

Assessing Fetal Health by Pregnant Women in China Using Mobile Health Application

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Abstract: *This study endeavours to tackle the critical problem of inadequate evidence-based content in mobile health applications (mHealth apps), which adversely impact the accuracy of pregnancy outcomes. To this end, a conceptual framework for evaluating the visualization of fetal health is proposed through a systematic literature review method. This research aims to achieve the following objectives: (1) identify crucial health information that pregnant women in China need to know, (2) determine the best mHealth apps for pregnant women in China, and (3) evaluate the key components for assessing fetal health using mHealth apps among pregnant women in China. The results include fetal health variables, pregnancy complication variables, healthy diet variables, self-care practice variables, and user interface variables. This study contributes to proposing a design of mHealth apps by generating evidence-based visualized fetal assessment methods to foster prenatal attachment and reduce adverse pregnancy outcomes. This study presents a theoretical framework for mHealth apps aimed at pregnant women.*

Keywords: pregnant women, mHealth apps, assess fetal health

1. Introduction

The rapid development of internet technology has led to an increasing number of Chinese women utilizing mobile health applications (mHealth apps) to access health information during pregnancy (Larsson, 2009). However, the information provided by these apps is not always evidence-based, which can result in adverse pregnancy outcomes for Chinese pregnant ladies. Therefore, there is a crucial need to develop evidence-based mHealth apps specially designed for Chinese pregnant women to assess fetal health. Previous research has explored various aspects of health information sought by women during pregnancy, including fetal health (Hadar et al., 2022), pregnancy complications (M. N. Islam, Bouwman, et al., 2020), healthy diet (Wirawan et al., 2023), and self-care practices (Christensen et al., 2003). However, these studies did not address design strategies for assessing fetal health using mHealth apps to prevent adverse pregnancy outcomes and complications. In this paper, we conducted a systematic literature review synthesis process that documented critical health information for

pregnant women in China, identified the best mHealth apps for pregnant women, and evaluated the key components for assessing fetal health using mHealth apps. The outcomes of this research include the conceptual framework of antenatal attachment, the conceptual framework of fetal health visualization, and the conceptual framework of behavior change for fetal health. Additionally, the systematic review generated the conceptual framework of visualizing fetal health.

The main findings of our study suggest that integrating feedback from clinicians and pregnant women in the pre-prototype phase of mHealth apps can help generate evidence-based visualization data for assessing fetal health. Furthermore, antenatal attachment plays a significant role in engaging pregnant women in good healthcare practice and lifestyle behavior changes to reduce the likelihood of pregnancy complications. Finally, a Co-design strategy can not only give the possibilities to getting feedback from pregnant women and clinicians, but also can help overcome transdisciplinary cooperative barriers. This study contributes to the design aspect of mHealth apps, ensuring evidence-based information for pregnant women. It also provides new insights into the relationship between behavior change, antenatal attachment, and fetal health. The research outline consists of a literature review on the subthemes of pregnant women in China, mHealth apps, and fetal health assessment. Figure 1 illustrates the research outline that guides this work, leading to the generation of three conceptual frameworks: Fetal information for prenatal attachment, visualization data for fetal health, and tailored healthy lifestyle for pregnant women. Lastly, we discussed the conceptual framework for visualization fetal health.

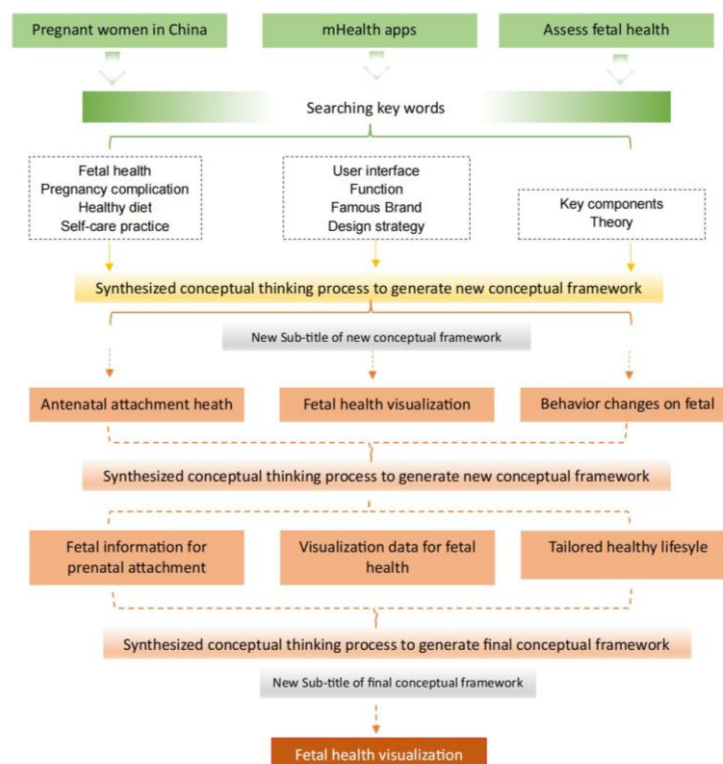


Figure 1: Outline of the Research

2. Methods

The paper’s review of the literature employs the “systematic literature review synthesis process”. This approach is a distinct kind of literature review that establishes the preliminary

conceptualization stage of the theoretical framework for the research through an understanding of pertinent existing literature. Ibrahim’s research question (RQ) construct categorization technique was used to identify three distinct RQ constructs, the “WHO”, “WHAT,” and “HOW”, in order to develop the major research questions for this study (Ibrahim, 2011). The "WHO" is the subject of the study, the "WHAT" is the body of data or expertise required to address the issue, and the "HOW" is the intended effect of the research. This study uses Chinese pregnant women as its “WHAT”, and fetal health assessment as its “HOW”. The “WHAT” and “HOW” components were the ones this study selected to investigate. The following research questions are addressed in this study: (1) What health information is critical to know for pregnant women in China? (2) What is the best mobile health application for pregnant women in China? (3) What are the key components to assess fetal health by pregnant women in China using mobile health application? Pregnant women, mobile health apps, and fetal health were the keywords used in a bibliographic search in the WOS, SCOPUS, and Google Scholar databased based on the research questions and study objectives.

The key points and conclusions of the selected publications’ abstracts, as well as the ways in which their work might further study in the future and any weakness, were later reviewed. The value of each of the 70 abstracts was determined before it was assigned to a particular sub-theme and given a thorough evaluation. The outcomes of this exercise produced synthesis summaries for each major theme, which were then cross-analysed to integrate potential solutions and prioritise the synthesis summaries to analyse the crucial elements of fetal health assessment by pregnant women in China using mHealth apps. Following the guidelines in the Point of Departure (POD) tree diagram and the documentation of the synthesis process using the EAGLE Navigator online system, the major synthesis extracts were produced. The flowchart for the literature review process is shown in Figure 2 of the paper.

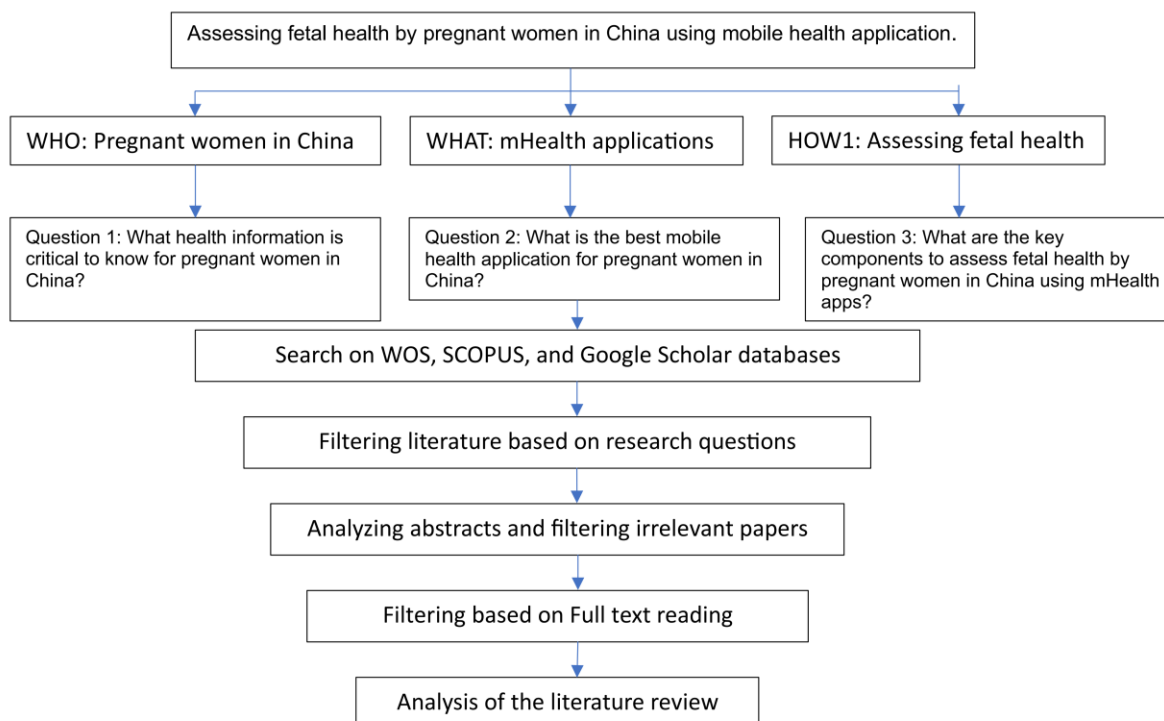


Figure 2: The Workflow of the Systematic Literature Review Synthesis Process Adapted with Permission. Copyright 2018, Ibrahim and Mustafa Kamal

3. Results and Discussions

3.1 What health information is critical to know for pregnant women in China?

The identification and understanding of critical health information are vital for pregnant women in China to ensure a healthy pregnancy and positive maternal and fetal outcomes. Extensive research conducted by Costa et al., (1998), Islam et al., (2020), Khalil et al., (2013), Norbeck & Tilden, (1983) has shed light on the various complications that can arise during pregnancy. These studies highlight the importance of recognizing, preventing, and managing pregnancy complications to mitigate potential risks to both the mother and the developing fetus. Moreover, research conducted by Borge et al., (2017), Doyle et al., (2017); Wirawan et al., (2023) emphasizes the significant of maintain a healthy diet during pregnancy. Understanding the impact of nutrition on maternal and fetal health is essential for promoting optimal growth and development. Additionally, self-care practices during pregnancy play a crucial role in ensuring the well-being of pregnant women. The research by Christensen et al., (2003) underscores the importance of self-care practices, including proper prenatal care, stress management, and lifestyle adjustments, to promote maternal health and reduce potential risks. This study aims to comprehensively analyse the variables associated with each of these health information domains and subsequently explore the critical health information that pregnant women in China need to be aware of.

3.1.1 Fetal Health

Fetal development and its associated outcomes during pregnancy have garnered significant attention among researchers. Scaioli et al., (2015) highlighted the importance of understanding fetal health, as it remains a highly searched topic by pregnant women. Furthermore, Farrant & Heazell, (2016) reveal a concerning statistic that 46%-50% of women experience decreased fetal movements and abnormal fetal status before a diagnosis of stillbirth. This highlights the criticality of focusing on fetal health as a primary research area.

One influential factor in promoting healthy behaviours during pregnancy is maternal-fetal attachment (MFA), which encompasses the interactions and emotional connection between women and their unborn children (Alhusen et al., 2012). They emphasized that lower MFA levels are associated with reduced engagement in healthcare practices during pregnancy and a higher likelihood of adverse outcomes. However, their study primarily focused on the effects of MFA on the fetus, leaving room for improvement by proposing strategies to enhance MFA. Therefore, building upon Alhusen et al., (2012) findings, this study aims to introduce fetal health visualization data as a means to facilitate interactive experiences between pregnant women and their fetus, ultimately enhancing MFA and mitigating negative pregnancy outcomes. In addition to MFA, the level of physical activity in pregnant women has been identified as a factor activity in the second trimester can have protective effects on birth weight, preterm birth, and intrauterine growth restriction. Conversely, Dave highlights the increased likelihood of fetal macrosomia resulting from engaging in heavy work during pregnancy. While Dave's research provides valuable insights on the duration and appropriate levels of physical activity during pregnancy, it falls short in addressing healthcare practices for pregnant women. Hence, this study will focus on planning and guiding physical activity during pregnancy to reduce the negative impact of inappropriate physical activity on fetal health.

Nutrition during pregnancy is widely recognized as a crucial factor affecting fetal development, with nutrients transmitted to the fetus through the placenta (Vahter, 2009). Various studies support the notion that inadequate nutritional supply during fetal development can affect physical health and cognitive abilities in adulthood. While these authors highlighted the link

between maternal nutrition and fetal health, they were not focus on addressing strategies for guiding pregnant women in achieving a nutritious diet. Therefore, this study will focus on evidence-based interventions, providing pregnant women with nutritional information to foster healthy dietary practices and promote optimal fetal development. Apart from the variables discussed thus far, factors such as early maternal age(Berg & J, 1981), primiparity, unwanted pregnancy(M. N. Islam, Bouwman, et al., 2020), and living in slum areas(M. N. M. N. I. Islam, Islam, et al., 2020) can significantly impact fetal health. However, the authors mentioned above predominantly focus on the negative influences of these variables on fetal health, neglecting the need for guidance and support to protect the healthcare behaviours of pregnant women. therefore, this research will integrate these variables into evidence-baased health interventions for pregnant women, aiming to establish prenatal attachment and encourage heathy behaviours to reduce adverse outcomes and low birth weight.

3.1.2 Pregnant Complication

Complications during pregnancy can have detrimental effects on the health of both the mother and the fetus. Lyall et al., (2012) pointed out the association between pregnancy complications and conditions such as Autism and Asperger's syndrome. Several researchers have investigated various variables related to pregnancy complications, including high thyroid levels(Allahem & Sampalli, 2022) and excessive gestational weight gain(Walker & Kang, 2021) which contribute to adverse pregnancy outcomes. Levin & Defrank, (1988) has suggested that life changes and anxiety can increase the risk of premature birth and prenatal complications in pregnant women. additionally, advanced maternal age (defined as ≥ 40 years)(Khalil et al., 2013) and younger maternal age (less than 18 years)(M. N. Islam, Karim, et al., 2020) are associated with a higher incidence of adverse gestational weight gain consultation for overweight pregnant women, focusing on setting specific, measurable, attainable, realistic, and trackable behavioral goals in line with established guidelines. This approach assists pregnant women with obesity in monitoring their overall health. While Walker's (2021) points are supported by this research, his focus remains limited to health interventions for overweight pregnant women and neglecting other pregnancy complications.

Therefore, our research aims to broaden the scope by assisting pregnant women in translating health goals into practical actions in their daily lives, with the ultimate goal of reducing the likelihood of pregnancy complications. This will be achieved through the provision of health counseling, empowering pregnant women to set individualized, achievable, and traceable behavioral goals.

3.1.3 Healthy Diet

The concept of a "healthy diet" during pregnancy encompasses various factors that contribute to maternal and fetal well-being. Researchers have explored different variables related to healthy diet for pregnant women, aiming to understand their impact on maternal health status and pregnancy outcomes. Wirawan et al., (2023) observed a lack of research on maternal and child nutrition-related morbidity in developing countries. It is widely acknowledged that the nutrition diet during pregnancy plays a crucial role in the long-term health of both the mother and the fetus(Bland et al., 2020). However, Borge et al., (2017) noted that although there is a small positive association between better maternal diet quality during pregnancy and child neurodevelopment, more comprehensive research is needed. Similarly, Savage et al., (2018) highlighted a strong association between maternal diet during pregnancy and the infant's microbiome, emphasizing the importance of nutrition for early development. Hrolfsdottir et al., (2016) pointed out that a high intake of animal protein is associated with higher concentrations of inflammatory factors, indicting the potential impact of dietary choices on maternal health.

Regarding healthy diet variables, Nash et al., (2013) concluded that food environment does not appear to have a significant influence on diet quality during pregnancy. Doyle et al., (2017) identified that pregnancy women who are young, have a low education level, or do not adhere to general health advice are at a higher risk of inadequate dietary intake.

Our study supports the findings of the aforementioned research as they all emphasize the relationship between a healthy diet and maternal health status. However, there is limited research on how to effectively modify pregnant women's healthy behaviors through interventions targeting their perception of nutritious diet. In summary, while existing research underscores the importance of a healthy diet during pregnancy and its impact on maternal and child health, further investigation is needed to develop effective interventions that can effectively influence pregnant women's dietary choices. Therefore, our study aims to fill this gap by integrating nutrition interventions into the promotion of healthy behavioral changes among young, low-educated pregnant women in China.

3.1.4 Self-care Practice

Self-care practice variables for pregnant women involve a range of behaviours and activities aimed at promoting their physical and mental well-being during pregnancy. Large number of scholars did research on the issue. The study conducted by Aboulkhair Farag et al., (2022) suggests that women who maintain their health during pregnancy and postpartum are more likely to have improved delivery outcomes and long-term health. However, existing research predominantly focuses on self-care practices during pregnancy, types of care services, and interventions related to care service courses. Boonpongmanee et al., (2003) the potential of learned resourcefulness in reducing depression and promoting prenatal self-care practices among pregnant Thai women. Bamanikar & Kee, (2013) emphasizes the importance of intensive dental health education in improving oral and dental health, leading to positive pregnancy outcomes. Moawed, (2014) stresses the crucial role of midwives in enhancing perinatal outcomes and maternal dental health through risk factor screening and education on prevention strategies. Aboulkhair Farag et al., (2022) demonstrates that educational sessions positively impact knowledge, self-care practices, and perception of proper weight gain during pregnancy among advanced age pregnant women. Moreover, Omidvar et al. (2018) propose the need to address psychological risk factors during pregnancy, including variables such as home and social support, social interaction needs and entertainment, and pregnancy ecology, which significantly influence pregnant women's psychological well-being. These findings align with current research; however, the studies primarily focus on self-care practices without specific attention to pregnant women in China.

While a significant body of research has explored self-care practice variables for pregnant women, the existing literature tends to focus on various aspects such as self-care practices during pregnancy, types of care services, and interventions related to care service courses. Studies conducted by Aboulkhair Farag et al. (2022), Boonpongmanee, Zauszniewski, and Morris (2003), Bamanikar (2013), Moawed (2014), Aboulkhair (2022), and Omidvar et al. (2018) have shed light on different dimensions of self-care practices and their effects on pregnant women's well-being and health outcomes. However, the majority of these studies have not specifically examined self-care practices among pregnant women in China. Therefore, there is a need to explore self-care practices within the Chinese context, considering the unique cultural, social, and healthcare factors that may influence the well-being of pregnant women in China. By addressing this research gap, the current study aims to contribute to the understanding of self-care practices and their implications for the physical and mental well-being of pregnant women in China.

3.1.5 The process of Conceptual Framework Formation

The results shows that the critical health information to know for women which evidenced by experts during pregnancy could reduce the pregnant complications and have effect on establish antenatal attachment. In summing up, this study proposes to focus on the effects of experts evidenced health information in terms of physical activity, body changes and tracking nutrients, fetal development, and psychological health on pregnancy outcomes. Thus, the point of departure (POD) is that by providing health information evidenced by experts' opinions: physical activity, body changes and tracking, nutrients, fetal development, and psychological health to meet various phases of pregnancy, achieve a tailored, healthy lifestyle, establish antenatal attachment, and reduce pregnancy complications. Figure 3 is the conceptual framework for the critical information to know for pregnant women in China to reduce pregnancy complications.

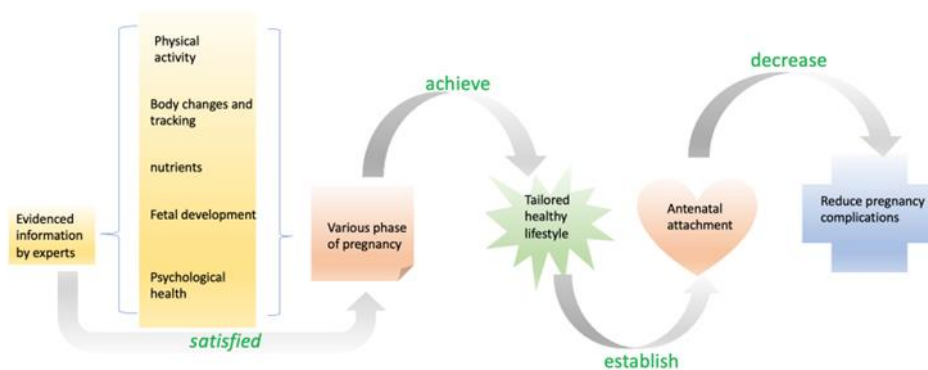


Figure 3: Proposed conceptual framework for Antenatal attachment health

3.2 What is the best mobile health application for pregnant women in China? Can they help to decrease the barriers of pregnant women using mobile health application?

The increasing reliance of Chinese women on mobile health applications during pregnancy to access health information is a notable trend in the face of advancing in internet technology (Larsson, 2009). The user interface of these mHealth apps plays a crucial role in shaping user experience and satisfaction, making it a significant factor to consider (Alsswey et al., 2018). Additionally, the functionality offered by these apps is a key determinant of their appeal to users. Notably, well-known brands of mobile health apps in China hold a high reputation among pregnant women. Furthermore, adopting a co-design strategy can enhance the quality and reliability of evidenced information provided by mobile health apps for pregnant women (Marent et al., 2018). This section aims to examine the variables related to user interface, functionality, brand reputation, and design strategy in the context of mobile health apps for pregnant women in China.

3.2.1 User interface

App adoption and maintenance are significantly impacted by the user interface and experience of mobile apps, which affect users' perceptions and satisfaction (Vlahu-Gjorgievska et al., 2023). The user interface is the medium through which a large number of interactions that affect the user experience occur (Samrgandi, 2021). Peters et al., (2018) highlighted an attractive user interface with creative and innovative design attributes, beautiful background graphics, colors and social interactive characteristics will increase user engagement, enjoyment, and user experience. Peter et al., (2018) research is supported by our research. However, the author did not mention pregnant women's user preference on mobile user interface. Alsswey et al., (2018) stated that the behavioral intention to utilize the mHealth apps

user interface was significantly positively influenced by perceived ease of use and attitude toward use. Our research agrees with Alsswey et al., (2018) viewpoints. However, the author only mentioned the Arab elderly users. Thus, this study will focus on the positive significant effects of perceived ease of use and attitude on the behavioral intention of pregnant women to use the user interface of mHealth apps.

3.2.2 Function of mHealth apps

In recent years, several studies have focused on the design and implementation of mHealth apps tailored for pregnant women. These studies aim to improve various aspects of maternal health, including nutrition, mental well-being, physical activity, and disease management. This section review examines the findings of multiple studies conducted in this domain and highlights their contributions and limitations.

The studies conducted by Choi, (2019), Green et al., (2022), Kodama & Takaki, (2022), Kumar et al., (2022), Park et al., (2022); Sandborg, (2022); Yang, (2020), Zahmatkeshan et al., (2021) provide critical insights into the use and impact of mHealth apps for pregnant women. Yang (2020) highlights the positive reception of a mobile food app among pregnant women, emphasizing its ability to connect healthcare professionals and provide convenient access to evidence-based pregnancy information and nutritionist opinions. In terms of mental health for pregnant women during pregnancy, Kumar et al. (2022), Green et al. (2022), and Kodama et al. (2023) proposed their research for alleviating psychological distress through evidenced-based interventions including smartphone apps in improving sleep, anxiety, and stress. Additionally, Choi et al. (2016) and Sandborg et al. (2021) highlighted the potential benefits of professional physical activity through mobile health apps during pregnancy can support healthy habits and mitigate excessive gestational weight gain. Finally, Zahmatkeshan et al. (2021) and Park et al. (2022) underscored the potential of mHealth apps interventions to enhance pregnancy outcomes in gestational diabetes mellitus patients.

While these studies offer valuable contributions, it is important to acknowledge their limited scope of focus. Yang (2020) and Kodama and Takaki (2023) solely concentrate on the nutritional status of pregnant women, overlooking other relevant factors. Similarly, Choi et al. (2016) and Kodama and Takaki (2023) limit their research to pregnant women in the United States, specifically focusing on maternal mental and physical activity health information. Zahmatkeshan et al. (2021) narrow down their study to pregnant women with gestational diabetes, but only in Iran. Park et al. (2022) and Sandborg et al. (2021) also concentrate on pregnant women with gestational diabetes and healthy, but their research is confined to specific mobile health applications. As well as Green et al. (2022) only contribute to the certain application which were called "Calm".

To address these limitations and further contribute to the field, this study will concentrate on mobile health applications for pregnant women, aiming to provide evidence-based pregnancy information, professionals' opinions, and convenient delivery of health information, building upon the findings of Yang (2020). According to Kumar et al. (2022), Kodama and Takaki (2023), and Green et al. (2022) our research will focus on reducing the risk of mental health deterioration among pregnant women in China through providing mental health services and improving sleeping quality using mobile health apps. According to Zahmatkeshan et al. (2021) and Park et al. (2022), the research will focus on the measures including various content elements (success stories, a message board, a section for frequently asked questions and answers, and links to gestational diabetes education centers) for decreasing the bad outcomes of pregnant women with gestational diabetes. Finally, inspired by Sandborg et al. (2021), the

study will examine the effectiveness of a mobile health app tailored for Chinese pregnant women, aiming to mitigate excessive gestational weight gain by increasing knowledge, fostering awareness, and promoting healthy habits throughout pregnancy.

In summarize, our research will focus on the approach to engage co-creativity among stakeholders on developing evidence-based pregnancy apps that incorporate behavior change techniques for good impact on pregnancy outcomes.

3.2.3 Famous Brand

This critical review examines the research conducted by Andy, (2017) and Ji, (2023) on mHealth apps for pregnant women in China. While these studies provide valuable insights into the usage and features of various health apps, they also have limitations in terms of scope and focus. This review aims to highlights these limitations and propose areas for future research to address the gaps.

Andy (2017) conducted a statistical and comparative analysis of 40 health industry app services in the market, identifying six commonly used health services. However, the study did not specifically mention pregnant women, overlooking their unique needs and preferences. As a result, further research is required to explore the most frequently used mobile health apps for pregnant women in China. Tu Dou, (2018) identified several commonly used pregnancy-related mobile apps among Chinese women, such as Baby Tree, Pregnancy Housekeeper, Meiyu Pregnancy, Cui Yutao Nursery, Nian Gao Mama Nursery, and Himalayan. While these findings provide insights into popular apps, the study does not delve into the functionality or effectiveness of these apps in supporting pregnant women's health. Ji, (2023) investigated the use of mobile health apps for pregnant women in China and highlighted specific apps that offer practical information, stress reduction programs, fetal movement counters, and online communities for sharing experiences. However, the study's focus on app content neglects the importance of visualization data records, which can enhance the usability and effectiveness of mobile health apps for pregnant women. While the aforementioned studies provide critical comments on mobile health apps in China, they fail to fully explore the potential of visualization data records. Future research should prioritize the inclusion of visualization data to improve the delivery of pregnancy health information, tailor app design to individual needs, monitor fetal movement, and facilitate meaningful experiences sharing among users.

In conclusion, the studies conducted by Andy, (2017) and Ji, (2023) contribute to the understanding of mobile health apps for pregnant women in China. However, their limitations in terms of overlooking pregnant women's needs and neglecting the importance of visualization data records call for further research. Future studies should focus on identifying and analyzing mobile health apps specifically tailored to pregnant women, incorporating visualization data for enhanced usability and effectiveness in promoting maternal health and well-being.

3.2.4 Design Strategy

Refer to design strategy of mobile health apps, much research uses Co-design, user centered design, and participatory design in developing mobile health apps.

Rathnayake et al., (2021) conducted a Co-design of an mHealth apps for family caregivers of people with dementia to address functional disability care needs. Keshavjee et al., (2022) conducted research on how to motivate users continued use of mHealth apps. Dederichs et al., (2022) conducted a case study in piloting an innovative concept of e-Mental health and mHealth workshops with medical students using a participator co-design approach and app

prototyping. Rathnayake et al., (2021) emphasized that the co-design process made sure that end users' actual experiences as well as the insights and knowledge of significant stakeholders were incorporated into the creation of the application prototype. Keshavjee et al., (2022) highlighted that the following perspectives could motivate continued use of mHealth apps: 1) disease-specific needs, 2) non-disease specific needs, 3) behavioural theoretical aspects of app usage and 4) app-intrinsic usage motivators. Dederichs et al. (2022) highlighted that Co-design workshop was welcomed among medicine students to propose kinds of ideas for developing mHealth apps. However, their research did not mention pregnant women user preference and demands. Thus, though our research agrees with the above viewpoints, we will use co-design to collect ideas and demands from stakeholders of developing mobile health apps, employing a participatory co-design approach formulating app prototyping, and incorporate new functions into mHealth apps to maintain users' ongoing engagement.

Overall, while these previous studies offer valuable insights in their respective areas, they fail to adequately address the needs of pregnant women in the context of mHealth apps. Our research aims to bridge this gap by focusing on pregnant women's requirements and employing co-design design approaches to develop tailored and effective mHealth solutions for this specific user group.

3.2.5 The Process of Conceptual Framework Formation

According to Ramli et al., (2018), it was found that employing collaboration strategies allows expert users to effectively utilized their professional expertise and knowledge during design collaborations. Thus, Co-design could integrate the feedback from clinicians and pregnant women make the mHealth apps evidenced and allow for personalized and targeted interventions to support users in managing pregnant women's health conditions effectively. The aim of this research is to evaluate the best design strategy of mHealth apps for pregnant women to formulate visualized health data record towards decrease using barriers for pregnant women. this study found that mobile health apps which involve users' preference could be appreciated by the users. Additionally, user centered could involve users' wants and needs to improve the user interactive between users and applications. Besides, Co-design gives the change to integrate feedback from clinicians and users into the development of mHealth apps especially in the pre-prototype phase. However, the user preference and user interaction effectiveness could lead evidence-based visualization records and reduce the using barriers for pregnant women. To summarize, the good design strategy for mHealth apps should help to get feedback from users (pregnant women) and clinicians to generate evidence-based visualization records and help users to formulate tailored health lifestyle. As can be seen from Figure 4, the idea proposes that integrating co-design with user-centered design into the pre-prototype phase of the development process towards getting feedback from pregnant women and clinicians to improve the UI interaction effectiveness to lead evidence-based visualization data records to decrease the using barriers for pregnant women.

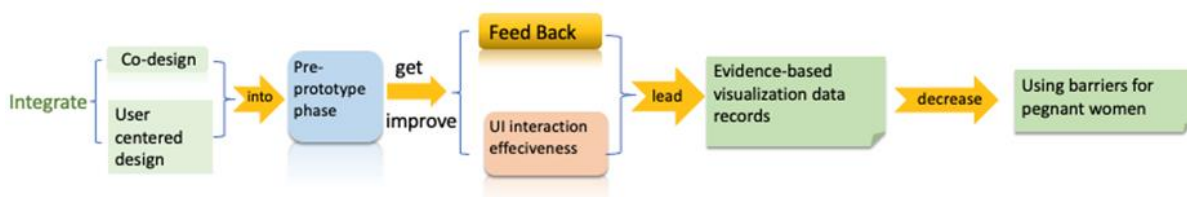


Figure 4: Proposed Conceptual Framework for Fetal Health Visualization Data

3.3 What are the key components to assess fetal health by pregnant women in China using mobile health application? Can they lead good effect on fetal health?

The key components of mHealth apps for pregnant women revolve around fetal surveillance and assessing fetal health to reduce fetal loss, perinatal morbidity, and maternal distress. Numerous scholars have conducted research on factors influencing fetal health and approaches for assessing it.

3.3.1 Key components for mHealth apps of pregnant women in China to assess fetal health

Liu et al., (2022) focused on the impact of the initial COVID-19 outbreak during the first trimester of pregnancy in Wuxi, China, while Clapp, (1991) reviewed the influence of maternal exercise on the well-being of the human embryo and fetus. Hadar, Wolff, Tenenbaum-Gavish, Eisner & Shmueli (2022) explored the use of mobile self-operated home ultrasound systems for remote fetal assessment, and Musgrave, Kizirian, Homer & Gordon (2022) conducted a systematic search of mobile phone apps in Australia aimed at improving pregnancy outcomes. Hussain, Smith & Yee (2020) did a systematic study of mobile phone-based behaviour interventions for pregnant women in high-income nations to increase maternal and foetal health, while Mazumdar, Choudhary & Swetapadma (2017) developed an innovative method for fetal health monitoring using cardiocography measurements and artificial neural networks. Our research aligns with the findings of Hussain, Smith, and Yee et al., acknowledging the importance of assessing fetal health through mHealth apps. In line with Liu et al. (2022), our study focuses on identifying factors that impact pregnancy outcomes among Chinese women, aiming to reduce the rates of premature delivery and low birth weight. Building on the recommendations of Musgrave et al. (2022) and Clapp (1991), we propose the use of mobile health apps to facilitate regular exercise and promote healthy behavior changes during pregnancy for optimal fetal health. Moreover, the research by Hadar et al. (2022) and Mazumdar et al. (2017) emphasizes the use of mobile health apps for remote fetal assessment, enabling monitoring of fetal heart activity, amniotic fluid volume, fetal tone, fetal body, and breathing movements. Taking inspiration from Hussain et al. (2020), our study advocates for mobile phone-based health behavior interventions to cultivate positive beliefs, behaviors, and health outcomes among pregnant women in China.

In summary, this sub-theme centers on pregnant women in China utilizing mobile health apps to assess fetal health indicators (such as fetal heart activity, amniotic fluid volume, fetal tone, fetal body, and breathing movements) to make informed behavior changes (such as exercise and diet) for the well-being of their unborn child. In conclusion, it discusses the use of mobile health apps to assess fetal health indicators and promote healthy behaviors among pregnant women. The research specifically focuses on identifying factors that impact pregnancy outcomes among Chinese women and proposes the use of mobile health apps to facilitate regular exercise and promote healthy behavior changes. Additionally, it advocates for mobile phone-based health behavior interventions to cultivate positive beliefs, behaviors, and health outcomes among pregnant women in China. Overall, the sub-theme centers on the importance of utilizing mobile health apps for fetal health monitoring and promoting healthy behaviors during pregnancy.

3.3.2 The Process of Conceptual Framework Formation

In this section, the aim of this research paper is to analyze the key components to assess fetal health for using mHealth apps of pregnant women in China (see Figure 5). The study finds that the key components including fetal heart activity, amniotic fluid volume, fetal tone, fetal body, and breathing movements, and pregnant women using mHealth apps to assess fetal status to lead good health for fetus. In addition, pregnant women can use the mHealth apps to change

their behavior to formulate health lifestyle towards fetal health. Based on the above results, this study concludes that pregnant women in China can avoid higher rates of premature delivery and low birth weight out by using mobile health apps to assess fetus status which will make them change their behavior towards improving fetal health.

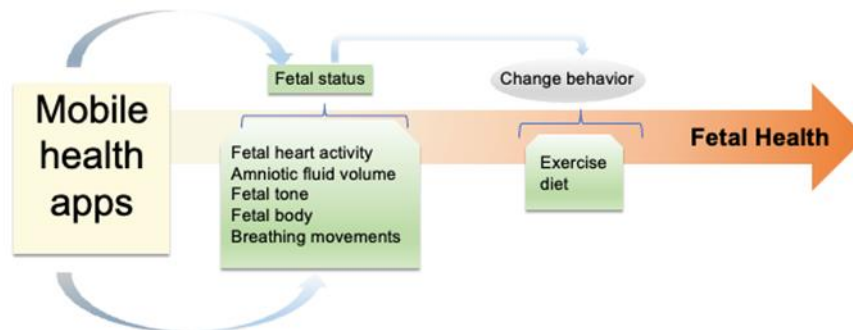


Figure 5: Proposed Conceptual Framework for Behavior Change on Fetal Health

4. Discussion

mHealth apps have become a popular resource for women during pregnancy, allowing them to access a plethora of health information. However, it is important to critically examine the quality and reliability of the information provided. These apps claim to cover a wide range of topics, including fetal health, pregnancy complications, self-care practices, and healthy diets. The purported goal of these searches is to assess fetal health, promote self-care, and prevent adverse birth outcomes and excessive weight gain. Unfortunately, the information available through these apps often lacks the necessary expertise and evidence-based foundation. Expert-backed information, encompassing areas such as physical activity, body changes and tracking, nutrition, fetal development, and psychological health, is crucial for pregnant women. Although pregnant women in China may express appreciation for information endorsed by experts, it is imperative to question whether this information truly contributes to the formulation of tailored and healthy lifestyles or the reduction of pregnancy complications. Blindly relying on these apps may result in a false sense of security and inadequate decision-making during a critical period of pregnancy.

mHealth apps as a convenient tool for women during pregnancy in China to use in circumstances of lacking pregnancy experience. However, the efficiency is not always making sense. The study in the design perspective to exploratory the design strategy of mHealth apps for pregnant women to make it evidenced and reliability. The study found that Co-design with user-centered design is the most often used design strategy in the past research. User centered design strategy can give the chance for pregnant women to participate in the pre-prototype phase of the mHealth apps. The co-design strategy could get clinicians evidenced health information into the development phase of mHealth apps. Through this way not only to improve the interaction between pregnant women and mobile health apps, but also can reduce the interdisciplinary cooperative barriers. Finally, to generate evidence-based visualization data records to help pregnant women to assess fetal health.

This study document the critical health information to know for pregnant women in China, and identify the best mHealth apps for pregnant women, and the components for pregnant women assess fetal health through mHealth apps. This study divided its analysis and discussion into six steps to better meet the demands of the research. The research sequence was created with the intention of evaluating the benefits and drawbacks of various perspective combinations and

suggesting the best course of action for the bigger investigation. With reference to the POD Tree Diagram in Figure 6, this part describes how to further synthesize the preliminary findings to produce a potential theoretical proposition for further research.



Figure 6: Point of departure (POD) Tree Diagram for “Assessing Fetal Health for Pregnant Women by Using mHealth Apps” Ibrahim, (2011) Copyright 2018, Ibrahim and Mustafa Kamal

Through the research and discussion in section 3.1 of the study, this study conducted that analyzing the health information which is critical to know for pregnant women in China, such as physical activity, body changes and tracking, nutrients, fetal development, and psychological health which was evidenced by experts to meet various phases of pregnancy, achieve a tailored, healthy lifestyle, to establish antenatal attachment, through this way can decrease the pregnancy complication(see POD1). In section 3.2, this study conducted that the design strategy for the best mobile health application for pregnant women in China, such as Co-design and user centered design, they could provide new sights into the existing issue that the current mobile health application lacking end-users’ preference. To integrate pregnant women and clinicians’ feedback into the pre-prototype phase of the development process to improve the user interface interaction effectiveness to lead the evidence -based visualization data records to decrease the barriers of pregnant women using mHealth apps (see POD2). The combination of POD1 and POD2 revealed that co-design and user-centered design may obtain input from expectant women and medical professionals. This feedback can be integrated into the design process of mobile health apps to visualize the fetal clinical information to improve prenatal attachment and reduce pregnancy complications (see POD4).

In section 3.3, this study discovered that the key components to assess fetal health by pregnant women in China using mobile health application are fetal heart activity, amniotic fluid volume, fetal tone, fetal body, and breathing movements. Through using mobile health apps to assess fetal health and promote healthy behaviors among pregnant women. Therefore, this section concludes that pregnant women in China can avoid higher rates of premature delivery and low birth weight by using mobile health apps to assess fetus status which will make them change their behavior towards improving fetal health (see POD3). After combining POD2 and POD3, this study discovered that to integrate feedback from pregnant women and doctors into the design phase pre-prototype of mobile health apps can generate evidence-based visualization

data to lead good fetal health (see POD5). After synthesizing POD3 and POD1, this study discovered that by providing pregnant women with expert evidenced health information from mHealth apps to achieve tailored healthy lifestyles and reduce pregnancy complications towards avoiding adverse pregnancy outcomes (see POD6).

Going through the POD Tree Diagram, after synthesizing POD4 and POD5, this study found that through generating evidence-based visualization data to establish prenatal attachment to change behavior towards tailored healthy lifestyle to reduce pregnancy complications (see POD7). After synthesizing POD5 and POD6, this study discovered that by providing tailored healthy lifestyle for pregnant women to reduce pregnancy complications and adverse outcomes (see POD8)(Luo et al., 2022).

As the conclusion of this synthesis exercise between POD7 and POD8, this study found that by integrating feedback from clinicians and pregnant women into the mHealth apps' pre-prototype phase, evidence-based fetal health assessing visualization data will be generated to establish prenatal attachment to change behavior towards tailored healthy lifestyle to reduce pregnancy complications and adverse outcomes (see POD9). Based on POD9, this study posits that a potential solution can be achieved by creating an integrated process for visualization fetal health to establish antenatal attachment and change behavior to lead tailored healthy lifestyle and decrease pregnancy complications and adverse outcomes (see Figure 7).

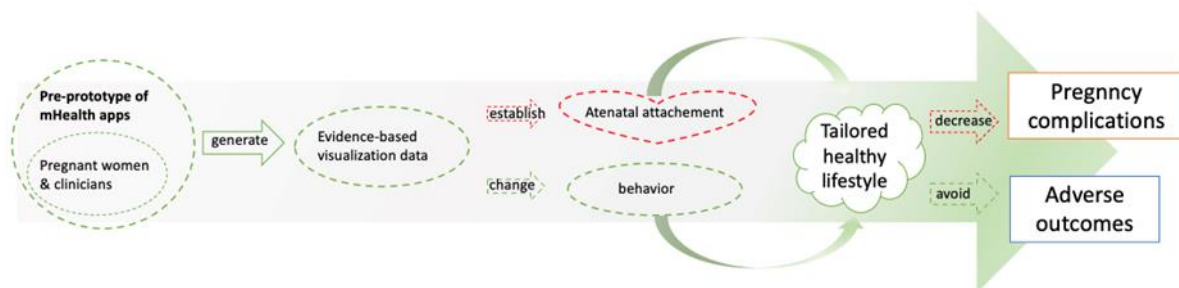


Figure 7: Proposed Conceptual Framework of Visualization Fetal health for Avoiding Adverse Outcomes

5. Conclusion

This paper aims to evaluate the key components to assess fetal health by pregnant women in China using mobile health application. Results found by involving pregnant women and clinicians in the mHealth apps pre-prototype phase towards generating evidence-based fetal development visualization data to establish a prenatal attachment to change pregnant women's behavior to avoid pregnancy complication to improve fetal health. Evidenced health information is highly appreciated by pregnant women. They also preferred to get visualized fetal status health information from mHealth apps because it could provide chances for them to establish good prenatal attachment. Additionally, good antenatal attachment could guide pregnant women healthcare practice towards health behavior change to lead good pregnancy outcomes. This study also found that co-design and user centered design strategy which was applied into the early design phase of mHealth apps could reduce the interdisciplinary cooperative barriers between pregnant women and clinicians and generating evidenced health information for pregnant women. This study contributes to developing a framework for visualization fetal health in mHealth apps and bring new horizon in pregnant women behavior change through mHealth apps evidence-based interventions. What's more, the new sights on prenatal attachment with behavior change will be potential creative. Further studies need to be done in terms of behavior change theory of women during pregnancy and co-design strategy in developing mHealth apps for pregnant women to visualize fetal development data towards

avoiding adverse pregnancy outcomes.

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