DEVELOPMENT AND EVALUATION OF THE EFFECTIVENESS OF A MOBILE APPLICATION MODULE ON MEDICATION ADHERENCE, MEDICINE BELIEFS, HEALTH LITERACY AND BLOOD PRESSURE FOR OLDER ADULT STROKE SURVIVORS IN CHINA

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LIST OF SYMBOLS

$\triangle$	Margin error
$\leq$	Less than or equal to
$\geq$	More than or equal to
α	level of significance
$\sim$	Tilde
σ	Standard deviation of variables
δ	Detectable difference in pop means
m	Ratio between control and intervention group

LIST OF ABBREVIATIONS

AF	Atrial fibrillation
AHA	American Heart Association
ANOVA	Analysis of variance
BMI	Body Mass Index
BMQ	Beliefs about Medicines Questionnaire
BP	Blood pressure
CI	Confidence intervals
CONSORT	Consolidated Standards of Reporting Trials
CVD	Cardiovascular disease
DALYs	Disability-adjusted life-years
DBP	Diastolic blood pressure
e-MAIMOASS	Mobile application intervention module among older adults stroke survivors
ES	Effect size
GMAS	General medication adherence scale
GMAS-C	Chinese version of the general medication adherence scale
HBM	Health Belief model
HCP	Healthcare provider
HREC	Human Research Ethics Committee
ICH	Intracerebral haemorrhage
ISRCTN	International Standard Randomized Controlled Trial Number
IS	Ischemic stroke
JEPeM-USM	Jawatankuasa Etika Penyilidikan Manusia Universiti Sains Malaysia
KMO	Kaiser-Meyer-Olkin
mHealth	Mobile health
mRS	Modified Rankin Scale
NGT	Nominal group technique
OR	Odds ratio
PA	Physical activity
PEOU	Perceived ease of use

PRISMA	Preferred Reporting Items for Systematic Reviews and Meta-Analyses
PU	Perceived usefulness
RCT	Randomised Controlled Trial
ROC	Receiver operating curve
SAH	Subarachnoid haemorrhage
SBP	Systolic blood pressure
SE	Self-efficacy
SMS	Short Messaging Service
SPSS	Statistical Program for Social Sciences
SUS	System Usability Scale
TAM	Technology Acceptance model
UK	United Kingdom
USA	United States
UMUX	Usability Metric for User Experience
VIF	Variance inflation factor
WHO	World Health Organization

LIST OF APPENDICES

PEMBANGUNAN DAN PENILAIAN KEBERKESANAN MODUL APLIKASI MUDAH ALIH TERHADAP PEMATUHAN UBATAN, KEPERCAYAAN PERUBATAN, LITERASI KESIHATAN, DAN TEKANAN DARAH UNTUK PEMANDIRI STROK WARGA EMAS DI CHINA

ABSTRAK

Penjagaan strok yang bertambah baik telah mengakibatkan peningkatan ketara sebanyak 84% dalam bilangan pesakit strok di seluruh dunia dalam dua dekad yang lalu. Seiring dengan penuaan masyarakat, lebih banyak penyelidikan diperlukan untuk pesakit strok yang lebih tua. Pandemik COVID-19 telah mewujudkan keperluan untuk membangunkan aplikasi mudah alih kesihatan (mHealth). Walau bagaimanapun, data mengenai keberkesanan inovasi mHealth dalam bidang strok adalah terhad. Kajian ini bertujuan untuk membangunkan dan menilai keberkesanan aplikasi mudah alih bagi pemandiri strok warga emas dalam mematuhi ubat, kepercayaan terhadap ubat, literasi kesihatan mengenai strok, dan tekanan darah (BP) di Chenzhou, China. Kajian ini dibahagikan kepada tiga fasa: mengenal pasti ketidakpatuhan ubat dan faktor-faktornya (Fasa 1), membangunkan aplikasi mudah alih (Fasa 2), dan menilai kegunaan dan keberkesanannya bagi pesakit strok warga emas (Fasa 3). Fasa 1 adalah kajian keratan rentas yang melibatkan 402 pemandiri strok warga emas dari tiga hospital peringkat tertiari di China. Dalam Fasa 2, modul intervensi aplikasi mudah alih (e-MAIMOASS) telah dibangunkan dan divalidasi melalui ujian Alpha dan Beta. Dalam Fasa 3, 82 pemandiri strok warga emas secara rawak ditempatkan sama ada dalam kumpulan e-MAIMOASS (n=41) atau kumpulan kawalan (n=41). Semua subjek harus melaporkan kepatuhan ubat dan BP pada peringkat awal, susulan 1 bulan

dan 3-bulan. Kepercayaan ubatan dan literasi kesihatan dinilai pada peringkat awal dan tiga bulan selepas intervensi. Dalam Fasa 1, 61.4% peserta menunjukkan ketidakpatuhan ubat. Berbanding dengan individu yang mempunyai pendidikan rendah atau kurang, mereka yang mempunyai tahap pendidikan sekolah rendah mempunyai peluang ketidakpatuhan pengambilan ubat yang lebih rendah sebanyak 0.450 kali, manakala mereka yang mempunyai tahap pendidikan menengah atau kolej rendah mengalami penurunan sebanyak 0.440 kali. Semakin tinggi jumlah ubat preskripsi yang diambil oleh seseorang individu setiap hari, semakin tinggi kemungkinan ketidakpatuhan pengambilan ubat (OR = 1.315). Hubungan yang signifikan didapati antara ketidakpatuhan ubat dan literasi kesihatan (β = -0.059), skor BMQ Specific-Necessity (β = -0.130), dan skor BMQ Specific-Concerns (OR=1.127). Dalam Fasa 2, e-MAIMOASS yang telah divalidasi dengan lima komponen utama menerima maklum balas positif dan kepuasan pengguna. Dalam Fasa 3, pesakit strok warga emas dengan intervensi menunjukkan peningkatan kepatuhan ubat (p<0.001), penurunan tekanan darah sistolik (SBP) yang signifikan (p=0.009), peningkatan literasi kesihatan (p=0.024), dan skor keperluan BMQ yang lebih baik (p=0.002) berbanding dengan kumpulan kawalan. Skor kegunaan untuk e-MAIMOASS direkodkan dengan purata 70.36 ± 7.05, melebihi ambang Skala Kegunaan Sistem (SUS sebanyak 68. Kesimpulannya, e-MAIMOASS berkesan meningkatkan kepatuhan ubat, kepercayaan ubat, literasi kesihatan mengenai strok, dan BP bagi pesakit strok warga emas. Walau bagaimanapun, lebih banyak kajian perlu dijalankan untuk meningkatkan hasil daripada intervensi yang menjanjikan ini.

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ABSTRACT

Improved stroke care has resulted in a significant 84% increase in global stroke survivors over the past two decades. As society ages, more research is needed for older stroke survivors. The COVID-19 pandemic has spurred the development of mobile health (mHealth). However, the data on the efficacy of the mHealth innovations in stroke is limited. This study aims to develop and evaluate the effectiveness of a mobile application for older adult stroke survivors on medication adherence, medicine beliefs, health literacy on stroke, and blood pressure (BP) in Chenzhou, China. The study was divided into three phases: identifying medication non-adherence and its factors (Phase 1), developing a mobile application (Phase 2), and evaluating its usability and effectiveness for older aadult stroke survivors (Phase 3). Phase 1 was a cross-sectional study that involved 402 older adult stroke survivors from three tertiary hospitals in China. In Phase 2, a mobile application intervention module (e-MAIMOASS) was developed and validated. In phase 3, 82 older adult stroke survivors were randomly allocated to either the e-MAIMOASS group (n=41) or the control group (n=41). All subjects had to report medication adherence and BP at baseline, 1-month, and 3-month follow-ups. Medicine beliefs and health literacy were assessed at baseline and three months post-intervention. In Phase 1, 61.4% of participants exhibited medication non-adherence. Compared to individuals with primary education or less, those with a junior school education level had their odds of medication non-adherence decrease by 0.450

times, while those with a senior secondary or junior college education level experienced a decrease of 0.440 times. The higher the number of prescription medications an individual takes per day, the greater the likelihood of medication non-adherence (OR = 1.315). A significant association was found between medication non-adherence and health literacy (β = -0.059), BMQ Specific-Necessity score (β = -0.130), and BMQ Specific-Concerns score (OR=1.127). In Phase 2, a validated e-MAIMOASS comprising five core components received positive feedback and user satisfaction from Alpha and Beta testing. In Phase 3, older adult stroke survivors with the intervention exhibited enhanced medication adherence (p<0.001), significantly lower systolic BP (SBP) (p=0.009), improved health literacy (p=0.024), and better BMQ necessity scores (p=0.002) compared to the control group. The usability score for e-MAIMOASS was recorded with an average of 70.36 ± 7.05, surpassing the System Usability Scale (SUS) threshold of 68. In conclusion, the e-MAIMOASS effectively improved older adult stroke survivors' medication adherence, medicine beliefs, health literacy on stroke, and BP. However, more studies need to be conducted to improve the outcomes of this promising intervention.

CHAPTER 1

INTRODUCTION

1.1 Background of the Study

Globally, stroke remained the second-leading contributor to death after ischaemic heart disease and ranked as the third leading factor causing disability in adults (Feigin et al., 2021; Kyu et al., 2018; Zhang et al., 2021). In 2019, the global incidence of stroke and prevalent strokes reached 12 million and 101 million, respectively (Feigin et al., 2021). Stroke has been responsible for 143 million disability-adjusted life-years [DALYs], with 6.55 million individuals succumbing to the effects of a stroke (Feigin et al., 2021). It is noticeable that due to the growing population and aging demographics, along with an ongoing high prevalence of risk factors, stroke prevalence is rising globally (Sharrief & Grotta, 2019). Feigin et al. (2021) indicated that should the present trends persist, there would be over 200 million stroke survivors and 25 million new stroke cases by 2050. Additionally, they forecasted approximately 300 million DALYs resulting from stroke and 13 million annual stroke-related deaths.

In China, stroke ranks as the primary cause of death and is associated with the highest DALY loss of any disease (Wu et al., 2019). A previous review estimated that stroke was responsible for nearly 1·1 million deaths per year in the country in 2013, among a global total of 7 million reported in 2013 (Brainin, 2019). In addition, the yearly number of new stroke cases contributes to roughly 25% of the total global incidents of stroke annually (GBD 2019 Diseases and Injuries Collaborators, 2020). Tu et al. (2023) indicated that the estimated overall prevalence of stroke in mainland China was 2.6% in 2020. With inadequately controlled stroke-related risk factors and an aging population, the burden of stroke is increasing in China (Tu & Wang, 2023).

Stroke happens mainly in the older population (Mubin et al., 2022). Khan et al. (2021) studied the National Inpatient Sample database from 2002 to 2017 and concluded that the older group was the largest among 11,381,390 weighted stroke cases. Feigin et al. (2021) noted that age-specific stroke prevalence and incidence rates increased substantially from 1990 to 2019 among those older than 70 years. Moreover, the burden of stroke was mainly derived from the 50–74 years and 75 years or older population (GBD 2019 Diseases and Injuries Collaborators, 2020). Population aging and improved acute management of patients would lead to an increasing number of older people who are living with the effects of stroke. Older patients with stroke experience more significant disability, more hospital readmission, and higher mortality than young (Tsao et al., 2022). Shortly, with the advent of an aging society, there is an objective need for more efforts on research targeting strokes in older.

Stroke survivors have an elevated risk of having a recurrent stroke (Chen et al., 2020; Del Brutto et al., 2019). Approximately 25–30% of all strokes are attributed to recurrent occurrences (Hankey, 2014). The chances of stroke recurrence among survivors within 1, 5, and 9 years of follow-up are 17%, 41%, and 53%, respectively (Chen et al., 2020). A prospective nationwide hospital-based cohort study from China by Tu et al. (2021) demonstrated that the 12-month stroke recurrence rate among survivors was 5.7%. The rates ranged between 2.5% (95% CI 1.7–3.3%) for subarachnoid haemorrhage (SAH) and 6.4% for ischemic stroke (IS). In a very recent study by Skajaa et al. (2022), the overall 1-year and 10-year adjusted recurrence risks after IS were 4% and 13%, respectively. Similarly, for first-time intracerebral haemorrhage (ICH), the adjusted risks were 3% and 12%, respectively. Analyzing data from 109 tertiary hospitals, He et al. (2017) discovered that the cumulative 2-year stroke recurrence rate was 3.80% for SAH, 8.71% for IS, and 5.31% for ICH among

101,926 discharged patients, respectively. Furthermore, a systematic review found that stroke recurrence rates remain consistent over time, highlighting the need for future studies to address the challenges of secondary prevention (Kolmos et al., 2021). Recurrent strokes lead to more significant disability (Elwan et al., 2021) and mortality (Zhuo et al., 2020) than first-time strokes. Overall, these studies highlight the need for further improvement in secondary stroke prevention to prevent the recurrence of stroke in the future.

Most strokes are due to modifiable factors (Hill & Towfighi, 2017). The burden of death from IS attributable to insufficient risk factor control occurred primarily in older individuals, particularly those aged over 80 years (Fan et al., 2023). Šedová et al. (2021) reported that effective interventions directed at stroke prevention focusing specifically on modifying risky factors will change the thinking and attitudes of those in a risk group. Nowadays, the problems we are facing in the prevention of recurrent stroke are poor knowledge of identifying symptoms of stroke and risk factors among stroke survivors, unsatisfying stroke care, and low adherence to therapy programs (Nindrea & Hasanuddin, 2023).

In recent years, smartphones and mobile applications have become increasingly prevalent among older adults (Zhong & Rau, 2020). Busch et al. (2021) surveyed 154 smartphone users aged 60 and above in Norway, finding that they spent an average of 159.4 minutes per day using their smartphones. According to “The 49th Statistical Report on the Development of China’s Internet”, the number of Internet users in China exceeded 1.03 billion by the end of 2021, with 119 million netizens aged 60 and older. The mobile phone subscriber base has grown steadily. In December 2021, smartphones accounted for 99.7% of internet access devices, surpassing 1,029

million users (Cnnic, 2021). With the popularity of smartphones among older adults, mHealth technology has shown promise to influence patient behavior positively among this population. It goes on to use the definition of mHealth as "the use of mobile phones, wearable sensors, and other wireless technologies to provide patients and healthcare workers with support to improve health" (Pandian et al., 2018). The global impact of the COVID-19 pandemic has generated an unprecedented drive for culturally sensitive mHealth development (Giansanti, 2021). Additionally, Rowland et al. (2020) emphasized that mHealth technologies will ultimately play a crucial role in empowering patients to manage their health independently through digitally enabled care pathways, thereby offering additional benefits to healthcare delivery systems. Studies have shown that mHealth facilitates interventions as they can be easily accessed, allow for high scalability, and provide at a low cost (Dugas et al., 2020; Hussain-Shamsy et al., 2020; Zhang et al., 2020).

The American Heart Association (AHA) supports mHealth interventions while pointing out an urgent need for research to target broader stakeholders, including older adults (Burke et al., 2015). Similarly, Ahmed et al. (2018) reported that older adults potentially could gain the most from application-based interventions. The prevalence of mobile technology makes mobile application interventions a promising strategy for expanding the reach of secondary prevention. In addition, Burns et al. (2022) suggest that despite growing difficulties in using a smartphone after a stroke, nearly 50% of respondents indicated using their smartphones at least as often as before their stroke. However, Verma et al. (2022) indicated that the data on the efficacy of mHealth innovations in stroke survivors is limited. Overall, these studies highlight the need for the development of mHealth intervention targeted at older adult stroke survivors.

1.2 Problem Statement & Study Rationale

Globally, stroke stands as a prominent contributor to death and disability. It has conclusively been shown that stroke disproportionately affects older adults (Lu et al., 2018; Tu et al., 2022; Xia et al., 2019; Yousufuddin & Young, 2019). Evidence suggests that as our population ages and life expectancies increase, preventing strokes in older adults will be a crucial focus to alleviate the future global burden of stroke (Béjot et al., 2019; Gorelick, 2019; Yao et al., 2023). However, the current enormous and continuously growing burden of stroke indicates that prevention strategies for stroke have been relatively ineffective (Hill & Towfighi, 2017; Wu et al., 2019). Overall, there seems to be some evidence to indicate that novel stroke prevention strategies should be encouraged, specifically in older adult stroke survivors.

There is compelling evidence that most of the stroke burden was attributable to modifiable risk factors (Feigin et al., 2017; O'Donnell et al., 2016). Several studies thus far have highlighted the importance of preventing stroke by risk factor modification (Baker et al., 2013; Gorelick, 2019; Hackam & Spence, 2007; Hall et al., 2024; Kleindorfer et al., 2021; Libruder et al., 2022), which including but not limit to improving medication non-adherence, health literacy, and hypertension (Mafruhah et al., 2023; Mekonen et al., 2020; Posawang & Vatcharavongvan, 2024; Wang et al., 2017; Wu et al., 2019). Unfortunately, despite its importance for lessen the burden of stroke, there is increasing concern that interventions target these modifiable risk factors were not associated with improved control of modifiable risk factors or the prevention of recurring cardiovascular incidents (Bridgwood et al., 2018; Guillaumier et al., 2022).

Specifically, a large and growing body of literature has reported that actual medication persistence and adherence in stroke survivors were problematic regardless of its apparent benefits (Pan et al., 2017; Ruksakulpiwat et al., 2020; Wei et al., 2017; Yang et al., 2022; Zhang et al., 2015; Zhang et al., 2021). Stroke survivors present low health literacy (Rosenbaum et al., 2016; Zhao et al., 2020). In addition, BP control remains suboptimal worldwide among stroke survivors, with a third of those having either untreated or inadequately treated BP (Lin et al., 2022). The studies presented thus far provide evidence that medication non-adherence, health literacy, and hypertension interventions among stroke survivors have yet to be implemented effectively. Future studies are warranted to implement innovative, cost-effective, and sustainable programs among this population.

Notably, there is a lack of data on the prevalence of medication non-adherence and the factors associated with it among older adult stroke survivors. This gap affects creating an appropriate strategy to improve medication adherence among this population. Medication beliefs outweighed clinical and sociodemographic factors as predictors of reported adherence (Horne & Weinman, 1999) and have the potential value to improve medication adherence (Gujral et al., 2014; Ruksakulpiwat et al., 2020; Schüz et al., 2011; Yoo et al., 2023). Recognizing medication beliefs' potential to enhance medication adherence makes monitoring and emphasizing them in interventions vital (O'Carroll et al., 2011). So far, however, medication beliefs have seldom been the main focus of adherence-improving interventions (Zwikker et al., 2012). Therefore, interventions aimed at improving medication adherence among older adult stroke survivors should address medication beliefs and understand the prevalence and factors associated with medication non-adherence.

mHealth interventions, such as smartphone applications, may improve stroke survivors' medication adherence and clinical indicators (Choi et al., 2023). A promising area that warrants further research is using digital technologies for primary stroke prevention in older adults (Feigin et al., 2022). There are few stroke-specific applications with cultural appropriateness and sustainability despite the rapid growth of mobile health applications (Singer & Levine, 2016). Furthermore, most applications were not specifically geared toward older adults (Cao et al., 2023; Grindrod et al., 2014; Helbostad et al., 2017), and significant limitations hinder the incorporation of stroke-specific applications into clinical practice (Salgueiro et al., 2023). In addition, existing applications for stroke survivors and caregivers focus primarily on language and communication difficulties (Piran et al., 2019). There is ample opportunity for improvement in this area. Developing and testing applications that address a broader range of needs for stroke survivors and caregivers could be a significant step forward.

It is worth noting that there is a striking lack of information regarding the impact of interventions using mobile applications among older adult stroke survivors in particular (Cao et al., 2024). In addition, Tajudeen et al. (2022) noted that the bulk of research concerning mHealth and older adults originates from developed and high-income countries.

Overall, the evidence presented in this section suggests that there is an urgent need to focus on developing and evaluating a mobile application intervention that enhancing medication, medicine beliefs, health literacy and BP among older adult stroke survivors.

1.3 Research Objectives

1.3.1 General objective

The general objective of this study is to develop and evaluate the effectiveness of the mobile application for older adult stroke survivors on medication adherence, medicine beliefs, health literacy on stroke and BP in Chenzhou, Hunan Province, China.

1.3.2 Specific objectives

The specific objectives of this study are outlined in the following three phases：

Phase 1:

i. To determine the prevalence of medication non-adherence and its associated factors among older adult stroke survivors in Chenzhou, Hunan Province, China.

Phase 2:

ii. To develop a mobile application intervention module for older adult stroke survivors (e-MAIMOASS) on medication adherence, medicine beliefs, health literacy on stroke, and BP.
iii. To validate the mobile application intervention module for older adult stroke survivors (e-MAIMOASS) on medication adherence, medicine beliefs, health literacy on stroke, and BP.

Phase 3:

iv. To evaluate the usability of the mobile application intervention module (e-MAIMOASS) as a tool for older adult stroke survivors.
v. To evaluate the effectiveness of the mobile application intervention module (e-MAIMOASS) as a tool for older adult stroke survivors on mdication adherence, medicine beliefs, health literacy on stroke, and BP.

1.4 Research Questions

The research questions of this study are as follows:

i. What is the prevalence of medication non-adherence and its associated factors among older adult stroke survivors in Chenzhou, Hunan Province, China?

ii. How does the mobile application conceptualise in the context of older adult stroke survivors?
iii. Is the mobile application a valid intervention module for older adult stroke survivors?
iv. Is the mobile application a usable tool for older adult stroke survivors?
v. Is the mobile application for older adult stroke survivors effective in improving medication adherence, medicine belief, health literacy on stroke, and BP?

1.5 Hypothesis

The following three research hypotheses are relevant to this study:

H1: The mobile application is a valid intervention module for older adult stroke survivors.

H2: The mobile application has good usability for older adult stroke survivors.

H3: The mobile application for older adult stroke survivors is effective in improving medication adherence, medicine belief, health literacy on stroke, and BP.

1.6 Conceptual and Operational Definitions

1.6.1 Medication adherence

Medication adherence generally refers to how closely patients align with their healthcare provider's (HCP) recommendations when taking prescribed medications (De Geest & Sabaté, 2003). In this study, medication adherence is characterized by the consistency with which patients adhere to their daily medication regimen and persist in taking the prescribed medication, measured using the Chinese version of the general medication adherence scale (GMAS-C) (Wang et al., 2021).

1.6.2 Older adults

Older adults have been defined as the later part of life and the period of life after youth and middle age. Conventionally, in most developed countries, individuals

aged 65 or older are considered older adults (Orimo et al., 2006). In China, the definition of older adults has been at least 60 years of age (Zhang et al., 2020). Therefore, this study focused on older adults aged 60 years and above.

1.6.3 Mobile application

A mobile application is defined as software or applications designed to carry out particular tasks for users and works on mobile devices like smartphones, personal digital assistants, and electronic devices (Chang, 2015). In this study, mobile application refers to software or applications compatible with mobile devices, like tablets and smartphones, rather than desktop or laptop computers (Brown & Kim, 2018; Kaasinen et al., 2000).

1.6.4 Stroke survivors

Stroke survivors are individuals who continue their lives after post-hospital discharge for stroke care, whether within a community setting or in a rehabilitation environment (Zawawi et al., 2020). In this study, the term "stroke survivors" refers to individuals who resume their daily activities after being discharged from the hospital following stroke treatment, whether through outpatient clinic follow-ups or within a rehabilitation setting.

1.6.5 e-MAIMOASS

e-MAIMOASS, short for Electronic Mobile Application Intervention Module for Older Adult Stroke Survivors, is a digital platform meticulously crafted to assist older adult stroke survivors in various aspects. It aims to aid them in managing medication adherence, addressing medicine beliefs, enhancing health literacy pertaining to stroke, and optimizing BP levels. This is accomplished through

interactive and personalized interventions seamlessly delivered via a user-friendly mobile application interface.

1.6.6 Evaluation effectiveness

Evaluation effectiveness is a methodical approach that involves gathering and analysing data to ascertain the extent to which the program has fulfilled its predefined objectives (Boulmetis & Dutwin, 2000). This study evaluates the effectiveness of the intervention according to medication adherence, medicine beliefs, health literacy on stroke, and BP.

1.6.7 Medicine beliefs

Medicine beliefs refer to the patients' self-perceived sensitivity to recognize the need for prescribed medication and concerns about potential drawbacks like side effects, dependence, or long-term consequences (Broekman et al., 2018). In this study, medicine beliefs denote individuals' beliefs about the necessity of prescribed medication and their associated concerns (considering beliefs about the risks of dependence, the possible adverse effects of the drug, and long-term toxicity), which Beliefs about Medicines Questionnaire (BMQ) measured (Yang et al., 2014).

1.6.8 Health literacy

Health literacy encompasses social and cognitive skills, as well as resources that empower individuals to access, comprehend, and utilize health information and services to foster and sustain overall well-being (Ratzan, 2001). In this study, health literacy refers to the three domains comprising basic knowledge of strokes, healthy lifestyles and behaviors, and basic skills measured by the Health Literacy Scale for Stroke Patients (Jiru et al., 2020).

1.6.9 Stroke

The present definition of stroke by the World Health Organization (WHO) (introduced in 1970 and still used today) describes it as a sudden onset of focal (or global) disruption of cerebral function lasting more than 24 hours (except interruptions caused by death or surgery) without resolution of symptoms (Aho et al., 1980). In this study, stroke is defined as a clinical syndrome marked by the rapid onset of symptoms or signs indicating focal (or occasionally global) loss of cerebral function and lasting over 24 hours (or resulting in death) with no discernible cause other than non-vascular in origin. Patients were categorized into infarction or hemorrhage based on computed tomography or magnetic resonance imaging descriptions.

1.7 Significant of the Study

The significant implication of the study is to provide the body of research pertaining to mobile application intervention among older adult stroke survivors in the field of secondary prevention of stroke. The critical areas where this study makes an original contribution are listed as follows:

Firstly, our study, delving into the critical issue of medication non-adherence among older adult stroke survivors, offers valuable insights for healthcare providers. Understanding the factors associated with non-adherence enables tailored interventions, ultimately leading to improved medication adherence, reduced risks of recurrent strokes, and enhanced overall well-being for older stroke survivors.

Secondly, we meticulously crafted and tested a user-friendly mobile application tailored specifically for older adult stroke survivors, aimed at enhancing stroke prevention within this demographic. This innovation significantly contributes to improving the quality of life and fostering enhanced recovery among older stroke

survivors. Consequently, our findings hold the potential to make a substantial impact on overall well-being and independence within this population.

Thirdly, only a few mobile applications are designed for older adults because most existing mobile applications are crafted to cater to the needs of younger users and are built upon the perspectives and expertise of youthful developers. Thus, this study contributes to a more inclusive digital environment and provides an example for others wishing to develop similar mobile applications.

Fourthly, this study would fill the gap in the current body of research by showing the effectiveness of mobile application intervention in improving medication adherence, medicine beliefs, health literacy on stroke, and BP among older adult stroke survivors. Older adults are often excluded from technology trials. Hence, our study focused on an overlooked group, providing a valuable opportunity to explore the usability of smartphone technology for older adult stroke survivors with significant disabilities and long-term care needs. The results provide valuable information to the health care practitioners in understanding potentially important strategies on which future interventions among this population may focus.

Lastly, by leveraging technology to deliver personalized interventions, healthcare providers, including nurses, can streamline care processes, reduce the burden on healthcare facilities, and allocate resources more effectively. This approach ultimately leads to improved patient outcomes and satisfaction

1.8 Chapter Summary

This chapter explains in detail the background of the research and the problem statement that this study addresses. The research objectives, questions, and hypotheses

are outlined. The definitions of terms and research significance are also identified and described. Chapter 2 summarizes the current body of research and outlines the conceptual framework for this study.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

This chapter thoroughly reviews relevant literature and discusses in detail the conceptual framework used in this study. The chapter begins by providing an overview of strokes, encompassing epidemiology, characteristics of stroke survivors, risk factors, recurrence, and preventive measures. It then delves into interventions aimed at improving medication adherence, medicine beliefs, health literacy on stroke, and BP control among older adult stroke survivors. Following this, the literature on mobile applications among older adult stroke survivors is explored, including their usage, targeting stroke management, and the effectiveness of mobile application interventions. Additionally, guidelines and theoretical frameworks for developing mobile applications for older adult are discussed. Lastly, the chapter presents the conceptual framework of the study, synthesizing the literature to provide a theoretical basis for the research.

2.2 An Overview of Strokes

2.2.1 Stroke epidemiology

Stroke is a significant global health issue. It is acknowledged as the primary cause of disability and morbidity, with substantial economic costs associated with post-stroke care (Feigin & Brainin, 2019). It shows that although there has been a downward trend of stroke-related deaths and DALYs in the past 30 years, the overall burden of stroke in terms of the total number of people affected by or left disabled from it has increased globally (Wang et al., 2017; Zhou et al., 2019). Approximately 795,000 individuals undergo a first-time or recurring stroke annually (Tsao et al.,

2022). Evidence suggests that stroke has experienced an alarming growth trend from 1990 to 2019. Incident strokes increased by 70.0%, DALYs went up by 143.0%, stroke-related deaths rose by 43.0%, and prevalent strokes grew by 102.0% (Feigin et al., 2022). In 2020, the worldwide incidence of stroke was 11.71 million cases; notably, around 7.59 million cases were attributed to IS, while ICH and SAH caused 3.41 million and 0.71 million cases, respectively (Tsao et al., 2023). Stroke caused approximately 7.08 million deaths in 2020, of which 3,48 million were related to IS, 3.25 million were attributable to ICH, and 0.35 million were caused by SAH (Tsao et al., 2023). Of note, the overall global expenses associated with stroke in 2017 amounted to US$891 billion (from $746 billion to $1,077 billion), representing 0.66% of the global Gross Domestic Product (Owolabi et al., 2022).

China bears a high and increasing stroke burden, with approximately 2.3 million stroke-related deaths, 17.8 million existing cases, and 3.4 million fresh occurrences of strokes in the year 2020 alone (Tu et al., 2023). Since 2005, stroke has consistently held the position as the primary cause of death in China. The annual stroke-related deaths in the country contribute to approximately one-third of the total global stroke mortality each year (Chao et al., 2021; Wang et al., 2020). Furthermore, stroke ranked as the primary cause of DALYs in 2017 across all age groups based on China Stroke Statistics 2019 (Wang et al., 2020). In the initial comprehensive analysis of stroke prevalence trends in China from 2013 to 2019, Tu et al. (2022) noted a notable rise in the weighted prevalence of stroke, climbing from 2.28% in 2013 to 2.58% in 2019.

Although stroke is no longer a disease of older adults, as over 60% of strokes happen in people younger than 70 years (Feigin & Brainin, 2019; Feigin et al., 2022),

older adults are disproportionately affected. Approximately 75% of all strokes happen in individuals aged 65 and above (Yousufuin & Young, 2019). In China, stroke prevalence among individuals aged 60 and above was 5.56% in 2019 (Tu et al., 2022). Lu et al. (2018) indicated that between 1992 and 2016, the rate of new stroke occurrences rose by 3.7% annually in the population aged ⩾65 years. In addition, stroke mainly occurs among Chinese people aged ≥70-79 years (Xia et al., 2019). In China, more than 70% of stroke-related mortality risk is observed in individuals aged 65 years and older, with over 80% occurring in individuals aged 60 and above (Wang et al., 2017). Many researchers have argued that the likelihood of stroke increases as individuals age, irrespective of gender (Li et al., 2017; Tsao et al., 2022; Wang et al., 2020). With the aging of our population and longer life expectancies, there is an expected increase in the overall occurrences of stroke, particularly among older adults (Béjot et al., 2019). Up to the year 2050, there will be a doubling of the number of strokes in the United States (USA), mainly occurring in people aged 75 years and older (Gorelick, 2019). Moreover, there will be an estimated 4.79 million new stroke incidents in individuals aged 65 years and above in China (Yao et al., 2023). Stroke in the older is particularly problematic as these patients are often complicated with multiple diseases and affected by cognitive impairment when compared with stroke in young adults. Khan & Silver (2019) regarded older adult stroke survivors as a distinct group that requires a comprehensive approach integrating preventive measures. Thus, future efforts should focus on improving stroke health care and secondary prevention to anticipate and, whenever feasible, reduce the burden of stroke, especially for older adults.

2.2.2 Stroke survivors

With advancements in treatment and stroke care, there is an expected increase in the number of stroke survivors (Rudberg et al., 2021). Due to the aging population and the latest technologies, China is expected to experience a significant increase in stroke survivors aged 60 years and older by 2050, with an anticipated rise of 104.70% in incidence (Yao et al., 2023). Stroke survivors often suffer from various functional constraints, poor mental health, and cognitive deficits (Norrving et al., 2018; Szczepańska-Gieracha & Mazurek, 2020). These issues notably impact the socio-economic well-being of the nation, particularly in the absence of comprehensive stroke care that covers prevention to community-based treatment (Zawawi et al., 2020).

Caring for stroke survivors is a multifaceted and complex task, with goals that constantly change and adapt to the individual survivor's needs (López-Espuela et al., 2018). Previous research has indicated that unmet needs were identified among stroke survivors (Guo et al., 2021; Zawawi et al., 2020). Additionally, stroke survivors express feelings of abandonment due to inconsistent care, limited availability of community services, and insufficient, overly general information about stroke and preventive measures (Pindus et al., 2018). With an escalating number of stroke survivors, addressing their needs becomes crucial. More insight is needed to enhance long-term care for this population.

2.2.3 Stroke recurrence

Stroke survivors face an increased likelihood of recurrence, which make up 25~30% of all strokes (Hankey, 2014). Though the use of secondary prevention is increasing, the recurrence rate seems unchanged over the previous 20 years (Kolmos et al., 2021). A study based on Danish nationwide health registries spanning 2004 to 2018 revealed that, following adjustments for competing risks, the probabilities of

recurrence within 1 year and 10 years were 4% and 13% for first-time IS and 3% and 12% for first-time ICH (Skajaa et al., 2022). In a retrospective analysis involving data from 109 tertiary hospitals and 101,926 discharged patients, the 2-year cumulative recurrence rates for stroke were 3.80% for SAH, 8.71% for IS, and 5.31% for ICH, respectively (He et al., 2017). Xu et al. (2022) conducted a population-based cohort study spanning ten years and demonstrated that the recurrent stroke rate was 12.5% within 12 months after stroke onset. A substantial number of studies have shown that recurrent strokes result in increased risks of prolonged hospitalization, mortality, long-term disability, and dementia (Khanevski et al., 2019; Pendlebury & Rothwell, 2009; Putaala, 2014; Zhang et al., 2021). Therefore, secondary stroke prevention has room for further improvement to curb stroke recurrence (Coull et al., 2004).

2.2.4 Risk factors for stroke

Extensive research has been done to determine the factors that are attributed to stroke. These studies conclude that multiple factors may increase the risk of a stroke occurring. These factors can be classified as either modifiable or non-modifiable. Key non-modifiable factors are factors beyond an individual control to change or adjust to prevent stroke, which include age (Ekker et al., 2019; Yousufuddin & Young, 2019), ethnicity (Gardener et al., 2020; Lin et al., 2021; O'Donnell et al., 2016), and genetics (Boehme et al., 2017; Malik et al., 2018; Rutten-Jacobs et al., 2018). On the other hand, modifiable factors such as clinical and lifestyle factors are factors that can be changed or adjustable to prevent an individual from developing stroke. Clinical factors such as hypertension, dyslipidaemia, diabetes, as well as atrial fibrillation (AF), may be associated with stroke occurrence (Owolabi et al., 2018). Simultaneously, there is solid and convincing evidence that poor lifestyle factors like physical inactivity, unhealthy

diet, smoking, obesity, and excessive alcohol consumption may have contributed to the increased stroke risk (Feigin et al., 2021).

2.2.5 Stroke prevention

Robust and compelling evidence suggests that >90% of all strokes are preventable (Diener & Hankey, 2020). Hackam & Spence (2007) showed that employing both secondary prevention medications and adopting lifestyle changes resulted in a cumulative relative risk reduction of 80% in individuals who have experienced a transient ischaemic attack or stroke. Baker et al. (2013) point out that secondary prevention strategies focus on modulating various risk factors, including pharmacological treatments and control of BP. In addition, Magnani et al. (2018) illustrated the significant impact of health literacy on primary and secondary prevention of cardiovascular disease (CVD). Health literacy is crucial for developing prevention initiatives and delivering health care (Magnani et al., 2018), leading to better decisions, more substantial commitment, and superior efficiency levels (Santos et al., 2017).

2.2.5(a) Adherence to pharmacological treatments

Several studies have revealed that secondary prevention medications (antithrombotic, statin, aspirin or clopidogrel, and antihypertensive therapies) tend to lower the risk of stroke recurrence (Flach et al., 2020; Rodríguez-Bernal et al., 2021; Toyoda et al., 2019). However, patient's adherence to medication primarily attributed to the success of preventing recurrent stroke and adverse outcomes (Zhang et al., 2021). A meta-analysis revealed that in parallel with managing risk factors, adhering to prescribed medications from healthcare professionals is critical in preventing recurrence and additional adverse consequences associated with strokes after the first stroke has been controlled (Zhang et al., 2021). Meanwhile, scientists have a consensus

that lower medication adherence levels are linked to an elevated risk of stroke and death (Liu et al., 2021; Mafruhah et al., 2023). Bergström et al. (2017) have emphasized that it is reasonable to think that treatment with secondary preventive drugs contributed to decreasing recurrent IS events. In the same vein, Mafruhah et al. (2023) found that the contribution of non-adherence to medications for the four primary stroke-related diseases (i.e., hypertension, AF, hyperlipidaemia, and diabetes) to stroke development and mortality was relevant. Therefore, it is crucial to optimize adherence to therapy.

2.2.5(a)(i) Medication non-adherence among stroke survivors

Despite its evident success in reducing the risk of stroke recurrence, medication non-adherence raises concerns for healthcare systems, clinicians, and stakeholders such as payers. While most patients were prescribed multiple medications to prevent further health issues after a stroke, between 20% and 33% discontinued treatment within one year post-discharge (Dalli et al., 2021). Even in European countries, the use of secondary preventive drugs was suboptimal. Approximately 33% of patients discontinue the use of more than one secondary stroke prevention drug within 14 months following a stroke (Ullberg et al., 2017). Zhang et al. (2021) found that 64.1% of patients with stroke demonstrated high medication adherence, with a corresponding persistence rate of 72.2%. A growing body of literature reported that medication adherence among stroke survivors in China was poor (Pan et al., 2017; Ruksakulpiwat et al., 2020; Wei et al., 2017; Zhang et al., 2015).

Older adults are more likely to exhibit non-adherence (Cross et al., 2020). Poor medication knowledge, adverse side effects, confusion about treatment necessity, and polypharmacy have all been identified as contributing to poor adherence among older adults (Foley et al., 2021). For older adults with chronic diseases, failure to

adhere to medication regimens may lead to increased costs of care, therapeutic failure, and mortality (Taheri Kharameh et al., 2018; Walsh et al., 2019). Most studies have only focused on factors that impact medication non-adherence in older adults with diabetes and hypertension (Saqlain et al., 2019; Xu et al., 2020). Up to now, no study has investigated the medication non-adherence of older adult stroke survivors; no study has yet explored the associated factors with medication non-adherence for this population.

2.2.5(a)(ii) Factors associated with mediation non-adherence among stroke survivors

A review aimed at finding out psychological factors that significantly affect medication adherence in stroke survivors discovered that 'Beliefs about Consequences,' 'Emotions,' and 'Knowledge' exerted the greatest influence on medication adherence in this population (Crayton et al., 2017). Research on factors influencing medication adherence among stroke survivors could offer valuable insights into these challenges.

a) Medicine beliefs

A large body of evidence documented medicine beliefs as predictors of adherence. A recent study by Nie et al. (2019) reported that medicine beliefs are a useful conceptual model for explaining Chinese patients' medication adherence behaviour. Medication adherence was affected by medicine beliefs in multimorbid older adults (Félix & Henriques, 2021; Schüz, Marx, et al., 2011). Much of the current literature concludes that positive medicine beliefs are linked to better adherence (AlHewiti, 2014; Kim et al., 2020; Nie et al., 2019; Park et al., 2018). Specifically, Cicolini et al. (2016) conducted a multicenter cross-sectional study and found that higher levels of necessity or concerns about medicines were positively associated with

higher adherence. A cross-sectional study where 306 IS survivors were assessed reported that perceived concern regarding the potential side effects of medications significantly influenced self-reported medication adherence (Ruksakulpiwat et al., 2020). Another study illustrated that the perception of medication necessity was a manageable factor associated with compliance in treating patients who have suffered a stroke (Cheiloudaki & Alexopoulos, 2019).

Previous research has indicated that despite the apparent association, medication beliefs have seldom been the main focus of adherence-improving interventions (Zwikker et al., 2012). However, for non-adherent patients whose medication beliefs contributed to their non-adherence, further research on medication beliefs is necessary (Gujral et al., 2014). Numerous studies have highlighted the potential value of targeting medication beliefs to improve medication adherence (Gujral et al., 2014; Ruksakulpiwat et al., 2020; Schüz et al., 2011; Yoo et al., 2023).

b) Drug doses

Generally speaking, an increasing number of drugs prescribed is associated with non-adherence, but this was not consistent. For example, a study examining Korean stroke survivors' medication adherence within the first year of acute IS showed that those who were prescribed more medications tended to have better adherence (Kim et al., 2020). For another example, a nationwide population-based study revealed that < 4 total prescribed drugs (OR 1.24, 95% CI 1.05–1.47) were notably linked to early discontinuation of antiplatelet medication within the initial year among post-ischemic stroke survivors (Kim et al., 2021). Furthermore, according to Rajahthurai et al. (2022) the complexity of medication regimens often serves as a common reason for inadequate stroke therapy.

c) Social support

There is substantial evidence that social support, whether informal or formal assistance received from other community members, is a vital factor that might have a positive impact on adherence (Gast & Mathes, 2019). Social support from friends and family has been consistently reported to improve medication adherence, concurrently cutting down the time healthcare professionals devote to managing chronic conditions (Sabate, 2003). A five-year cohort study that involved 108 stroke survivors underscores the significance of family members and caregivers in aiding stroke survivors with medication management, especially in situations involving cognitive function deficits (Rohde et al., 2019). Stroke survivors who received medication help got more adherent (Rohde et al., 2019). Compared with patients who saw at least three close friends or relatives monthly, those who saw >10 per month had a higher prevalence of medication adherence (Mondesir et al., 2018). Integrating functional and structural components in social support was linked to improved medication adherence among individuals with risk factors for coronary heart disease (Mondesir et al., 2018).

d) Health literacy

Saqlain et al. (2019) revealed that health literacy significantly contributes to medication adherence. Investigations from France and the United Kingdom (UK) have reported that poor health literacy is associated with poor medication adherence (Bauler et al., 2014; Jamison et al., 2016). An updated literature review showed that older adults with diminished health literacy are less likely to adhere to medication and treatment regimens (Satriana et al., 2021). According to the cross-sectional study results of 6,871 Danish citizens aged 50–80, adequate health literacy was notably