	43.10%	17.24%	58	5.52	2
Relevance	1.69%	1.69%	3.39%	8.47%	23.73%	44.07%	16.95%	59	5.51	3

Applicability of Pregnancy Apps to Health Needs. Question sixteen intended to understand whether the health information provided on their pregnancy app(s) applies to the needs of the pregnant women (n=59). This question used a seven-point Likert scale, the options being strongly disagree, disagree, somewhat disagree, neutral, somewhat agree, agree, and strongly agree. A higher weighting was attached to strongly agree and agree. According to Table 4 above, 24 (40.68%) of the women agree that health information provided by their pregnancy app(s) was applicable to their needs, followed by 20 (33.90%) responding “somewhat agree,” and 8 (13.56%) responding “strongly agree.” Thus, a total of 52 (88.14%) either strongly agreed, agreed, or somewhat agreed. Only 5 (8.47%) were neutral and 2 (3.39%) somewhat disagreed.

Figure 11. Applicability of Pregnancy Apps

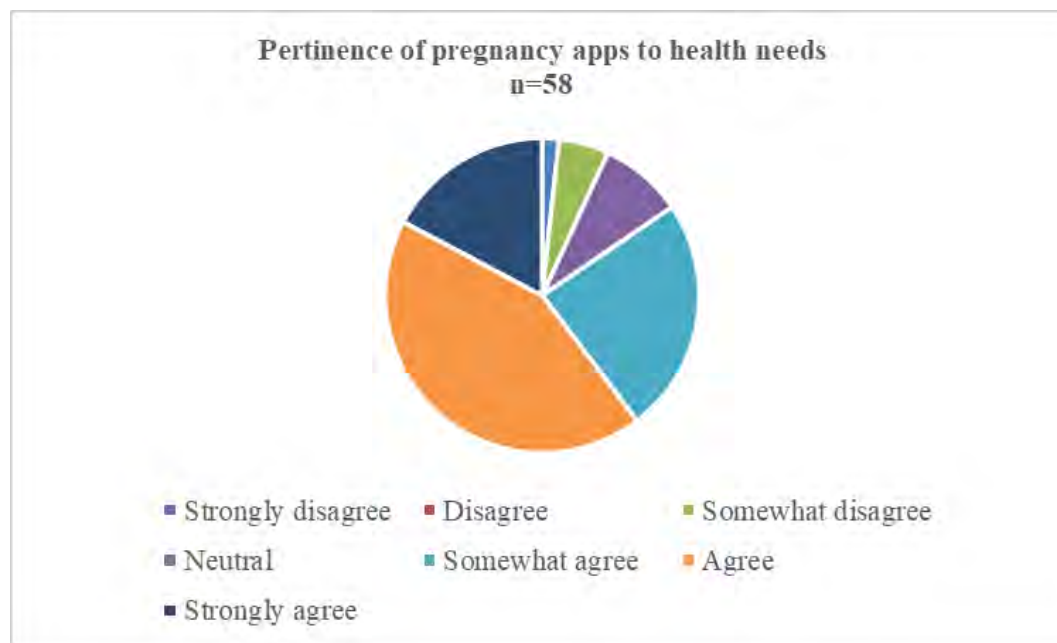
Relatedness of Pregnancy Apps to Health Needs during Pregnancy. For question seventeen on relatedness of pregnancy apps to health needs of pregnant women (n=59), almost half of the participants 28(47.46%) agree to believe internet health information provided by pregnancy apps was related to their needs, followed by those who indicated somewhat agree 14(23.73%) and 8(13.56%) indicated strongly agree. A total of 50(84.75%) either strongly agreed or agreed or somewhat agreed to relatedness of pregnancy app(s) to their health needs during their current pregnancy. Only few women indicated neutral 4(6.78%) while a total of 5(8.46%) identified with somewhat disagree 3(5.08%), disagree 1(1.69%) and strongly disagree 1(1.69%).

Figure 12. Relatedness of pregnancy apps to health needs during pregnancy



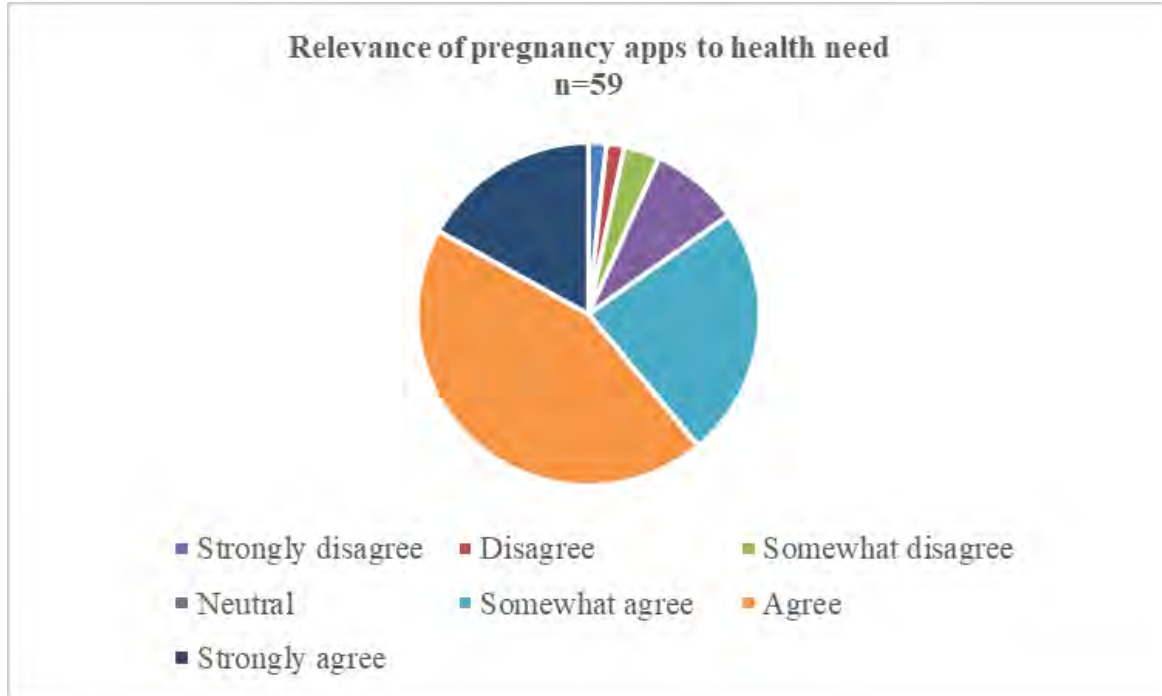
Pertinence of Pregnancy Apps to Health Needs. The data given in Table 4 on the pertinence of the app information to the health needs of the women (n=58) shows that 25 (43.10%) indicated “agree,” followed by “somewhat agree” 14 (24.14%) and 10 (17.24%) indicated “strongly agree.” On the other hand, 5 (8.62%) were neutral, 3 (5.17%) indicated “somewhat agree” and 1 (1.72%) indicated “strongly disagree.”

Figure 13. Pertinence of Pregnancy Apps to Health Needs



Relevance of Pregnancy Apps to Health Needs During Pregnancy. For question nineteen on relevance of pregnancy apps to health needs of pregnant women (n=59), majority of the participants 26 (44.07%) agreed that they believed internet health information provided by pregnancy apps was relevant to their needs, followed by those who indicated “somewhat agree” 14 (23.73%) and 10 (16.95%) who indicated “strongly agree.” A total of 50 (84.75%) either strongly agreed, agreed, or somewhat agreed to relevance of pregnancy app(s) to their health needs during their current pregnancy. Only a few women indicated “neutral” 5 (8.47%) while 2 (3.39%) identified with “somewhat disagree,” 1 (1.69%) disagree, and 1(1.69%) strongly disagree.

Figure 14. Relevance of pregnancy apps to health needs



Understandability of Information from Pregnancy Apps

Understandability in this context refers to the degree to which users of pregnancy apps comprehend or understand the information contents being relayed on the apps. Information carrier factors/characteristics has been noted to affects the selection and usage of information source (Basnynat et al., 2018). A very important aspect of an information carrier is its communication ability i.e., comprehensibility of the information source (Basnynat et al., 2018; Sbaffi & Zhao, 2018).

Table 5 shows the degree of understandability of the participants of app health information quality by ranking understandability in first place, readability in second place and comprehension of contents in third place.

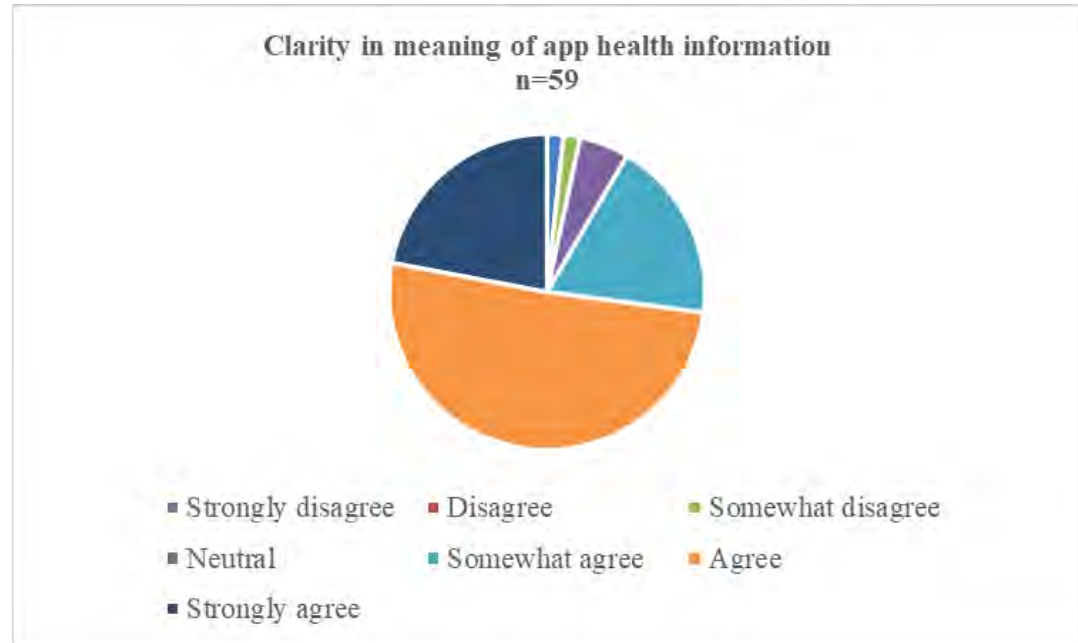
Table 5. Understandability of information from pregnancy apps

n=59	Strongly disagree	Disagree	Somewhat disagree	Neutral	Somewhat agree	Agree	Strongly agree	Total	Weighted Average	Rank
Clarity in meaning	1.69%	0.00%	1.69%	5.08%	18.64%	50.85%	22.03%	59	5.80	4
Readability	0.00%	0.00%	3.45%	10.34%	12.07%	46.55%	27.59%	58	5.84	2
Comprehension	0.00%	1.69%	3.39%	6.78%	16.95%	40.68%	30.51%	59	5.83	3
Understandability	0.00%	1.69%	1.69%	6.78%	16.95%	44.07%	28.81%	59	5.86	1

Clarity in Meaning of App Health Information. This question aimed to determine the perceptions of the participants on clarity in meaning of health information provided by their pregnancy app(s) (n=59). A seven-point Likert scale was used, the options being strongly disagree, disagree, somewhat disagree, neutral, somewhat agree, agree, and strongly agree.

Most of the participants 30 (50.85%) agree to clarity in meaning of health information provided by pregnancy apps, 13 (22.03%) indicated “strongly agree” and 11 (18.64%) identified with “somewhat agree.” A total of 55 (91.52%) either strongly agreed, agreed, or somewhat agreed to clarity in meaning of health contents delivered on their pregnancy app(s). Only 3 (5.08%) were neutral while two participants indicated “strongly disagree” and “disagree,” 1 (1.69%) and 1 (1.69%) respectively.

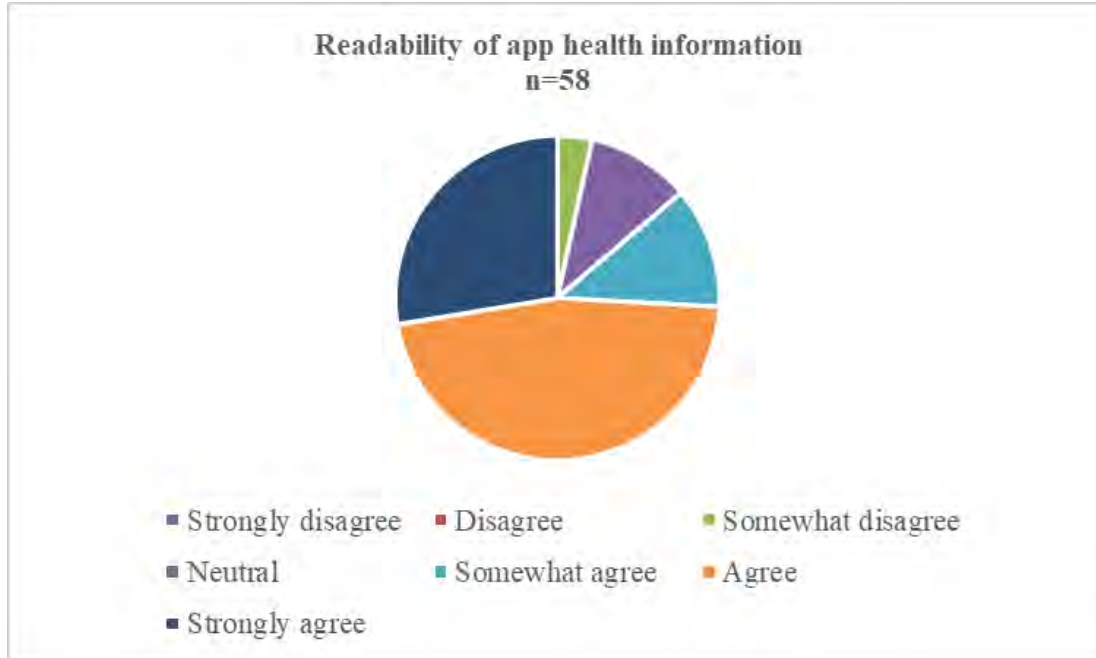
Figure 15. Clarity in Meaning of App Health Information



Readability of App Health Information. Question twenty-one was included to determine the experiences of the participants on the readability of health information provided on pregnancy apps (n=58). A seven-point Likert scale was used, the options being strongly disagree, disagree, somewhat disagree, neutral, somewhat agree, agree, and strongly agree.

According to Table 5 above, 27 (46.55%) of the participants agree, 16 (27.59%) strongly agree and 7 (12.07%) somewhat agree. Only 2 (3.45%) participants somewhat disagree while 6 (10.34%) were neutral on the readability of health information on pregnancy apps.

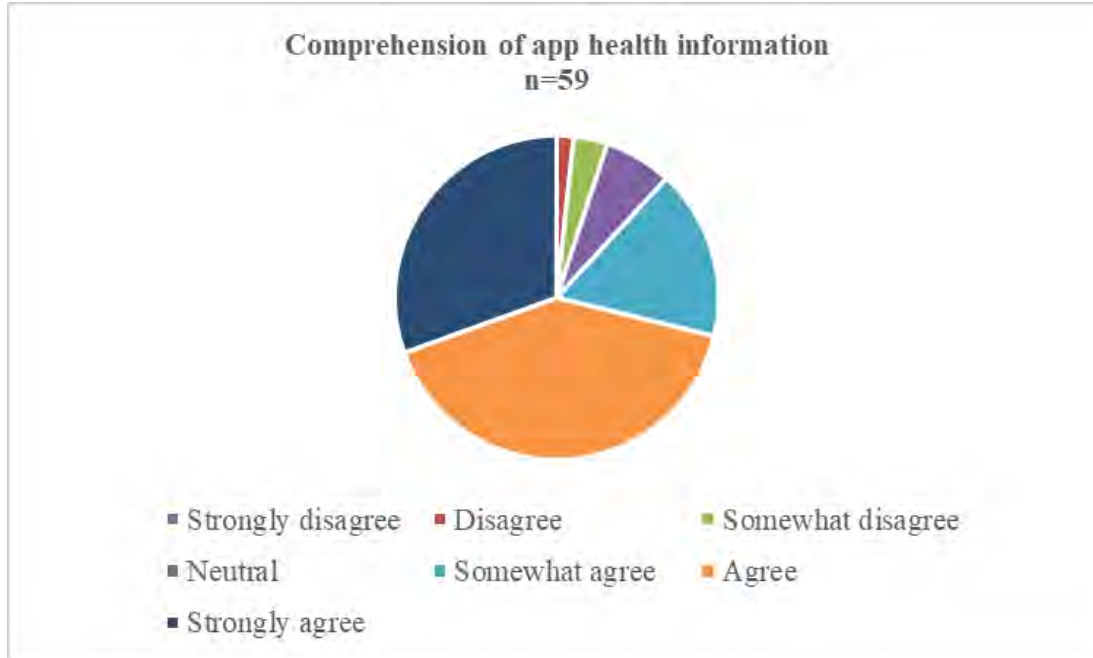
Figure 16. Readability of App Health Information



Comprehension of App Health Information. Comprehension of health information is very crucial to patients to make informed decision on their health. Question twenty-two (See Appendix) was asked to determine whether the pregnancy apps used by the pregnant women was offering easy to comprehend health contents (n=59). A seven-point Likert scale was used, the options being strongly disagree, disagree, somewhat disagree, neutral, somewhat agree, agree, and strongly agree.

Based on the responses, 24 (40.68%) of the participants agreed, 18 (30.51%) indicated “strongly agree” and 10 (16.95%) indicated “somewhat agree.” Conversely, 4 (6.78%) were neutral, 2 (3.39%) indicated “somewhat disagree” and 1 (1.69%) disagreed with the comprehensiveness of app health information during current pregnancy.

Figure 17. Comprehension of App Health Information

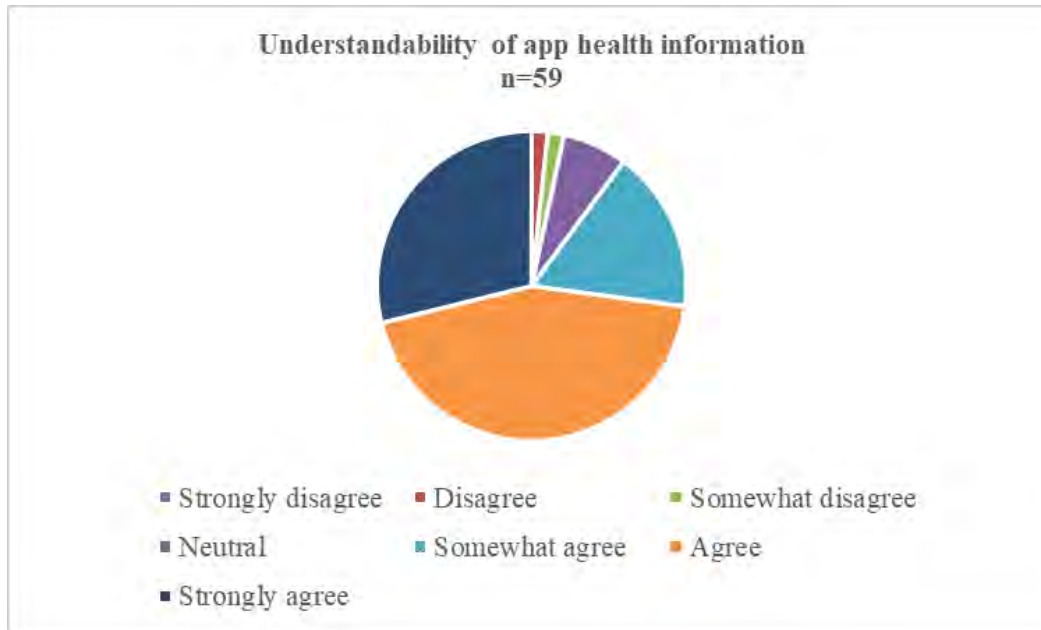


Understandability of App Health Information. This question was asked to determine the degree to which participants understand internet health information provided by pregnancy apps during their current pregnancy (n=59). A seven-point Likert scale was used, the options being strongly disagree, disagree, somewhat disagree, neutral, somewhat agree, agree, and strongly agree.

The scale of “agree” attracted the highest responses 26 (44.07%), followed by strongly agree 17 (28.81%), and somewhat agree 10 (16.95%). The majority of the participants 53 (89.83%) had some degree of agreement on pregnancy app information being understandable. However, 4 (6.78) indicated “neutral,” 1 (1.69%) indicated “somewhat disagree” and 1 (1.69%) indicated “strongly disagree.”

Figure 18. Understandability of App Health Information.

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Usefulness of App Health Information

Perceived usefulness of information provided by a pregnancy app is regarded as utility. The usefulness of the information source, in this case pregnancy apps, is the ability of the app to meet the needs of pregnant women (Reifegerste, Blech & Dechant, 2020; Basnyat et al., 2018). Utility/perceived usefulness is the forerunner of credibility (Basnyat et al., 2018). Perceived usefulness of the pregnancy app(s) reveals the level of trust for the technology by its users. Hence, the perceived usefulness of pregnancy app is a pointer to the how the technology is meeting their pregnancy needs and the perceived credibility of technology.

According to the Table 6 below, the participants ranked “informative” and “helpful” metrics in first place, followed by “valuable” in third place and “useful” in fourth place.

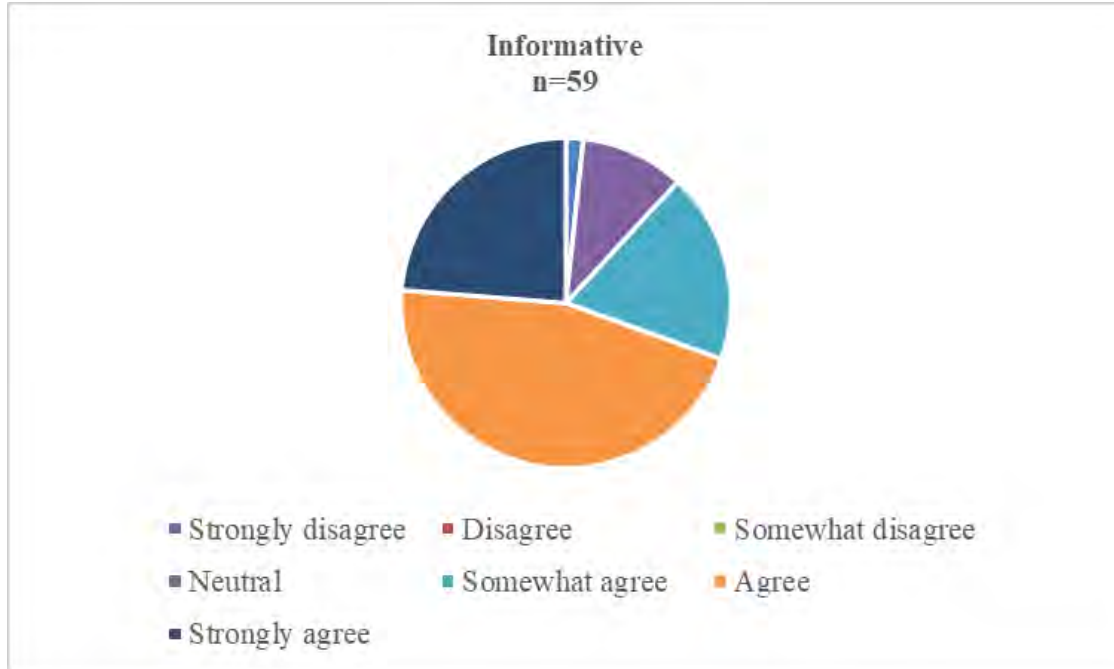
Table 6. Usefulness of App health information

n=59	Strongly disagree	Disagree	Somewhat disagree	Neutral	Somewhat agree	Agree	Strongly agree	Total	Weighted Average	Rank
Informative	1.69%	0.00%	0.00%	10.17%	18.64%	45.76%	23.73%	59	5.76	1
Valuable	1.69%	0.00%	3.39%	10.17%	18.64%	44.07%	22.03%	59	5.64	3
Helpful	1.72%	0.00%	0.00%	5.17%	24.14%	50.00%	18.97%	58	5.76	1
Useful	1.69%	1.69%	1.69%	11.86%	16.95%	49.15%	16.95%	59	5.56	4

Informative. Question twenty-four was asked to determine whether the app information contents were informative (n=59). The participants had to select from a seven-point Likert scale, the options being strongly disagree, disagree, somewhat disagree, neutral, somewhat agree, agree, and strongly agree. A higher weighting was thus attached to strongly agree and agree.

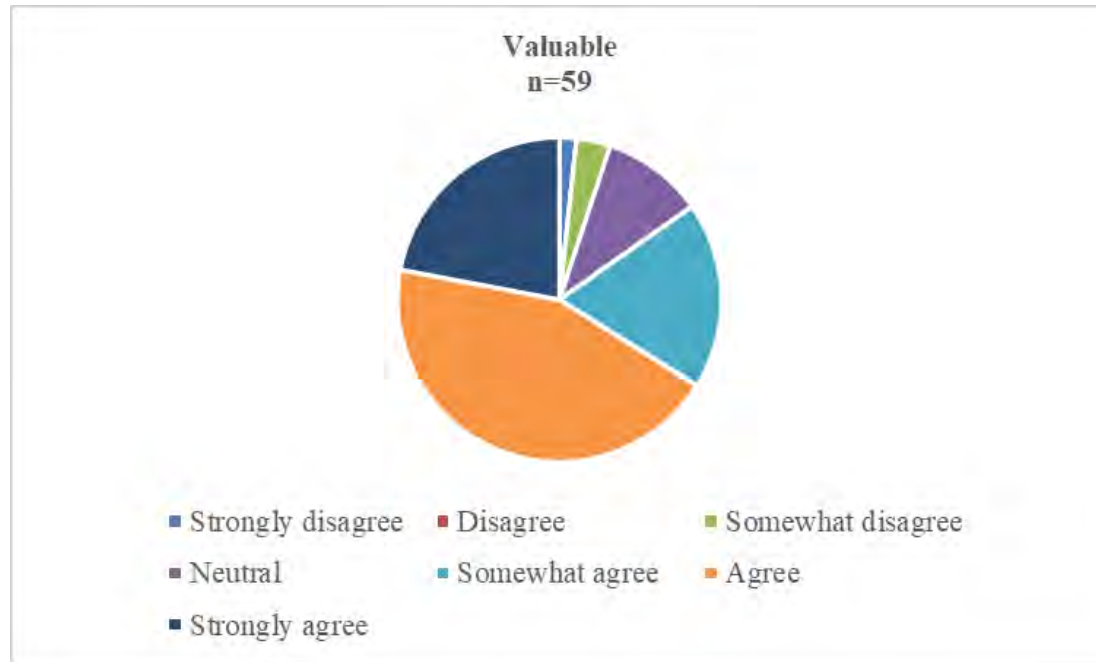
The question “For your health information needs, to what degree do you believe internet health information provided by pregnancy app(s) was informative” shows that 27 (45.76%) indicated “agree,” followed by strongly agree 14 (23.73%) and somewhat agree 11 (18.64%). However, only 6 (10.17) were neutral while 1 (1.69%) indicated “strongly disagree.”

Figure 19. Informativeness of App Health Information



Valuable. Another metrics for measuring the perceived usefulness/utility is perceived value benefited from the informational contents to trigger informed decision-making. Question twenty-five aimed to determine how the participant perceived the value of the information provided on pregnancy apps (n=59). A seven-point Likert scale (the options being strongly disagree, disagree, somewhat disagree, neutral, somewhat agree, agree, and strongly agree) was used. A higher weighting was thus attached to strongly agree and agree.

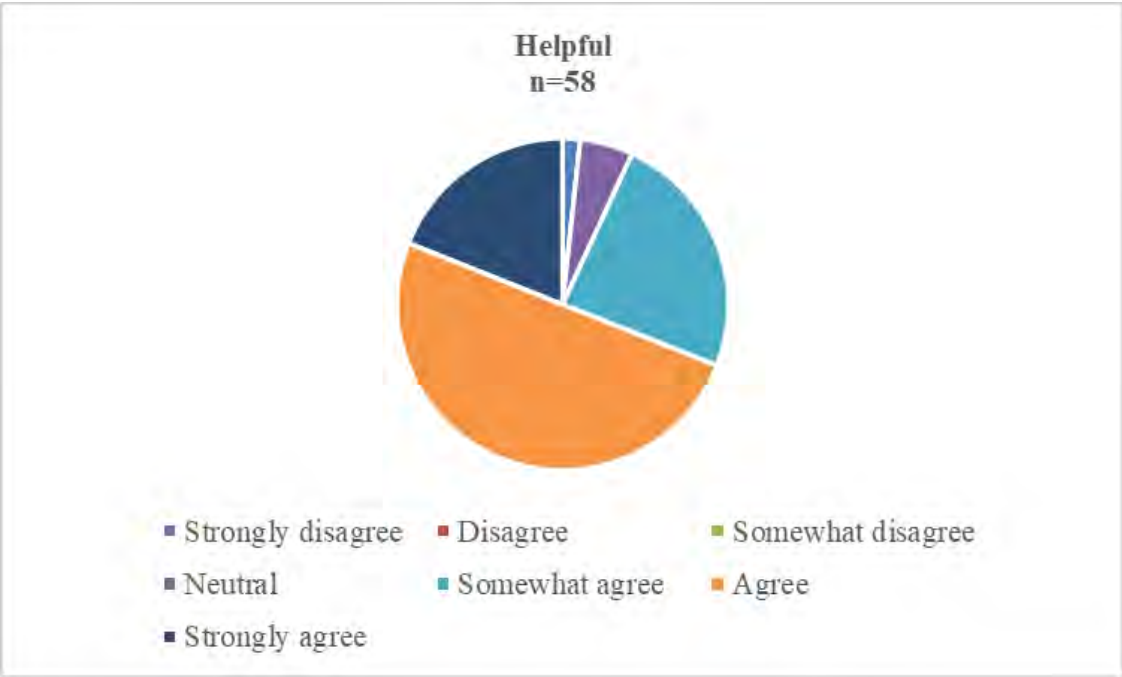
Based on the data from Table 6 above, 26 (44.07%) indicated “agree,” 13 (22.03%) “strongly agree,” and 11 (18.64%) indicated “somewhat agree.” Lesser numbers indicated neutral 6 (10.17%), while 2 (3.39%) indicated “somewhat disagree” and 1 (1.69%) “strongly disagree.”

Figure 20. Value of app health information

Helpful. Question twenty-six explored whether the information provided on pregnancy apps were helpful to the participants. A total of 58 women responded to this question and they had the option of selecting from a seven-point Likert scale, the options being strongly disagree, disagree, somewhat disagree, neutral, somewhat agree, agree, and strongly agree. A higher weighting was thus attached to strongly agree and agree.

Half of the women (29 [50%]) indicated “agree,” followed by 14 (24.14%) who indicated “somewhat agree” and 11 (18.97%) who indicated “strongly agree.” A total of 54 (93.04%) either strongly agreed, agreed, or somewhat agreed. Only 3 (5.17%) indicated “neutral” and 1 (1.72%) indicated “strongly disagree.”

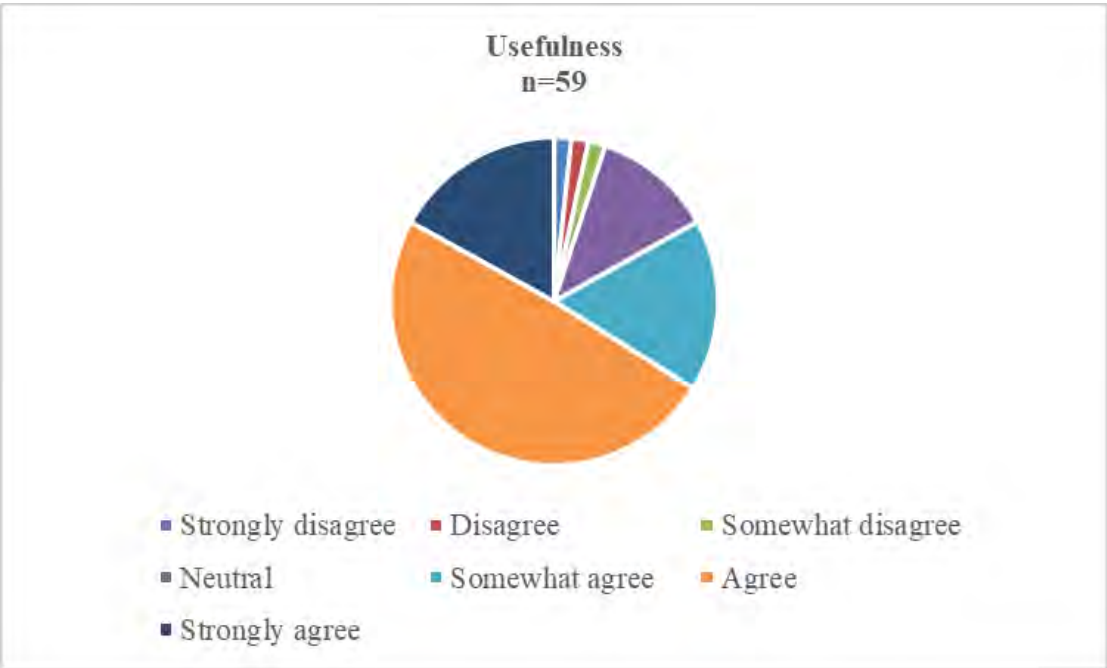
Figure 21. Helpfulness of App Health Information



Useful. Question twenty-seven unveils how the participants perceive the health information received from pregnancy apps to be useful to their health needs. A total of 59 women responded to this question using a seven-point Likert scale, the options being strongly disagree, disagree, somewhat disagree, neutral, somewhat agree, agree, and strongly agree. A higher weighting was thus attached to strongly agree and agree.

According to Table 6, almost half of the participants indicated “agree” 29 (49.15%), 10 (16.95%) indicated “strongly agree” and 10 (16.95%) indicated “somewhat agree.” However, 7 (11.86%) indicated “neutral,” followed by “somewhat disagree” 1 (1.69%), “strongly disagree” 1 (1.69%) and “disagree” 1 (1.69%).

Figure 22. Usefulness of App Health Information



Adequacy of App Health Information

Table 7 below shows that the option “For my health information needs, I believe internet health information provided by pregnancy app(s) contained the necessary topics or categories” was ranked in first place, followed by the option “For my health needs, I believe internet health information provided by pregnancy app(s) was adequate” in second place, and the option “For my health information needs, I believe internet health information provided by pregnancy app(s) was sufficient” ranking third place.

Table 7. Adequacy of app health information

n=59	Strongly Disagree	Disagree	Somewhat Disagree	Neutral	Somewhat Agree	Agree	Strongly agree	Total	Weighted Average	Rank
Sufficiency of app health information	3.39%	5.08%	8.47%	16.95%	25.42%	30.51%	10.17%	59	4.88	3

Technology and Pregnant women

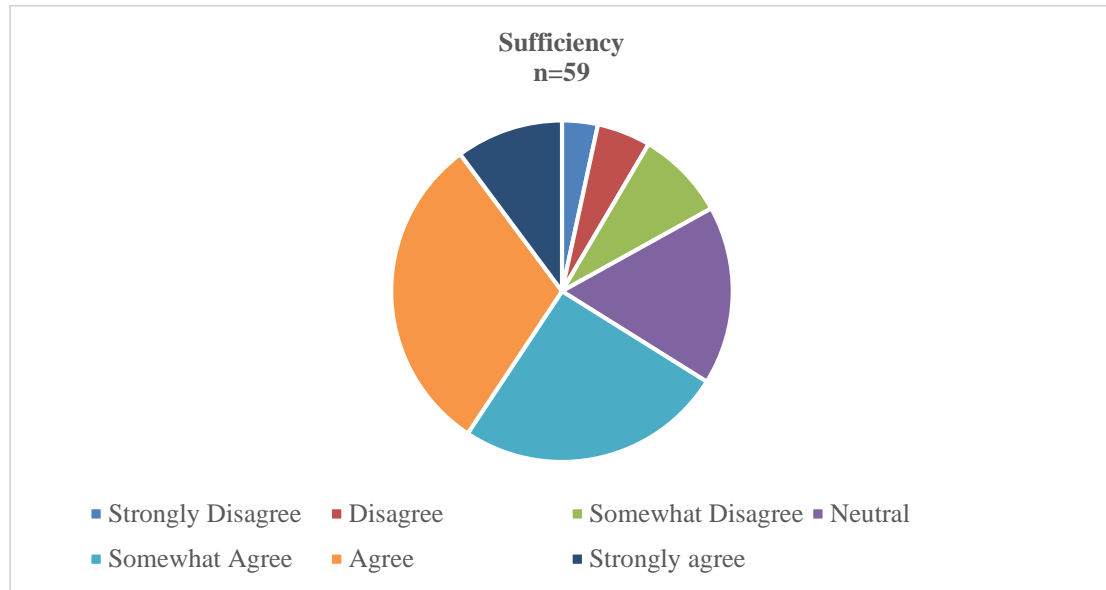
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Completeness of app health information	3.39%	5.08%	11.86%	11.86%	30.51%	27.12%	10.17%	59	4.83	4
Adequacy of app health information	3.45%	3.45%	6.90%	17.24%	22.41%	36.21%	10.34%	58	5.02	2
Adequacy of topics or categories used in app health information	1.69%	3.39%	3.39%	11.86%	22.03%	45.76%	11.86%	59	5.34	1

Sufficiency of App Health Information. Sufficiency is one of the attributes of adequacy of internet health information quality (Laugesen et al., 2015). Question twenty-eight was asked to determine whether the information conveyed on pregnancy app(s) is sufficient for meeting the participants' health needs (n=59). A seven-point Likert scale (the options being strongly disagree, disagree, somewhat disagree, neutral, somewhat agree, agree, and strongly agree) was used. A higher weighting was thus attached to strongly agree and agree.

Based on the responses, 18 (30.15%) indicated "agree," 15 (25.42%) indicated "somewhat agree," and 6 (10.17%) indicated "strongly agree." Thus, a total of 39 (65.74%) either strongly agreed, agreed, or somewhat agreed. Conversely, from the disagree scales, 2 (3.39%) indicated "strongly disagree," 3 (5.08%) indicated "disagree" and 5 (8.47%) indicated "somewhat disagree." Hence, 10 (16.95%) were neutral while 10 (16.94%) either strongly disagreed, disagreed, or somewhat disagreed.

One-third of the participants noted that app health information is not sufficient enough to meet their ever-changing needs.

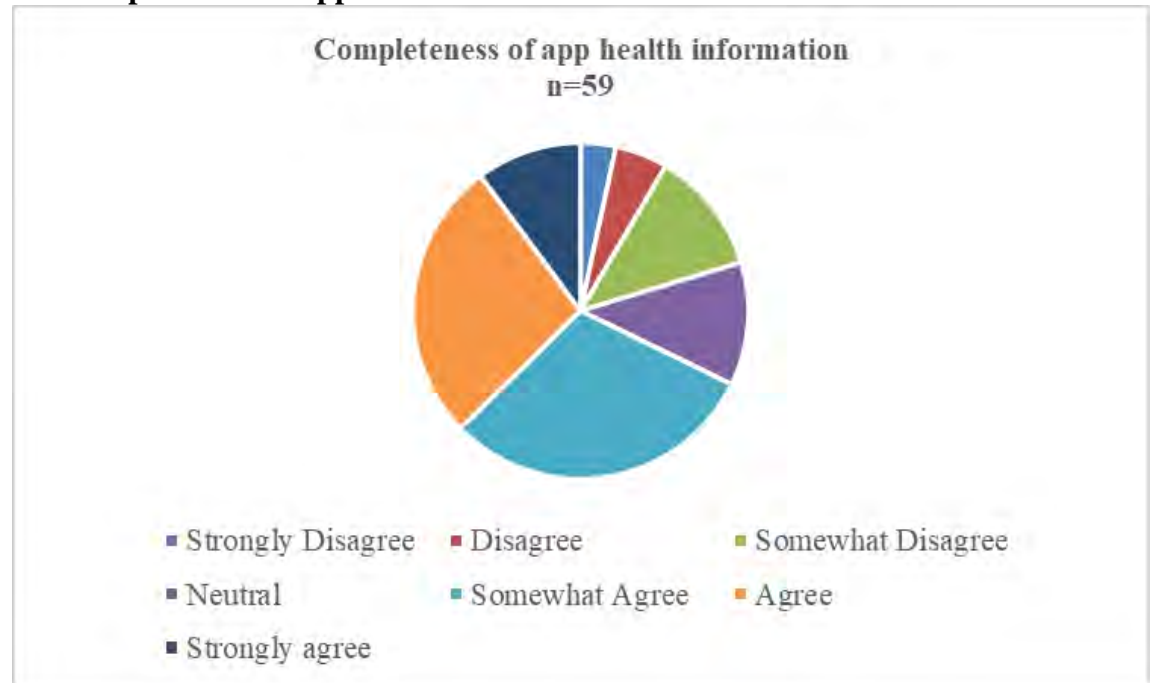
Figure 23. Sufficiency of App Health Information

Completeness of the App Health Information. Completeness is another important element of internet information quality (Al-Jefri et al., 2018; Laugesen et al., 2015). Question twenty-nine aimed to assess the completeness of app health information (n=59). A seven-point Likert scale (the options being strongly disagree, disagree, somewhat disagree, neutral, somewhat agree, agree, and strongly agree) was used. A higher weighting was thus attached to strongly agree and agree.

The participants perceived app health information to be complete in the following ratio: 18 (30.15%) indicated “somewhat agree,” 16 (27.12%) indicated “agree” and 6 (10.17%) indicated “strongly agree.” Thus, 40 (67.44%) either strongly agreed, agreed, or somewhat agreed. Only 7 (11.86%) were neutral, while 7 (11.86%) indicated “somewhat disagree,” 3 (5.08%) indicated “disagree” and 2 (3.39%) indicated “strongly disagree.”

From the disagreement scales, 12 (20.33%) either strongly disagreed, disagreed, or somewhat disagreed.

Figure 24. Completeness of App Health Information



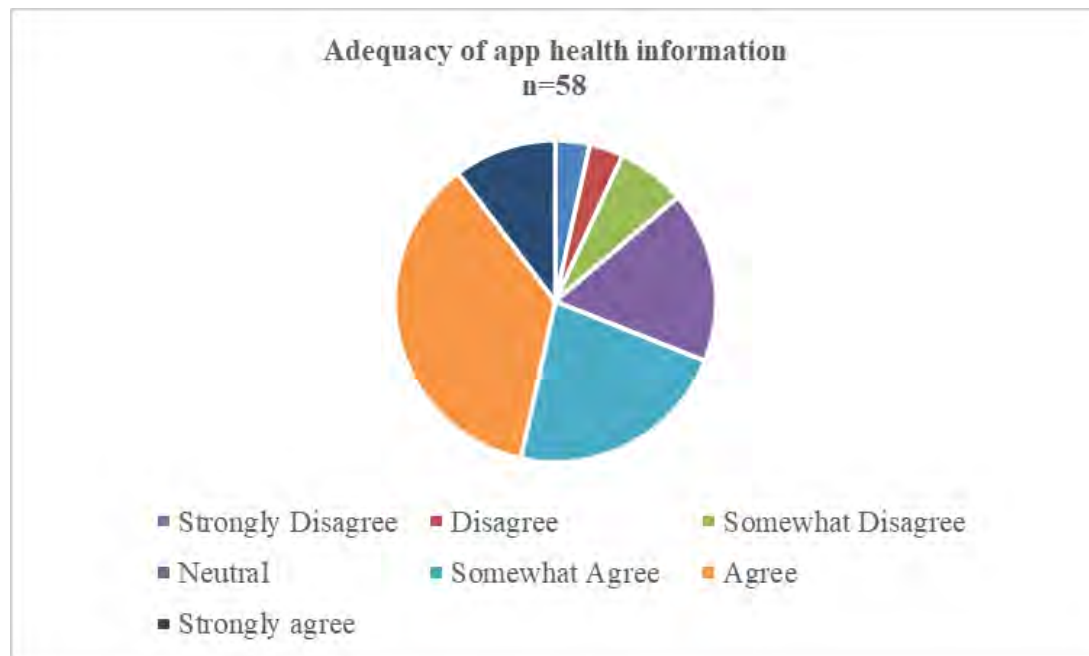
Adequacy of App Health Information. Question 30 was asked to determine the degree of adequacy of the information provided on pregnancy apps. A total of 58 participants responded to this question. A seven-point Likert scale (the options being strongly disagree, disagree, somewhat disagree, neutral, somewhat agree, agree, and strongly agree) was used. A higher weighting was thus attached to strongly agree and agree.

According to Table 7 above, 21 (36.21%) indicated “agree,” 13 (22.41%) indicated “somewhat agree,” and 6 (10.34%) indicated “strongly agree.” Thus, a total of

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40 (68.96%) either strongly agreed, agreed, or somewhat agreed. Only 10 (17.24%) were neutral, while 4 (6.90%) indicated “somewhat disagree,” 2 (3.45%) indicated “disagree” and 2 (3.45%) indicated “strongly disagree.”

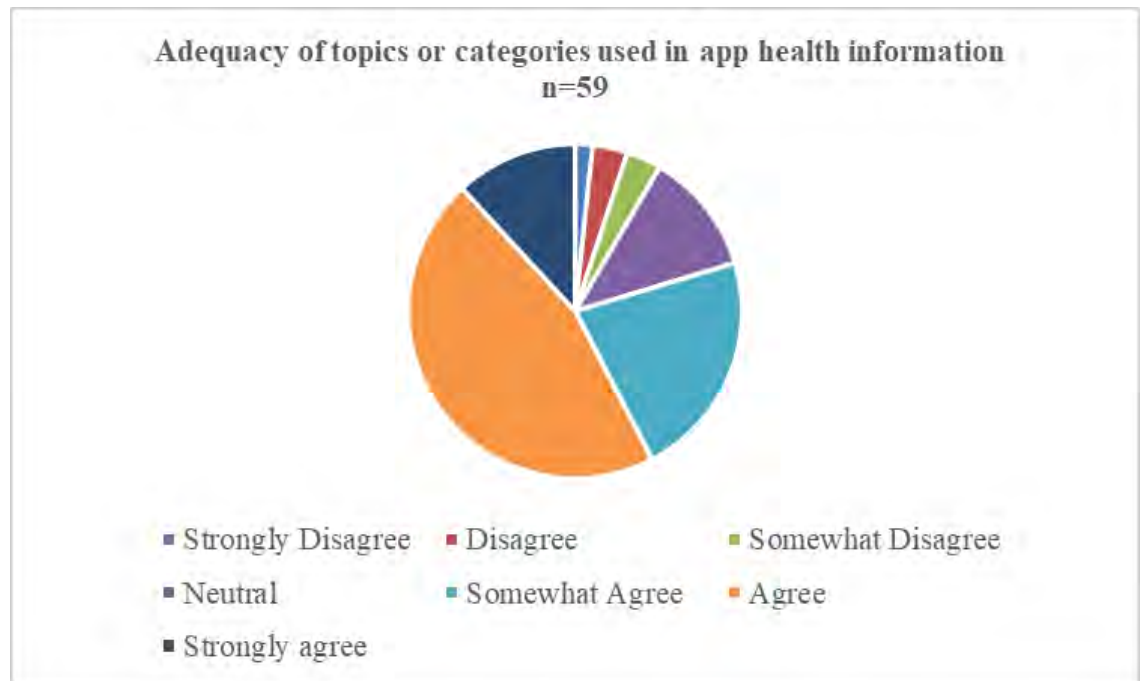
Figure 25. Adequacy of App Health Information



Adequacy of Topic and Categories used in App Health Information. The final question in the survey was to show whether the topics and categories used in pregnancy app(s) were meeting participants’ health needs (n= 59). A seven-point Likert scale (the options being strongly disagree, disagree, somewhat disagree, neutral, somewhat agree, agree, and strongly agree) was used. A higher weighting was thus attached to strongly agree and agree.

As displayed in Table 7, 27 (45.76%) indicated “agree,” 13 (22.03%) indicated “somewhat agree” and 7 (11.86%) indicated “strongly agree.” Only 7 (11.86%) were neutral, while 2 (3.39%) indicated “somewhat disagree,” 2 (3.39%) indicated “disagree,” and 1 (1.69%) indicated “strongly disagree.”

Figure 26. Adequacy of Topics or Categories used in App Health Information



Findings and Analysis of Online Case Studies Using Co-Design Conducted with Pregnant Women

Online case studies using the co-design approach was used to collect the qualitative data from four pregnant women and one gynecologist. The online sessions were held on Zoom software and all the sessions were video-recorded with participants' signed consent (see Appendix). Each online session with the participants lasted between

ten and thirty minutes. All the questions and tasks were in accordance with the online case study schedule in Appendix.

Participants included in the online case studies were pregnant women resident in the U.S. who offered to participate in the study from Facebook pregnancy support groups and a gynecologist practicing in the U.S. The online case studies gave all the participants the opportunity to shed more light on their personal experiences of pregnancy apps during their current pregnancy. It involved co-designing with the researcher to identify important features they have seen or would like to see on future pregnancy apps. It also gave the participants the opportunity to make known and write down their perceptions, views, opinions, and interests on the topic being discussed.

Co-design is a unique design approach involving the collaboration of end-users destined to use a particular product or service in the development phase of the product or service. It also entails the involvement of users of a technology in making decisions that affect the technology and how it is designed (Walker et al., 2020; Schuler & Namioka, 1993). Walsh et al. (2013) noted co-design as a subset of participatory design where potential users of a technology and design experts work together to solve a problem.

The co-design approach was adopted for the online case study because it allowed the involvement of end-users (pregnant women and gynecologist) in the design process to solve a problem. Additionally, it provided the avenue for end-users to voice their opinions, perceptions, and pain points, which can be included in future products thereby influencing the decision-making process of pregnancy apps and supporting the solving of

a problem with the user, rather than simply solving the problem for them (Walker et al., 2020; Walsh et al., 2013; Hecht & Maass, 2008).

The study did not include the real names of the participants for the purpose of anonymity, instead utilizing codes (e.g., P1, P3). All the pregnant women were asked the same questions to ensure consistency and the responses were analyzed using thematic analysis. Thematic analysis is a qualitative data analysis approach for discovering, analyzing, and reporting patterns within participants' set of qualitative data (Braun & Clarke, 2006). It is used because of its inductive ability to identify themes and potential to discover novel meanings from participants' perceptions, views, and experiences within large qualitative data.

The following are the questions and tasks provided to the pregnant women in the study.

1. Discussion on the use of app technology during pregnancy
 - a. What types of tasks do you get done daily using your pregnancy app?
 - b. Tell me about the positive experiences you have had with the pregnancy app?
 - c. What are the frustrations of using the app?
 - d. What do you think about pregnancy apps?
2. Discussion on mobile app design
 - a. What would you like to see on a pregnancy app?
 - b. When you download an app, what do you look for? Take a piece of paper and jot down three things that are important to you
 - c. If you have to pick only one feature that is most important to you, what would it be? You can select from already mentioned item.
3. Additional information you would like to share about this topic?

Discussion on the Use of App Technology during Pregnancy

Tasks or Activities Done Daily Using Pregnancy App(s). The researcher confirmed that all the participants had used pregnancy app(s) during their current pregnancy. Research has shown that pregnant women in developed countries are turning to pregnancy apps for meeting their information needs and connecting with other women, as well as using apps as a tracking tool during pregnancy (Musgrave et al., 2020). The researcher identified the following themes:

a) Track information on bodily changes

Studies on pregnancy have reported bodily changes as part of the changes experienced by women during pregnancy (Ghiasi, 2019; Javanmardi et al., 2018). Different changes caused by pregnancy trigger the need to seek information to fill the knowledge gap regarding the physical changes (Sharifi et al., 2020). Qing and Weiying's (2019) study confirmed 65.3% of the pregnant women used pregnancy apps to track information on body changes during pregnancy. P1 provided an example of why women seek out these apps, when she stated needing new information on physical changes: P1: "... *just to be informed about how my body is changing.*"

b) Check information on fetal growth and development

A survey study carried out among Chinese pregnant women found that 83.3% of the pregnant women used their pregnancy apps to check information on fetal development (Qing & Weiying, 2019). Similarly, the majority of the participants stated

that they used their pregnancy app(s) for checking information on fetal growth and development:

P1: *“...informed about how the baby is growing, what part of the baby is developing.”*

P2: *“What is going on with my fetus, what is he doing, and what is the movement about, growth like. So generally checking to know the growth process.”*

P3: *“I check for updates on the growth of the baby.”*

c) Track baby size

Three of the four participants mentioned that they used their pregnancy app(s) for tracking the size of the baby. Apparently, the three used the What to Expect app, which compares the baby size to fruit. The size of the identified fruit reveals the size of the growing baby to the mother. For example, at seven weeks of pregnancy, the app can say “your baby is as big as a blueberry”

P3: *“... some fun timeline facts like how big it is what size of fruit it is now.”*

P4: *“...then you know they compare it to a size of fruit or vegetable. I thought it was kind of unique.”*

d) Check weekly updates pregnancy

One of the participants regarded pregnancy app(s) as a reference tool used for seeking pregnancy information. Two participants noted that they used their pregnancy app(s) for staying abreast of weekly updates about their pregnancy. Information monitoring has been found to be one of the characteristics of pregnant women (Akanbi & Fourie, 2021). P1 noted that she only used her pregnancy app on a weekly basis.

P1: *“I tend to just use it once a week.... it comes up with all the updates of new articles and information about your pregnancy.”*

P2: *“So it’s pretty much to know like, okay, what’s going on like every week of the pregnancy.”*

The participants were interested in weekly information/updates. Information based on different stages of pregnancy is one of the most pressing needs of the participants.

e) Prenatal information

Prenatal care is one of the requirements for pregnant women to have a healthy pregnancy. Pregnancy apps are providing excellent platforms to deliver prenatal care to pregnant women (Bush et al., 2017). Responses from the participants showed that the apps served as an education tool, educating on what to expect during their next doctor’s visit. It also provided information on the likely tests and examinations required during their next prenatal visit. Some of the participants used their pregnancy app(s) to prepare for their next prenatal visits.

P1: *“So at this doctor’s visit this month you’ll probably have to do these different blood work, diabetes test all this stuff.”*

P3: *“... things like that, the shots and vaccinations.”*

f) Reminders and notifications

Research on pregnancy apps have shown that pregnant women use their pregnancy app(s) to remind them of their doctor’s appointments (Qing & Weiying, 2019; Lupton, 2016). One of the participants used one of the apps she downloaded as reminder for her next doctor’s visit.

P3: *“Also the reminders for what’s to ask at the next OB visit.”*

g) Nutrition information

Pregnancy-related nutrition information is popular among pregnant women (Snyder, Neufeld & Forbes, 2020). Three out the four participants were interested in knowing the right food to eat during their current pregnancy. (All of them had other non-American backgrounds.)

P2: *“Even knowing what kind of food to eat, that can boost his current process.”*

P3: *“...to see what foods are safe to eat during pregnancy.”*

P4: *“... kind of food is recommended...”*

h) Entertainment

One of the participants used her app for entertainment purpose. The What to Expect app compares fetal week age to size of a fruit, and one participant found this to be entertaining to her.

P4: *“Comparing the baby sizes to vegetable or fruit, that was pretty entertaining to me.”*

i) Reassurance

Pregnancy apps used by the participants were used for getting reassurance on some issues of concern about their pregnancy. Since all the participants were first-time expectant moms and had no experience on pregnancy, these apps may be filling in for their lack of personal experience.

P4: *“Just to compare how I’m feeling, I guess it was just like, okay, well I’m feeling this way, am I the only one?”*

P1: *“Because this is my first child and I feel like I don’t know much about babies and children, so having an app to say, hey, this month this is what you should expect, that’s really comforting and the most part it’s pretty spot-on.”*

j) Medical information

Some of the pregnancy apps provided medical information like symptoms experienced during pregnancy.

P1: *“...like you might experience heartburn, and then here’s an article about how to combat it, here is medication that you might take or exercises during this month.”*

P1: *“For me, it’s really informative because this is my first child.”*

The participants mentioned that the apps provided not just textual information, but also video information linked to different articles.

Positive Experiences with Pregnant Apps. Use of pregnancy apps is prevalent among women of reproductive ages (Hughson et al., 2018; Lupton & Pedersen, 2016). It is therefore important to understand the experiences of pregnant women using pregnancy apps. The usefulness of pregnancy apps can also be ascertained from the experiences of the women. The participants were asked to share positive experiences related to use of pregnancy apps during their current pregnancy. The following themes were identified within the qualitative data:

a) Information access

One of the advantages of pregnancy apps to pregnant women is increased information access (Brown et al., 2020). The participants noted that they used their apps for accessing pregnancy-related information. This is confirmed by P1 and P3.

P1: *“Usually I can go to that app, and there’ll be an article already sitting there on that kind of landing page that will address my issue.”*

P3: *“...some pretty good articles as you go through, it’s very appropriate for each of the trimesters like signs that you need to call the doctor, things to expect with you know, weight gain, remember how to ask for maternity leave from work, things like that.”*

The participants noted that the apps were well-tailored to their information needs.

b) Good information architecture

Information architecture deals with the structuring, organization and labeling of informational contents (Morville & Rosenfeld, 2006). Well-structured contents were seen on the pregnancy apps used by the participants. The information was presented in easy-to-read fashion and clear layout for easy comprehension of the contents. (The What to Expect app, for example, offered video contents in addition to textual contents.)

P1: *“Yeah, I think because it is broken down weekly.”*

c) Reassurance/Emotional support

Studies on pregnancy have found that pregnancy triggers emotions. Providing the right information can help women deal with pregnancy-related anxiety or fears. One of

the participants stated that she used her app to connect with other pregnant or experienced moms for emotional support.

P2: *“There’s this other app I have, it also helped me interact with other moms ... like their opinions about things, like just having people who is going through things you are going through is kind of helpful and useful.”*

Other support stated from the session is some apps connect health coaches to pregnant women and provide baby registry.

P3: *“Another positive for that one is that one’s linked to my insurance, like I guess health coach in it, that’s linked to my insurance.”*

Pregnancy apps are also being used as a tool for reducing pregnancy-induced fear about the fetus.

P4: *“I mean it’s kind of a reassuring thing because it’s always a fear when the baby stops growing or you know, stops the heart rate... So that just kind of kept me at ease.”*

d) Entertainment

Two participants noted the euphoric feeling derived from interacting with their pregnancy apps. A recent study found entertainment to be one of the ideal features pregnant women have interest in in pregnancy apps (Qing & Weiyang, 2019). Apps creating fun activities such as games may be beneficial for easing some the stresses associated with pregnancy.

P4: *“...Your baby is starting to be able to hear things outside, you know like that kind of stuff was really actually like fun to read.”*

e) Food recommendations/Nutritional information

Pregnancy-related nutritional information is essential for pregnant women, especially first-time moms as they are interested in knowing the right foods to eat to promote healthy outcomes for themselves and the baby (Snyder, Neufeld & Forbes, 2020). One of the participants noted the need for ethnic foods recommendations; this need is seen in women from non-American backgrounds.

P3: “...good on food safety, like you can search through it and it has a lot of options, even some like ethnic foods.”

Frustrations Experienced using Pregnancy Apps. User experience designers strive to create effective and efficient interactions for users. Beyond efficiency and effectiveness of user interfaces, more studies in human-computer interaction have stressed the value of creating more pleasurable and enjoyable experiences for users when interacting with digital devices or products (Taylor et al., 2015; Lazar, Feng & Allen, 2006).

User frustration is defined as “anything that annoys a user” (Lazar, Feng & Allen, 2006). It is the displeasure experienced when users are interacting with computers. Users feel frustrated when they are unable to complete a specific task or achieve a specific goal on a digital product. In the context of pregnancy, studies have shown that the activation levels of pregnant women using pregnancy app often decrease with time (Qing & Weiying, 2019; Ledford et al., 2017). It is important to understand the frustrations pregnant women experience when interacting with their pregnancy apps.

The participants highlighted the following frustrations when using their pregnancy app(s) and thematic analysis was applied:

a) Unexpected app behavior

Two of the participants noted the experience of being logged out unexpectedly from the app when interacting with it. One participant mentioned that the exit button 'X' for closing the videos feature logged her out of the app each time she tried to close a video and proceed with something else on the app.

P1: *"If you are viewing an article or video, if you want to close it early, you know the little X button to close that window and goes back to the homepage, but it's right next to the top corner, and so when I hit that button it sometimes closes the entire app rather than just the video. So, I wish that they would place the video arrow in a little bit different location."*

P1: *"It's happened multiple times."*

P4: *"Oh, sometimes they logged me out, that was really annoying because I have to log back in."*

b) Sign-up wall

One of the participants felt frustrated with the mandatory request to sign in to use the app. This issue has been noted in non-academic spaces, however there is a significant dearth of research on the sign-up wall experienced by mobile app users, especially pregnant women.

P4: *"I don't necessary remember my password every time, so I delete that once because of that reason."*

c) Loading time

The time it took for the app to load was a pain point for some of the participants. Time convenience in the context of the speed to achieve a given task when using a technology affects the perceived value of the technology by users (Kim & Baek, 2018). The loading time of an app has great effect on user engagement with an app and app success.

P3: *“...that one probably takes the longest to load.”*

d) Redundant details

Studies on pregnant women have reported that their information needs to be updated as the pregnancy progresses (Akanbi & Fourie, 2018). Once a need has been met, she moves on to other sources that can meet the current need. This shows the need to provide updated information to women during pregnancy and afterwards. For example, a woman who is in the second trimester of pregnancy has needs that have changed from what she needed in first trimester. Likewise, a woman who just went through child delivery is less interested in information related to delivery again, as she is now interested in information on how to care for the baby, breastfeeding information, and wound care to mention a few. This is clear from P4's statements below:

P4: *“I mean it was towards the ending, it just kind of gets old.”*

P4: *“...and then it's gonna have a repetitive thing at that point because you know the baby is practically full grown.”*

e) Advertisements

Qing and Weiying's (2019) study showed that 36.3% of its participants liked no-implanted advertisements when using pregnancy apps. Two of the participants in this study noted interruptions from different adverts, although one of them was aware that the app made its financial gains from the adverts and was not too bothered.

P3: *"There's a lot of ads, that one probably has the most ads."*

f) Incomplete tracking metrics

One of the key features of pregnancy apps noted by women is a tracking feature (Hughson et al., 2018; Daly et al., 2017). However, while some apps provide the tracking functionality, they are done incompletely. One of the participants stated that one the app she used does not track with dates. This was a pain point for her.

P2: *"One of the apps... does really track with dates... the other one does not really give me that functionality."* (She had to combine three different apps to maximize her pregnancy experience with health apps.)

g) Insufficient information

One of the participants noted that she used three different pregnancy apps because one was not offering sufficient information. One of the greatest needs of pregnant women during pregnancy is access to quality information to make informed decisions regarding their health and the unborn (Akanbi & Fourie, 2018; Javanmardi et al., 2018).

P2: *"One doesn't give me give me enough information."*

h) Chat feature

Connecting with other pregnant/experienced women is one of the needs of first-time mothers (Harpel, 2018).

P2: *“One also does not have the chat feature with other mamas, I have to refer to the other that has that functionality.”*

P2: *“I haven’t found that one particular app that does everything.”*

(P2 would like to have an app with three specific functionalities: track her fetus, provide adequate information and chat with other pregnant moms.)

Perceptions on Pregnancy Apps. Understanding the views, experiences, and expectations of users of a digital product is central in the field of user experience. This is key to creating more usable and satisfying products (Deka, 2016; Lazar, Feng & Allen, 2006).

All the participants viewed their pregnancy apps as “valuable,” “wonderful,” “helpful” and “good” tools to deal with pregnancy. The following themes were extracted within the qualitative data:

a. Reminder

Patients hardly ever remember all the advice and recommendations given by the physician during hospital visits. This is true for pregnant women.

Two of the participant view apps as a good resource for remembering obstetricians’ advice and recommendations.

P3: *“It is a good in-between your doctor’s visit to still get some information.”*

P4: *“Your OB does tell you a lot of it, but you also do forget what your OB tells you, especially when you’re only meeting with them once a month.”*

b. Information conduit

Pregnancy apps are information conduits for varying pregnancy information in different formats. Information is presented in different fashions, ranging from videos to textual, for easy comprehension of the contents.

P1: *“For me it's very, very valuable, I have found that I rarely even go to other websites for information because all the information I need is generally there in the app.”*

P4: *“There's a lot of like good information like... food you should be careful of, and that kind of stuff.”*

c. Reference point

Pregnancy apps are viewed as reference points where answers can be found to burgeoning questions at any stage of pregnancy.

P2: *“Especially for first time moms, we don't know what to expect. It just really helps, and it guides us. We have like a reference point.”*

d. Resourceful

Pregnancy apps provide answers to questions beyond health information. One participant stated she used information on her app to set up her nursery.

P3: *“... then something that you don't need to ask your doctor, like setting up a nursery, thing like that that doesn't really matter to them.”*

e. Entertainment

Pregnancy apps give euphoric feelings to pregnant women. Past studies have associated pregnancy with negative emotions, such as fear and anxiety. Some of these emotions are caused by the uncertainty of not knowing what is happening within.

It is interesting that pregnancy apps can affirm happenings within pregnant women bodily, which can remove potential negative emotions.

P4: *“I mean, I felt like I was more somewhat like bonded to the baby, because I knew more about what was going on in my body, otherwise you know, like when you’re first trimester, especially you don't really feel anything”.*

P4: *“So, at least, that's how I was, so it just made me feel like, okay, well something is actually growing inside of me.”*

Discussion on Mobile App Design

What Pregnant Women would like to see on a Pregnancy App. This question was asked to understand the expectations of the participants when they download any pregnancy app.

Table 8. Features pregnant women like to see on a pregnancy app

Features pregnant women would like to see on a pregnancy app	Quotes
Baby tracker	P1: <i>“It tells you the approximate, like how much longer you have to go in your pregnancy, really like that it tells you about the size of your baby, which is just fine.”</i> P2: <i>“I know what's going on in my baby’s growth and development.”</i>
Pregnancy/Body tracker	P2: <i>“So things like, I can track my pregnancy, I know what is going on in my body.”</i>
Baby size tracker	P1: <i>“... like that it tells you about the size of your baby, which is just fine”</i> P1: <i>“It tells you like how big your baby is in comparison to other stuff.”</i>

Snippets of information	<p>P1: <i>"I really like it has a list of articles on the homepage. It has a list of articles, like maybe five or six articles that's related to, say, your third trimester, and it's just it has like a short little snippet."</i></p> <p>P1: <i>"...what to pack in your hospital bag and if you want to click on it, you can; if you don't want to, that's fine, too."</i></p>
User-friendly/Intuitive menu (UI elements)	<p>P3: <i>"Just make sure it's user-friendly, that there's a menu so you can go flip back and forth."</i></p> <p>P3: <i>"...want the notifications from the app to remind you to take your prenatal vitamins, that's helpful, send you some emails, those kinds of notifications. But have a way to make sure you can opt out of it so it's not too much."</i></p>
Organized information	<p>P4: <i>"Again, there's like just little facts and information. And [What to Expect] is really like organized. That's what I really liked about it."</i></p>
Reliable information	<p>P4: <i>"They post articles from professional website. So, that was also helpful."</i></p>
Visually appealing layout (Visual design)	<p>P4: <i>"It's color-coded for the most part, but it's not like, making your eyes go, you know, crazy because there's so many colors."</i></p>
Common symptoms	<p>P1: <i>"...has a common symptoms section, and it tells you, like, at this point your baby will be moving more, expect this, and while you're thinking about it you should count how many kicks the baby is doing. Yeah, it's great."</i></p>
Nutritional recommendations	<p>P2: <i>"...know what nutrition to give and at what point."</i></p>
Chat	<p>P2: <i>"I can chat with other mamas, of course."</i></p>
Baby names	<p>P4: <i>"Like a flashcard of names."</i></p>

Features Looked for When a Pregnancy App is Downloaded. The participants were asked to use the blackboard feature on the Zoom software to write down three things that are important to them when they download an app.

Table 9. Important things looked for in a pregnancy app

Three things important to pregnant women when a pregnancy app is downloaded	Quotes
Information architecture <ul style="list-style-type: none"> - Clear organized information <ul style="list-style-type: none"> • Video category • Article category (textual information) 	
Information from medical professionals <ul style="list-style-type: none"> - Doctors - Nurses 	
Timeline <ul style="list-style-type: none"> - Information based on week /stage of pregnancy - Weekly updates 	P1: <i>“So I’m not getting irrelevant stuff like, oh you might have morning sickness while I’m in third trimester, not relevant.”</i>
Chat feature <ul style="list-style-type: none"> - Communicate with other mothers 	
Fetal/Mother development tracker <ul style="list-style-type: none"> - Weekly updates on the size of the baby 	
Pregnancy topics <ul style="list-style-type: none"> - Food recommendations - Checklists - Exercise restrictions/recommendations 	

Most Important Feature to the Participants in a Pregnancy App.

Table 10. Most important feature

Most important feature on pregnancy app to pregnant women	Quotes
Reliable/Relevant information	<p>P1: <i>"I think reliable information has to be the top of it. Like, for me, I love that it's sorted, organized, but if it's not relevant or if it's not reliable, if it's not accurate information, that would really frustrate me.</i></p> <p><i>I appreciate it, going in the app, reading an article and they say according to, you know, the Pediatric Society or whatever, like this is a thing you should look into, it makes it valuable. Like if the information isn't correct, I'm not going to waste my time."</i></p>
Baby development	<p>P2: <i>"A feature that tells you about how your baby is growing."</i></p>
Timeline	<p>P3: <i>"I guess I just I like to know what's happening, what to expect, what's normal, all at the appropriate time."</i></p>
Weekly updates	<p>P4: <i>"Weekly updates on how the baby's doing in there."</i></p>

Findings and Analysis of Online Case Study Using Co-Design with the Gynecologist

The intention was to involve three gynecologists for the online case study using co-design, but due to the pandemic and lack of access to pregnant women care givers, one only was used. The researcher sent out the research invitation to obstetrics and gynecological discussion forums on Facebook and sent emails to gynecological practices to solicit for interested gynecologists, but none gave positive responses. In the end, only one gynecologist showed interest.

Response from the gynecologist

The following are the questions and task administered to the gynecologist (P5) who participated in the online case study using co-design.

1. Discussion on the use of app technology by pregnant women during pregnancy
 - a. What kind of online sources of health information would you recommend to pregnant women?
 - b. Would you recommend health apps to pregnant women? Why?
 - c. What kind of tasks do you think pregnant women get done with pregnancy app?
 - d. Tell me about any positive experiences you have had with pregnant women who used pregnancy app.
 - e. What are the perceived frustrations you think pregnant women may experience using the app?
 - f. What do you think about pregnancy apps?
2. Discussion on mobile app design
 - a. What would you like to see on a pregnancy app?
 - b. What features would you recommend in an app for pregnant women? Take a piece of paper and jot down three things that are important to them.
 - c. If you have to pick only one feature that is most important, what would it be? You can select from already mentioned item.
 - d. Would you be interested in the design of health apps for pregnant women?
3. Additional information you would like to share about this topic?

Discussion on the Use of App Technology by Pregnant Women during Pregnancy

Online sources of health information recommended to pregnant women. This question was asked to determine the information sources the physician recommends to her patients. Studies have shown that women in their reproductive ages in developed countries use mobile health apps for receiving health information during pregnancy (Biviji et al., 2020; Chaudhry, Faust & Chawla, 2019).

P5 stated that she recommends the Babyscripts app to her patients. She also said that some of her patients use the BabyCenter website (babycenter.org) and the

BabyCenter app. P5 also recommends the U.S. Preventative Services, American College

of Obstetricians and Gynecologists, Center for Disease Control and Prevention (CDC), and UpToDate.com to her patients (pregnant women). UpToDate.com is, however, designed for physicians or advanced practitioners. The participant sometimes shares her access (password) with interested patients who need more information. The patient portal of her practice is also a good source of online health information to pregnant women.

The following themes were identified within the qualitative data:

Babyscripts App Functionalities. The participant noted the following functionalities and features of Babyscripts (the app used by her gynecological practice):

a) Weekly prenatal information

P5: *“It gives information, education, on a weekly basis to our pregnant patients.”*

b) Content from reputable sources

P5: *“It’s about everything to do with pregnancy, and its sources include the American College of Obstetricians and Gynecologists and Centers for Disease Control and Prevention (CDC), all reputable sources.”*

c) Transition care outside the clinic

P5: *“It basically gives smart end-to-end management of patients, enabling them and providers of transition care outside of the clinic and address any problems of access.”*

d) Efficient management of gynecologist workload

P5: *“As a provider, I’m able to automate a majority of my patients care while effectively allocating time and resources, especially to my higher risk patients, like people who have, like, high blood pressure.”*

e) Remote blood pressure monitor

Marko et al.'s (2019) study revealed that in-person prenatal visits can be reduced using mobile apps, particularly for women with low-risk pregnancies. The participant affirmed that her pregnant patients could measure their blood pressure remotely and the information can be linked to their medical records through the Babyscripts app.

P5: *“So with Babyscripts, they are able to, depending on which aspect of the app you use...*

You can get like, a Bluetooth-enabled blood pressure machine... you collect the blood pressure, the patient collected herself, it can send that result to the app, and that can also be integrated to the patient's medical record.”

P5: *“Patients are able to log their blood pressure, their sugars, if they have diabetes, their weights and other vitals that are important to them.”*

This app provides the care provider the means of providing quick medical attention to patients with high blood pressure or any health condition that might be detrimental to the health of the mother or fetus. Therefore, some pregnancy apps are very useful tools in delivering maternal healthcare, particularly women in resource-limited locations or remote areas. They foster remote collection of the patient's health information and promote patient-physician communication (Carter et al., 2019).

f) Push notifications

The Babyscripts app has the functionality of sending notifications on pregnancy information, doctor's office information and updates.

P5: *“We use the app to send push notifications about anything to do with pregnancy, as it relates to our practice to our patients. So, let's say they had a snow day, and we want to*

let patients know really quickly that the office is going to be closed, and it's only 6am in the morning; we're not there to call them, we can send a push notification that way."

g) Share new information

P5: *"If there's any new information, like when COVID first came out, we were able to send information really quickly."*

P5: *"Anytime there's a new provider, or provider has an article they want to share with patients, it's a very good way for the patient to then be able to use the app in that respect."*

h) Offer postnatal information

P5: *"If a patient wants to learn something about her pregnancy, or even after the baby's born after one year, the app gives information again on a weekly basis."*

i) Personalized messaging

P5: *"...has already done the good work of, you know, filtering through a triaging information and just giving the right information to the patient."*

j) Library of information

P5: *"It has like, a library of information that they can always access to without feeling like they're, you know they're getting incorrect information, there's no information overload."*

Recommendation of health apps to pregnant women. The participant responded positively to the question, "Would you recommend health apps to pregnant women?"

P5: *"Yes, absolutely, yes, and I do."*

The participant supports the use of pregnancy apps because:

a. Presents different learning styles

P5: *“I think that there’s different ways that we learn, some people learn by reading, some people learn by seeing visual.”*

b. Technology era

P5: *“We are in an era now where we use technology to help push us. We are all using Facebook and Instagram, that is the most common way of communicating and learning in this age.”*

c. Information access

P5: *“Now people want access to information and apps make it easy to access different types of information. So, having an app on your phone makes information access, I think, much better than it used to be before, when we had a simple flip phone, where you had to go to the library, using, you know, your antiquated computer to kind of get information that you need.”*

Tasks and Activities Pregnant Women Get Done with Pregnancy App

(Gynecologist Viewpoint). The participant believes that pregnant women use their pregnancy apps for the following:

a. Personal education
b. Documenting vitals
c. Knowing progress with their pregnancy
d. Writing down question to ask their provider at the next visit
e. Access information
f. Learn about their pregnancy

Positive Experiences the Gynecologist Has Had with Pregnant Women Who Used Pregnancy Apps

<p>a. Quick answers to questions</p> <p>P5: <i>“I never get to even get to answer those questions, because they’ve already looked up information in the app and gotten the answers that they needed.”</i></p>
<p>b. Quick information access</p> <p>P5: <i>“Not everyone has access to, you know, to Medline, all the research that we typically use as providers, apps make that very easy to be able to access because they do the research for you in a way.”</i></p>
<p>c. Reduces anxiety</p> <p>P5: <i>“...so by the time they get to me, there’s no more anxiety about you know what to expect”</i></p>
<p>d. Readable contents</p> <p>P5: <i>“...summarize it in a way that is easy for someone even in an eighth-grade education to understand. And I think that is very helpful. I think that is the greatest one, I think, for our patients.”</i></p>

Perceived Frustrations Experienced by Pregnant Women Using the App

(Gynecologist Viewpoint). Studies have shown that pregnant women exercise some frustrations when using their pregnancy app (Qing & Weiying, 2019; Mao et al., 2018).

a. Naivety with technology

The participant opined that the women who might experience some frustrations are those uncomfortable with using social media or smartphones in general.

P5: *“I think it would have to do with those who are not very comfortable with using social media or smartphones in general, may find it difficult to install, you know, those apps on*

their phone, but I think it's going to be few and far between because most people know how to use smartphones.”

This is in accordance with Biviji et al. (2020) and Daly et al. (2017) that many women in reproductive ages today are users of smartphones and tech savvy.

b. Patient’s understanding of the limitation

P5: *“I have not yet experienced patients who feel like they haven't been able to get the answers...”*

P5: *“So, I haven't personally had any patients tell me that they're frustrated with the app, not giving them information that they need.”*

P5: *“There's a limitation where you can't get on the app, and I think patients understand what the limitations are. And so, they're willing to wait to speak with a doctor to clarify anything that may not have been answered directly with the app.”*

(This is based on the gynecologist’s view of the Babyscripts app.)]

The gynecologist stated that she recommends the Babyscripts app to all her patients, and that none of the patients have complained. This shows the utility of pregnancy apps to pregnant women and care providers.

Perception About Pregnancy App. When asked to comment generally about the features and utility of pregnancy apps, the participant shared the following comments:

a. Good

P5: *“It’s not just good for the patient. It is also a convenience for us because we're able to push information to our patients, very easily, very readily, and then when you're able to pass on information about commonly asked questions to pregnant patients, then*

it decreases your workload because they're less likely to call you in the middle of night to be asking you questions that you know you can see in the app."

b. Educational and informative

P5: *"So, we don't get as many 'oh I lost my mucus plug,' you know, because the app will give you information about, 'Yep, it's common to lose your mucus plug when you're 36 to 38 weeks.' It doesn't mean you have to go to the hospital, doesn't mean you're about to have a baby, you know, in the next you know week or two."*

c. Saves health cost

P5: *"It decrease the amount that we get in the middle of the night from the on-call on Emergency line."*

d. Useful

P5: *"So, it definitely helps decrease the number of, I wouldn't say unnecessary because no, no question is unnecessary if you have a question because you don't understand, but it decreases a number of questions that could probably wait, 'til, you know, a business day to answer. Not detriment to patients."*

Discussion on Mobile App Design

What the Gynecologist would like to see in Pregnancy App. The participant was asked to mention the features she would love to see on a pregnancy app:

What the gynecologist would like to see in a pregnancy app	Quotes
- Information about different stages of pregnancy	
- Commonly asked questions	
- Feature that integrates vitals into patient's medical records	P5: <i>"It also should be integrated with your OB labs, so that if you had to go to a different hospital, different from your hospital, you can show them your app and the doctor who's taking care of you, who may not have seen you before, can have a very quick summary of your pregnancy."</i>

- Encouraging and controllable notifications	P5: <i>“I also would like an app that is not overwhelming to a patient and sending notifications like five times a day, so perhaps an app that a patient can control how often she receives those notifications.”</i>
- Nutritional recommendations	P5: <i>“...go over like nutrition if you're breastfeeding while you're pregnant, or if you have twins, something that was, you know, or you had diabetes, you know, an app that can give you recommendations on what you can do to modify your diet for the different comorbidities you may have.”</i>
- Prenatal details	P5: <i>“...so it tells you your height, your weight for each appointment, you're able to document any concerns that you may have so that you can bring it to your OBGYN to discuss”.</i>

Features Recommended in a Pregnancy App. The participant was asked to mention features she would recommend in a pregnancy app. She recommends:

Nutrition
Updates on Covid-19
Weekly updates on fetal development

Most Important Feature. The participant was asked to mention the most important feature she recommends on a pregnancy app:

Weekly updates on fetal development

Gynecologist's interest in the design of health apps for pregnant women. When asked the question about her interest in the design of a new health app for pregnant women, the participant's response was, "*Possibly, but my job is pretty demanding right now.*"

She further stated that she would like to be involved because her patients currently use pregnancy apps and would thus like to see further improvements to make them better.

Additional information. Women using pregnancy apps is a "win-win" for both patients and physicians.

P5: "*It's been a wonderful thing during the pandemic, it's proven to have really, really helped patients, a lot more than we anticipated that they would. It also helped physicians a lot. It's been a win-win situation for all involved really.*"

Conclusions

Past literature confirmed the shift to newer technologies for accessing medical information among pregnant patients. New studies on pregnant women have also reported the use of pregnancy apps among pregnant women in developed countries (DeNicola et al., 2020; Dalton et al., 2018). Use of pregnancy apps among women in their reproductive ages is driven by the internet and mobile technology advancement. Pregnant women prefer to source health information from their physicians (Holroyd et al., 2017), internet (Javanmardi et al., 2018), websites, (Fredriksen, Harris & Moland 2018; Fredriksen,

Harris & Moland, 2016) and pregnancy apps (DeNicola et al., 2020; Daly et al., 2017).

These were confirmed from the web survey and online case study responses.

Many literatures have stressed the challenges of internet health information among patients (Fredriksen, Harris & Moland, 2018; Hughson et al., 2018). Findings from this study reveal the inclusion of contents from health institutions and medical professionals in pregnancy apps. The online case study with the gynecologist revealed that some gynecological practices in the country are already incorporating pregnancy apps in the delivering of care to their pregnant patients. This confirms the adequacy and relevance of app technology for pregnant women. Similarly, DeNicola et al. (2020) and Marko et al. (2019) affirmed the usefulness of pregnancy apps for providing a more robust health care to pregnant patients. Integration of pregnancy apps into gynecological practices has the advantages of decreasing medical errors and accuracy of patient's health information, manage physicians' workload, promotes off-clinic patient-physician interactions and information access. These advantages are highlighted in literature, such as Tripodi et al. (2020) and Marko et al. (2019).

Literature in health sciences have noted that physicians in the U.S. are experiencing burnout and that there is shortage of obstetrics and gynecology professionals (West, Dyrbe & Shanafelt, 2018). Advantageously, the study found that the health app affiliated with the gynecologist's practice is helping with effectively allocating more time to high-risk pregnant women, managing workload by automation of workload (thereby increasing efficiency) and fostering remote communication with pregnant patients.

Reliability of health information is crucial to pregnant women when downloading health apps (Arcia, Stonbraker & Warner, 2019). This is confirmed in the online case studies carried out with pregnant women. This gap is also being filled with credible pregnancy apps conveying medical information verified by various health institutions and professionals. Reliability and credibility of internet health contents has been a concern of many researchers. The involvement of medical professionals in the development teams has been suggested by past studies. This study affirms the interest of medical professionals in the codesign of technology used by pregnant women.

Furthermore, past literature on patient compliance have stressed the importance of adherence to treatment plans on the part of the patients. Sanford and Rivers (2020) and Lu and Zhang (2019) mentioned different areas where patient compliance can be viewed, namely medication, lifestyle, treatment, and physician's instructions. The empirical findings found that the majority of the pregnant women had some levels of agreement with compliance to their physician's instructions, medication and supplements, suggested treatment, and follow-up tests for treatment. This is in accordance with Roldan Munoz et al. (2020) and Chandyo et al.'s (2017) studies.

A study stressed that some physicians are reluctant to discuss issues regarding gestational weight gain among pregnant patients. This is because some physicians sometimes feel uncomfortable discussing the topic with their patients (Knight-Agarwal et al., 2015). Likewise, the empirical findings show that the participants ranked patient compliance on healthier lifestyle, such as diet and exercise, as having lesser importance than the other items listed. This seems to be a sensitive topic to pregnant patients.

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Pregnancy apps are a good platform to provide information and help on topics care givers and pregnant women consider sensitive and feel uncomfortable discussing in person.

Chapter 5: Conclusion

This chapter is the concluding part of the study. It reiterates the problem statement, research questions and reflects on the purpose of the study. It also highlights how the study was conducted and summarizes the findings for research questions.

Recommendations for design and future research is provided.

Advancement in internet and mobile technology has given rise to use of mobile applications for searching for health information when compared with traditional sources. Mobile health applications offer a more flexible consultation model to patients by providing a portable, convenient, and accessible means of delivering and receiving health care. They also hold the capability of connecting patients with physicians in a short time. Furthermore, they offer easy and timely access to a wealth of online health information, provide access to personal experiences of other patients in similar health conditions and grant access to valuable, enhanced high-resolution audio and video health contents. However, there are serious concerns about the health information quality, accuracy, utility, and credibility of contents delivered on health applications to pregnant women.

Thus, to address the above problem, the following research questions were asked

- How does app design interface help with quality health information for pregnant women?
- How effective and adequate is health intervention through app technology for pregnant women?

- What design recommendations can be provided to improve health information for pregnant women? (Participatory design approach.)

The purpose of this study is to assess pregnant women's perceptions on mobile app design, utility, and credibility of health information provided on pregnancy apps for meeting their health needs during pregnancy. It also seeks to assess the effectiveness and adequacy of mobile app design for enhancing patient compliance, which is necessary for better health outcomes, including maternal health, in the U.S. The literature analysis in the second chapter shows that app technology has the potential of improving maternal health outcomes, patient compliance and patient-physician interaction. Empirical findings from the study also affirm the relevance of app technology in gynecological care delivery and for meeting the varying needs of pregnant women during pregnancy and afterwards.

Summary of conducting the empirical study

The study used explanatory sequential mixed methods research to explore the perceptions of pregnant women resident in the United States on mobile app design, utility, and information credibility. To achieve this, a self-report survey was used to assess patient compliance and perceived quality of internet health information. The anonymous web survey was used to gather the quantitative data from the participants. A total of 59 pregnant women responded to the web survey out of 89. On the other hand, the qualitative data were gathered from four pregnant women and one gynecologist using online case studies involving co-designing. The qualitative questions were developed to

help explain in detail how the participants viewed pregnancy-related app designs, utility, and information credibility of the contents displayed on the app(s).

How does app interface help with quality health information?

App technology is now commonplace among patients. Health applications are used in preventive healthcare and sometimes for health management. It is very crucial to understand how users of health apps, particularly pregnant women, perceive the utility of pregnancy apps during pregnancy because app technology is already being incorporated into healthcare in some parts of the country. As mobile apps are the most used information source among pregnant women today, it is important to note one of the most vital touchpoints between users and their mobile app(s) is the app interface.

App design interface is an important component of mobile devices which enables interaction between humans and computer. It is the mobile space that allows human-computer interaction for the purpose of completing a specific task and achieving a specific goal (Buzzi et al., 2019; Kuznetsov et al., 2016; Hu et al., 2019). The design of app interfaces has the capacity to influence the choices, decisions, and behaviors of users using the app (Schneider, Weinmann & Brocke, 2018).

Studies have shown that intuitive, user-friendly, and well-designed app interfaces affect how users perceive the information quality being conveyed. A well-designed app interface also affects app adoption by users, success in the marketplace, user engagement level and trust in the information contents (Hamzah, Persada & Hidayatullah, 2018; Deka, 2016). Comparably, the participants in the study also confirm the relevance of

well-organized/designed navigational menus, information layout, and user-friendly interfaces in pregnancy apps they decided to use during their current pregnancy.

How effective and adequate is health intervention through app technology for pregnant women?

Literature on newer technologies in health care have reported some level of success in integrating app health intervention in dealing with diseases such as diabetes, hypertension, depression, and obesity, also in the case of pregnancy (DeNicola et al., 2020; Lau et al., 2018; Faherty et al., 2017).

Integration of newer technology into the pregnancy health space is helping more women in their reproductive ages with better information access, support, and empowerment (DeNicola et al., 2020; Daly et al., 2017). App technology is effective and adequate in helping patients learn more about their health conditions, communicate with loved ones and physicians, and monitor their physiological and psychological metrics. The advantages and adequacy of app technology for maternal health is discussed in Chapter 2. Based on the efficacy of health intervention through app technology, some obstetrics and gynecological practices are already integrating app technology into their care delivery to foster better maternal care and patient-physician communication.

Even though some studies have expressed concerns on the quality of health information on apps, it is noteworthy that contents displayed on some pregnancy apps are created by health care professionals.

What design recommendations can be provided to improve health information for pregnant women? (Participatory design approach.)

Past literature has noted the impact of app technology in healthcare among different patients (Duan et al., 2020) including pregnant women (Marko et al., 2019; Marko et al., 2016). Notably, some researchers have also stressed the drawbacks associated with quality and comprehensibility of contents conveyed on app technology to target audience. The need for improved and better designed app interface cannot be overemphasized.

Involvement of end-users of a technology in the design phase is seen to be very vital for creating products that meet the goals and needs of the users (Walsh et al., 2013). Hence, the involvement of co-design technique in online case studies, which was used to gather the qualitative data for the study, provides better insights, context, and robust empirical findings. It also reveals the challenges and pain points experienced by pregnant women that may be impossible to be captured using another research method. Therefore, the following design recommendations were provided, which could improve health information for pregnant women using app technology:

- **Information architecture:** Simplifying information search on pregnancy apps by providing well-organized/designed informational contents i.e., wayfinding of contents on the app should be easy and intuitive to the users.
- **UI elements:** This study suggests the use of controllable notifications. It should allow users to be in control of how/when they want to receive notifications from the app.

- **Well-designed navigational menu:** Use of user-friendly menu for flipping back and forth between pages without getting overwhelmed.
- **Medical information from professionals:** Pregnancy requires health information for pregnant women to go through the period successfully. Pregnant women prefer health information provided on pregnancy apps to be from health professionals or health institutional bodies e.g., Association of Pediatrics. Considering this, the contents, advice, recommendations, and information offered on pregnancy apps must be from certified care providers dealing with pregnancy.
- **Comprehensible contents:** Users of app information have varying mental and cognitive capabilities as well as diverse backgrounds. Hence, the contents on apps should be readable and understandable by any level of reader/ user. The recommended reading level for online health contents should be used to determine what is being published to users.
- **Baby development-centered information:** Pregnancy information related to fetal development and bodily changes should be offered weekly.
- **Visually appealing layout:** Use of well-defined aesthetics/color impacts perceived credibility of the information and information processing.
- **Commonly asked question:** Snippets of information can be useful for resolving uncertainty among pregnant women.
- **Chat feature:** Emotional support and anxiety are dissipated when they hear from other mothers in similar conditions.

Limitations of the study

Access to participants was impeded because many of the social media groups the researcher relied on to source for participation does not support use of their platforms for research purposes. The researcher's survey link was not allowed to be posted on some Facebook pregnancy support groups. Craigslist, for example, failed to post the survey link and there was low turnout from Twitter.

The COVID-19 pandemic also affected the participant's responses to the anonymous survey as many were already stressed with the challenges accompanied with the pandemic.

Since the study used only pregnant women resident in the United States, perception about app technology might be different from women living in other countries. The study was also limited with the reality of the short time associated with pregnancy. One of the participants was a recently new mom.

In addition, the findings from this study cannot be generalized to the target population because of the non-experimental research method used.

Recommendations

Based upon the results of the research, this study recommends:

- Incorporation of app technology in more gynecological practices in the U.S., especially for women carrying high-risk pregnancies.
- Use of mobile technology for promoting pregnant women's compliance with physician's recommendations and advice. Also, use of apps for promoting patient-physician

communication and interaction.

- Designers of pregnancy health apps should convey only informational contents certified/approved by health/medical professionals and institutions.
- More adoption of app technology in maternal healthcare for disseminating relevant health information.
- Provision of pregnancy information based on gestational week e.g., week two of pregnancy.
- Incorporation of healthcare professionals and patients in co-designing of medical technology used by patients.
- Use of other sources to supplement social media platforms when looking for where to recruit research participants in future research.

Recommendations for Further Research

This study found that some gynecological practices are already incorporating app technology into their maternal care delivery. It is recommended that future research should consider testing the usability of the Babyscripts app (which is already in use by pregnant women) to affirm the usability and utility of app technology in health care.

Non-medical-related needs of women should also be considered in further research because literature on pregnant women have shown that they have information needs beyond medical-related needs, such as nutritional recommendation or social and personal considerations (e.g., women dealing with addiction or abuse, etc.).

This study developed some hypotheses based on self-efficacy theory and the health belief model that could not be tested in this study. Thus, it would be valuable for future research to investigate the relationship between the constructs of this conceptual model in line with patient compliance, in this case pregnant women.

Conclusion

The primary purpose of this study is to understand the perceptions of pregnant women on mobile app design, utility, and information credibility. Findings from this study show the value of mobile app technology in delivering health resources to pregnant women.

The relevance of patient compliance, patient-physician interaction and communication were addressed, and it is clear that mobile app technology is helping women in this area. Even though the majority of the participants agreed with app health information on relevance to health needs, relatedness to health needs, pertinence, understandability, utility, comprehensiveness, clarity and readability, one-third of them were concerned about the sufficiency of the health information conveyed on their pregnancy apps. Hence, there is need for more studies on the needs of pregnant women using newer technology for health purposes in the country.

Lastly, the increased maternal deaths in the country could be potentially reduced by encouraging more gynecological practices to incorporate medical apps in care delivery to interested pregnant women.

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Appendix A: Pregnant Women Consent Form for Survey

TITLE OF STUDY: Technology and Pregnant women: exploring pregnant women's perception of mobile app design, utility, and information credibility.

PRINCIPAL INVESTIGATOR: Olubukola Akanbi

I. INTRODUCTION/PURPOSE

The goal of this study is to know about the use of mobile phone applications (apps) among pregnant women. This study seeks to understand the usefulness of app design and information contents to pregnant women. I am being asked to participate in this study.

II. PROCEDURES

I am being asked to participate in this anonymous survey. Proceeding to the first page of the survey represent consent to participate in the research. I am being asked to select 'Yes' to proceed. The survey contains questions on usefulness and adequacy of apps used by pregnant women.

III. CONFIDENTIALITY

All collected information from this study will be stored on researcher's hard drive. The hard drive will be kept in a locked cabinet. Analysis will be done on passworded protected laptop. Only the researcher and her research team will have access to the collected data. All data will be destroyed upon the completion of the study. Agreeing to participate in this research implies my approval that information collected will be published in a doctoral dissertation. Also, in one or more conference papers and articles.

IV. POTENTIAL RISK AND BENEFITS

There is no known risk involved in participating in this study. I am aware that my involvement in this study may not be of benefit to me now. But this study will add to studies on technology and pregnant women.

V. VOLUNTARY PARTICIPATION

My participation is voluntary. I may choose to withdraw from the study at any time. There will be no loss of any benefits for not participating.

VI. CONTACT AND QUESTIONS

The principal investigator, Olubukola Akanbi, has offered to and has answered all questions concerning my involvement in this research study. If I have any further questions, I can contact, the principal investigator at 240-528-1043, olubukola.akanbi@ubalt.edu.

For more questions concerning this research study, please contact the UB Institutional Review Board (IRB) at: irb@ubalt.edu 410-837-4057

VII. SIGNATURE FOR CONSENT

The above-named investigator has answered my questions. I agree to be a research subject in this study.

Name (please print): _____

Signature: _____ Date: _____

Appendix B: Survey Questions**Section A: Information-related to Pregnancy****1. How far along are you in your current pregnancy?**

- a) 1-10 weeks
- b) 11-20 weeks
- c) 21-30 weeks
- d) 31-40 weeks
- e) Over 40 weeks (past due date)

2. Please indicate if this is your first pregnancy or not

- a) This is my first pregnancy
- b) I have been pregnant before
- c) I have been pregnant before, but it was not a full-term pregnancy
- d) Prefer not to say

3. Can you indicate approximately the number of prenatal visits for the current pregnancy?

- a) 1-4 visit(s)
- b) 5-8 visits
- c) 9-12 visits
- d) Other (please specify) -----

4. Where have you looked for health information relating to pregnancy during the current pregnancy? (Check all that apply)

- a) Websites
- b) Friends
- c) Pregnancy Applications (apps)
- d) Magazines
- e) Books
- f) Search engines
- g) Pamphlets
- h) Brochures
- i) Physicians
- j) Family
- k) Nine-month Calendars
- l) Blogs
- m) Discussion Forums
- n) Social networks
- o) Bulletins

- p) Electronic newsletters
- q) Other (Please specify) -----
- 5. Have you used any pregnancy or health related app during the current pregnancy?
 - a) Yes
 - b) No
- If Yes, please list the app(s)

Section B: Demographic information**6. What is your age?**

- a) 18-25
- b) 26-35
- c) 36-45
- d) 46-55
- e) Above 55

7. Which of the following best describes your ethnic background?

- a) Hispanic/Latino
- b) White/Caucasian
- c) Black or African American
- d) Asian American
- e) Native American
- f) Other (please specify) -----

8. Which of the following best describes your marital status?

- a) Married
- b) Not married
- c) Other (please specify)

9. Which of the following best describes your highest level of education?

- a) Have not completed high school
- b) Completed high school
- c) Associate degree
- d) Bachelor's degree
- e) Master's degree
- f) Doctoral degree
- g) Other post high school qualification(s)

10. Which of the following best describes your employment status?

- a) Employed
- b) Not employed
- c) Other (please specify)

Section C: Pregnancy and Patient Compliance**11. I am following or did follow the physician's suggestions exactly**

- a) Strongly disagree
- b) Disagree
- c) Somewhat Disagree
- d) Neutral
- e) Somewhat Agree
- f) Agree
- g) Strongly agree

12. I am following or did follow the physician's recommendations on use of medication and supplements

- a) Strongly disagree
- b) Disagree
- c) Somewhat Disagree
- d) Neutral
- e) Somewhat Agree
- f) Agree
- g) Strongly agree

13. I am following or did follow the physician's orders on healthier lifestyle, such as diet and exercise

- a) Strongly disagree
- b) Disagree
- c) Somewhat Disagree
- d) Neutral
- e) Somewhat Agree
- f) Agree
- g) Strongly agree

14. I have returned or plan to return to the physician on the schedule he or she suggested for treatment

- a) Strongly disagree
- b) Disagree
- c) Somewhat Disagree
- d) Neutral
- e) Somewhat Agree
- f) Agree
- g) Strongly agree

15. I have had or plan to have the follow-up tests for treatment, as recommended by the physician.

- a) Strongly disagree
- b) Disagree
- c) Somewhat Disagree
- d) Neutral
- e) Somewhat Agree
- f) Agree
- g) Strongly agree

Section D: Relevance: App health information quality

16. For your health information needs, to what degree do you believe the internet health information provided by pregnancy app(s) was applicable to your needs?

- a) Strongly disagree
- b) Disagree
- c) Somewhat Disagree
- d) Neutral
- e) Somewhat Agree
- f) Agree
- g) Strongly agree

17. For your health information needs, to what degree do you believe internet health information provided by pregnancy app(s) was related to your needs?

- a) Strongly disagree
- b) Disagree
- c) Somewhat Disagree
- d) Neutral
- e) Somewhat Agree
- f) Agree
- g) Strongly agree

18. For your health information needs, to what degree do you believe internet health information provided by pregnancy app(s) was pertinent to your needs?

- a) Strongly disagree
- b) Disagree
- c) Somewhat Disagree
- d) Neutral
- e) Somewhat Agree
- f) Agree
- g) Strongly Agree

19. For your health information needs, to what degree do you believe internet health information provided by pregnancy app(s) was relevant to your needs?

- a) Strongly disagree
- b) Disagree
- c) Somewhat Disagree
- d) Neutral
- e) Somewhat Agree
- f) Agree
- g) Strongly Agree

Understandability

20. For your health information needs, to what degree do you believe internet health information provided by pregnancy app(s) was clear in meaning?

- a) Strongly disagree
- b) Disagree
- c) Somewhat Disagree
- d) Neutral
- e) Somewhat Agree
- f) Agree
- g) Strongly Agree

21. For your health information needs, to what degree do you believe internet health information provided by pregnancy app(s) was easy to read?

- a) Strongly disagree
- b) Disagree
- c) Somewhat Disagree
- d) Neutral
- e) Somewhat Agree

- f) Agree
- g) Strongly Agree

22. For your health information needs, to what degree do you believe internet health information provided by the pregnancy app(s) was easy to comprehend?

- a) Strongly disagree
- b) Disagree
- c) Somewhat Disagree
- d) Neutral
- e) Somewhat Agree
- f) Agree
- g) Strongly agree

23. For your health information needs, to what degree do you believe internet health information provided by pregnancy app(s) was understandable?

- a) Strongly disagree
- b) Disagree
- c) Somewhat Disagree
- d) Neutral
- e) Somewhat Agree
- f) Agree
- g) Strongly agree

Usefulness

24. For your health information needs, to what degree do you believe internet health information provided by pregnancy app(s) was informative?

- a) Strongly disagree
- b) Disagree
- c) Somewhat Disagree
- d) Neutral
- e) Somewhat Agree
- f) Agree
- g) Strongly Agree

25. For your health information needs, to what degree do you believe internet health information provided by pregnancy app(s) was valuable?

- a) Strongly disagree
- b) Disagree
- c) Somewhat Disagree
- d) Neutral

- e) Somewhat Agree
- f) Agree
- g) Strongly Agree

26. For your health information needs, to what degree do you believe internet health information provided by pregnancy app(s) was helpful?

- a) Strongly disagree
- b) Disagree
- c) Somewhat Disagree
- d) Neutral
- e) Somewhat Agree
- f) Agree
- g) Strongly agree

27. For your health information needs, to what degree do you believe internet health information provided by pregnancy app(s) was useful?

- a) Strongly disagree
- b) Disagree
- c) Somewhat Disagree
- d) Neutral
- e) Somewhat Agree
- f) Agree
- g) Strongly agree

Adequacy

28. For your health information needs, to what degree do you believe internet health information provided by pregnancy app(s) was sufficient?

- a) Strongly Disagree
- b) Disagree
- c) Somewhat Disagree
- d) Neutral
- e) Somewhat Agree
- f) Agree
- g) Strongly agree

29. For your health information needs, to what degree do you believe internet health information provided by pregnancy app(s) was complete?

- a) Strongly Disagree
- b) Disagree
- c) Somewhat Disagree

- d) Neutral
- e) Somewhat Agree
- f) Agree
- g) Strongly agree

30. For your health information needs, to what degree do you believe internet health information provided by pregnancy app(s) was adequate?

- a) Strongly Disagree
- b) Disagree
- c) Somewhat Disagree
- d) Neutral
- e) Somewhat Agree
- f) Agree
- g) Strongly agree

31. For your health information needs, to what degree do you believe internet health information provided by pregnancy app(s) contained the necessary topics or categories?

- a) Strongly Disagree
- b) Disagree
- c) Somewhat Disagree
- d) Neutral
- e) Somewhat Agree
- f) Agree
- g) Strongly agree

Appendix C: Invitation to participate in a research study (Pregnant women)

I, Olubukola M. Akanbi, am a doctoral student in the Information and Interaction Design program at the University of Baltimore. The title of my study is: Pregnant women & Technology: exploring the perceptions of mobile app design, utility, and information credibility.

You are being asked to participate in an online study with the researcher. The meeting is focused on pregnancy apps design and your experiences during your current pregnancy. Participation in this online meeting is not associated with any known risk or harm and it will be approximately 30 minutes. The meeting will be held on Zoom.

You will be given an Amazon gift card of \$50 for participating in this study research study.

If you are interested, please sign-up by answering the questions below.

Name

Email

Available days

Available times

Appendix D: Invitation to participate research study (Physicians)

I, Olubukola M. Akanbi, am a doctoral student in the Information and Interaction Design program at the University of Baltimore. The title of my study is: Pregnant women & Technology: exploring the perceptions of mobile app design, utility, and information credibility.

You are being asked to participate in an online case study research. The discussion will be based on your views on pregnancy apps design and pregnant women. Participating in the meeting is not associated with any known risk. The discussion is going to be approximately 45 minutes. It will be held on Zoom.

You will be given a gift card of \$100 in the form of a gift card for participating in this research study.

If interested, please use sign up by answering the following questions below,

Name

Email

Available days

Available times

Appendix E: Questions for the Online Case Study (Pregnant Women)

This is a participatory study with the aim of understanding the perceptions of pregnant women regarding the app technology they use during pregnancy as well as uncovering new ideas and features that can promote the utility of pregnancy apps. Findings will be used to make recommendations on mobile app designs useful to pregnant women.

Questions

1. Discussion on the use of app technology during pregnancy
 - a. What types of tasks do you get done daily using your pregnancy app?
 - b. Tell me about the positive experiences you have had with the pregnancy app?
 - c. What are the frustrations of using the app?
 - d. What do you think about pregnancy apps?
2. Discussion on mobile app design
 - a. What would you like to see on a pregnancy app?
 - b. When you download an app, what do you look for? Take a piece of paper and jot down three things that are important to you
 - c. If you have to pick only one feature that is most important to you, what would it be? You can select from already mentioned item.
3. Additional information you would like to share about this topic?

Appendix F: Questions for the Online Case Study (Physician)

This is a participatory study with the aim of understanding the perceptions of pregnant women regarding the app technology they use during pregnancy as well as uncovering new ideas and features that can promote the utility of pregnancy apps. Findings will be used to make recommendations on mobile app designs useful to pregnant women.

Questions

1. Discussion on the use of app technology by pregnant women during pregnancy
 - a. What kind of online sources of health information would you recommend to pregnant women?
 - b. Would you recommend health apps to pregnant women? Why?
 - c. What kind of tasks do you think pregnant women get done with pregnancy app?
 - d. Tell me about any positive experiences you have had with pregnant women who used pregnancy app.
 - e. What are the perceived frustrations you think pregnant women may experience using the app?
 - f. What do you think about pregnancy apps?
2. Discussion on mobile app design
 - a. What would you like to see on a pregnancy app?
 - b. What features would you recommend in an app for pregnant women? Take a piece of paper and jot down three things that are important to them.
 - c. If you have to pick only one feature that is most important, what would it be? You can select from already mentioned item.
 - d. Would you be interested in the design of health apps for pregnant women?
3. Additional information you would like to share about this topic?

Appendix G: Pregnant Women Consent Form for Online Case Study**PRINCIPAL INVESTIGATOR:** Olubukola Akanbi**I. INTRODUCTION/PURPOSE**

The goal of this study is to know about the use of mobile phone applications (apps) among pregnant women. This study seeks to understand the usefulness of app design and information contents to pregnant women. I am being asked to participate in this study.

II. PROCEDURES

I am being asked to work together with other pregnant women. I know that the meeting will hold on Zoom. The Zoom meeting will reveal new ideas useful to pregnant women. I also understand that my feedback will be recorded for research purpose. The recording will be transcribed and later destroyed upon the completion of the study.

The online meeting will be about 30 minutes. I am aware that the study needs two different online sessions. I can take part in one or the two sessions. There will be no disclosing of medical records in any form. The meeting will involve discussions on use of mobile technology for meeting the needs of pregnant women. There are no right or wrong answers.

III. CONFIDENTIALITY

All collected information from this study will be stored on researcher's encrypted hard drive. The hard drive will be kept in a locked cabinet. Analysis will be done on passworded protected laptop. Only the researcher and her research team will have access to the recordings.

Please select one:

☐ Yes, I grant the researcher approval to have my video and audio recordings.

☐ No, I do not grant the researcher approval to have my video and audio recordings.

IV. POTENTIAL RISK AND BENEFITS

There is no known risk involved in participating in this study. I am aware that my involvement in this study may not be of benefit to me now. But this study will add to studies on technology and pregnant women.

V. VOLUNTARY PARTICIPATION

My participation is voluntary. I may choose to withdraw from the study at any time. There will be no loss of any benefits for not participating.

VI. COMPENSATION /COSTS

My participation in this study will award me a payment of \$50 per session in the form of gift card.

VII. CONTACT AND QUESTIONS

The principal investigator, Olubukola Akanbi, has offered to and has answered all questions concerning my involvement in this research study. If I have any further questions, I can contact, the principal investigator at 240-528-1043, olubukola.akanbi@ubalt.edu.

For more questions concerning this research study, please contact the UB Institutional Review Board (IRB) at: irb@ubalt.edu 410-837-4057

VIII. SIGNATURE FOR CONSENT

The above-named investigator has answered my questions. I agree to be a research subject in this study.

Name (please print): _____

Signature: _____ Date: _____

Appendix H: Physician Consent Form for Online Case Study**PRINCIPAL INVESTIGATOR:** Olubukola Akanbi**I. INTRODUCTION/PURPOSE**

The goal of this study is to know about the use of mobile phone applications (apps) among pregnant women. This study seeks to understand the usefulness of app design and information contents to pregnant women. I am being asked to participate in this study.

II. PROCEDURES

I am being asked to work together with other physicians. I know that the meeting will hold on Zoom. The Zoom meeting will reveal new ideas that can help pregnant women during pregnancy. I also understand that my feedback will be recorded for research purpose. The recording will be transcribed and later destroyed upon the completion of the study.

The online meeting will be about 45 minutes. There will be no disclosing of medical records in any form. The meeting will involve discussions on use of mobile technology for meeting the needs of pregnant women. There are no right or wrong answers.

III. CONFIDENTIALITY

All collected information from this study will be stored on researcher's encrypted hard drive. The hard drive will be kept in a locked cabinet. Analysis will be done on passworded protected laptop. Only the researcher and her research team will have access to the recordings.

Please select one:

☐ Yes, I grant the researcher approval to have my video and audio recordings.

☐ No, I do not grant the researcher approval to have my video and audio recordings.

IV. POTENTIAL RISK AND BENEFITS

There is no known risk involved in participating in this study. I am aware that my involvement in this study may not be of benefit to me now. But this study will add to studies on technology and pregnant women.

V. VOLUNTARY PARTICIPATION

My participation is voluntary. I may choose to withdraw from the study at any time. There will be no loss of any benefits for not participating.

VI. COMPENSATION /COSTS

My participation in this study will award me a payment of \$100 in the form of gift card.

VII. CONTACT AND QUESTIONS

The principal investigator, Olubukola Akanbi, has offered to and has answered all questions concerning my involvement in this research study. If I have any further questions, I can contact the principal investigator at 240-528-1043, olubukola.akanbi@ubalt.edu.

For more questions concerning this research study, please contact the UB Institutional Review Board (IRB) at: irb@ubalt.edu 410-837-4057

VIII. SIGNATURE FOR CONSENT

The above-named investigator has answered my questions. I agree to be a research subject in this study.

Name (please print): _____

Signature: _____ Date: _____

Appendix I: IRB Approval



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January 15, 2021

Olubukola Akanbi
University of Baltimore
1420 N. Charles Street
Baltimore, MD 21201

RE: **IRB Protocol #242– Approved under Expedited Review**

Dear Olubukola,

This letter serves as official confirmation of the Institutional Review Board's review of your protocol for a study entitled **"Technology and Pregnant women: exploring pregnant women's perception of mobile app design, utility and information credibility."**

The Institutional Review Board reviewed your application via expedited review (Research category #7) and concluded that your protocol poses no more than minimal risk to participants and adequately protects participant confidentiality. As a result, the Institutional Review Board approved your proposal.

Investigators are responsible for reporting in writing to the IRB any changes to the human subject research study, procedures, or personnel. This includes changes to the research design or procedures that could introduce new or increased risks to human subjects and thereby change the nature of the research. In addition, you must report any adverse events or unanticipated problems to the IRB for review.

If you have any questions, please do not hesitate to contact me directly by phone or via email.

As authorized by Dr. Gabriela Wasileski
Chair, Institutional Review Board

A handwritten signature in black ink, appearing to read 'Stefanie Hamberger'.

Stefanie Hamberger
Coordinator, Institutional Review Board

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