PROMOTING EXERCISE AMONG OLDER MALAYSIANS USING TEXT MESSAGES

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ABSTRACT

Using mobile technology to promote exercise has been effective. However, evidence is largely drawn from studies with young age groups in high-income countries. Using mobile phone text-messaging to promote exercise in older adults in a developing country is promising because mobile phone proliferation is high and many older adults are keen to use this technology. My primary study objective was to examine the effects of mobile phone text-messaging on an exercise intervention on weekly exercise frequency in older Malaysians. Secondary objectives were to investigate in what ways the text messages impacted study participants' exercise frequency, and to examine the effects of the intervention on secondary outcomes. The Malaysian Physical Activity for Health Study ($_{\text{my}}$PAtHS) was a 24-week, 2-arm parallel randomized controlled trial conducted in urban Malaysia. I recruited participants via health talks in residential associations and religious facilities. Non-exercising, mobile phone using, older Malaysians between 55 and 70 years, were eligible to participate in the study. Participants randomly allocated to the SMS condition received an exercise booklet and 5 weekly text messages over 12 weeks. The content of the text messages was derived from effective behaviour change techniques and further informed by formative pilot studies. Text messages ceased after 12 weeks. No-SMS condition participants received only the exercise booklet. Home visits were conducted to collect outcome data: (1) exercise frequency (primary outcome) and duration, and interview data at Weeks 12 and 24, (2) exercise self-efficacy, physical activity related energy expenditure, sitting time, BMI, grip and leg strength at baseline, and at Weeks 12 and 24. I analysed quantitative data per protocol using various regression models. A total of 43 participants were randomized into the SMS condition (*n* = 22) and No-SMS condition (*n* = 21). Intervention unrelated injuries forced four participants to discontinue after a few weeks. Overall retention was 86% (37/43). At Week 12 SMS condition participants exercised significantly more than No-SMS participants, 1.21 times, BCa 95% CI [0.18, 2.24], d = 0.76. The semi-structured interviews revealed that the text messages had influenced SMS condition participants who experienced exercise barriers. They described the text messages as being encouraging, a push, and a reminder. At Week 24 there was no significant difference between the research condition (mean difference 0.58, BCa 95% CI [-0.35, 1.55]), d = 0.39. There were no significant effects of the text messages on secondary outcomes. This study provided evidence that text-messaging is effective in promoting exercise in older adults from an upper-middle-income country, Malaysia. Although the effect of the text messages were not maintained when the text messages ceased, the results are promising and warrant more research on behavioural mobile health in older adults and other regions.

ABSTRAK

Penggunaan teknologi mudah alih untuk mempromosikan senaman adalah efektif. Walau bagaimanapun, sebahagian besar bukti kajian yang sedia ada adalah daripada kumpulan umur yang muda di negara-negara berpendapatan tinggi. Ia adalah penting untuk menyiasat sama ada intervensi pemesejan teks boleh mempengaruhi penyertaan senaman di kalangan warga tua daripada sebuah negara berpendapatan sederhana, Malaysia, memandangkan proliferasi yang besar terhadap penggunaan telefon bimbit di rantau kurang maju dan peningkatan minat warga tua untuk menggunakan telefon bimbit, terutama pemesejan teks. Objektif utama kajian adalah untuk mengkaji kesan jangka pendek dan jangka panjang daripada intervensi pemesejan teks terhadap kekerapan senaman di kalangan warga tua. Objektif kedua adalah untuk menyiasat bagaimana teks-mesej mempengaruhi kekerapan senaman peserta kajian dan untuk mengkaji kesan intervensi terhadap hasil sekunder. *The Malaysian Physical Activity for Health Study* (myPAtHS) merupakan ujian terkawal rawak selari selama 24 minggu, terdiri daripada 2 kumpulan, yang dijalankan di kawasan bandar di Malaysia. Para peserta direkrut melalui ceramah kesihatan di persatuan-persatuan penduduk dan pusat keagamaan. Rakyat Malaysia yang berumur antara 55 dan 70 tahun, tidak aktif, dan pengguna telefon bimbit adalah layak untuk mengambil bahagian dalam kajian ini. Peserta dibahagikan secara rawak ke dalam kumpulan SMS yang menerima buku panduan senaman dan 5 teks-mesej seminggu selama 12 minggu (secara berautomat). Kandungan teks-mesej diperoleh daripada teknik perubahan tingkah laku yang efektif. Teks-mesej tidak dihantar selepas 12 minggu. Peserta yang berada di dalam kumpulan Tanpa-SMS hanya menerima buku panduan senaman sahaja. Lawatan ke rumah telah dijalankan untuk mengumpul data: (1) kekerapan senaman dan temubual selepas minggu ke-12 dan selepas minggu ke-24, (2) hasil sekunder (senaman efikasi-kendiri, penggunaan tenaga yang berkaitan dengan aktiviti fizikal, masa digunakan untuk duduk, BMI, kekuatan cengkaman dan kekuatan kaki) pada garis dasar, pada minggu ke-12 dan ke-24. Data dianalisis dengan setiap protokol menggunakan pelbagai model regresi. Seramai 43 peserta dibahagikan secara rawak ke dalam kumpulan SMS (*n* = 22) dan kumpulan Tanpa-SMS (*n* = 21). Empat peserta mengalami kecederaan yang tidak berkaitan dengan aktiviti senaman yang dibekalkan dan tidak dapat meneruskan intervensi selepas beberapa minggu. Secara keseluruhan, pengekalan peserta adalah sebanyak 86% (37/43). Selepas 12 minggu, peserta dari kumpulan SMS melakukan aktiviti senaman lebih banyak berbanding peserta dari kumpulan Tanpa-SMS, 1.21 kali, BCa 95% CI [0.18, 2.24], *d* = 0.76. Analisis temubual mendedahkan bahawa teks-mesej yang telah mempengaruhi peserta dari kumpulan SMS yang mempunyai halangan melakukan aktiviti senaman. Mereka menyifatkan teks-mesej sebagai menggalakkan, mendorong, dan sebagai peringatan. Selepas 24 minggu, tidak terdapat perbezaan yang signifikan antara kumpulan penyelidikan (min perbezaan 0.58, BCa 95% CI [-0.35, 1.55]), *d* = 0.39). Tiada kesan yang signifikan untuk hasil sekunder. Kajian ini mengemukakan bukti bahawa intervensi pemesejan teks berkesan dalam mempromosikan senaman di kalangan warga tua dari negara yang berpendapatan sederhana, Malaysia. Walaupun kesan intervensi tidak kekal apabila teks-mesej diberhentikan, keputusannya adalah meyakinkan dan lebih banyak penyelidikan boleh dilakukan mengenai intervensi tingkah laku kesihatan mudah alih di kawasan lain.

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This is it! My adventurous PhD journey finds its conclusion with the completion of this thesis; and I could not be more proud. My pride does not stem from the fact that I have just put a hardly visible dent in the universe of knowledge, but my pride emanates from the fact that I was able to develop, implement, and evaluate a study in a far-away place that challenged me on a daily basis and made me question everything I thought I knew.

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b	:	Unstandardized Regression Coefficient
d	:	Cohen's *d* (Effect Size)
F	:	*F*-Ratio
M	:	Mean
n	:	Sample Size of a Group
N	:	Total Sample Size
p	:	*p*-Value
r	:	Correlation Coefficient
R^2	:	Coefficient of Determination
t	:	*t*-Value
BCa	:	Bias Corrected and Accelerated
CI	:	Confidence Interval
df	:	Degrees of Freedom
ICC	:	Interclass Correlation Coefficient
IQR	:	Interquartile Range
SD	:	Standard Deviation
SE	:	Standard Error

ß	:	Standardized Regression Coefficient
χ^2	:	Chi Square
$\hat{\varepsilon}$	:	Greenhouse-Geisser Estimation to Correct Sphericity Violations
η^2	:	Eta Squared (Effect Size)
ρ	:	Rho (Correlation Coefficient in the Population)
Δ	:	Change
ACSM	:	American College of Sports Medicine
AHA	:	American Heart Association
APA	:	American Psychological Association
BCT	:	Behaviour Change Technique
BCTTv1	:	Behaviour Change Technique Taxonomy Version 1
BMI	:	Body Mass Index
CALO-RE	:	Coventry, Aberdeen & London - Refined
CDC	:	Centers of Disease Control and Prevention
eHealth	:	Electronic Health
EU	:	European Union
EXSE	:	Exercise Self-Efficacy Scale
GDP	:	Gross Domestic Product

HAPA	:	Health Action Process Approach
HIC	:	High Income Country
IPAQ	:	International Physical Activity Questionnaire
ITU	:	International Telecommunication Union
LAPAQ	:	LASA Physical Activity Questionnaire
mHealth	:	Mobile Health
MELoR	:	Malaysian Elders Longitudinal Research
MET	:	Metabolic Equivalent for a Task
MOST	:	Multiple Optimisation Strategy Trial
MVPA	:	Moderate- to Vigorous Physical Activity
$_{\text{my}}$PAtHS	:	Malaysian Physical Activity for Health Study
NCD	:	Non-Communicable Disease
PA	:	Physical Activity
PBC	:	Perceived Behaviour Control
PDA	:	Personal Digital Assistant
PE	:	Physical Education
RCT	:	Randomised Controlled Trial
SCT	:	Social Cognitive Theory

SES	:	Social Economic Status
SMS	:	Short Message Service
SPSS	:	Statistical Package for the Social Sciences
TPB	:	Theory of Planned Behaviour
TTM	:	Transtheoretical Model of Health Behaviour Change
UN	:	United Nations
WHO	:	World Health Organization

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CHAPTER 1: INTRODUCTION

1.1 Introduction

The media commonly labels it “silver tsunami”, “ageing boom” or “demographic shift”. However, whatever term is chosen, the phenomenon referred to is the same, namely, unprecedented global population ageing that occurs at a rapid pace (United Nations, Department of Economic and Social Affairs, Population Division, 2013). The increased life expectancy of the global population and the increased time many humans enjoy in good health today would have probably sounded like a fairy tale to previous generations. Although many questions remain unanswered to this day, scientists have made great progress in explaining and delaying human ageing. One factor that influences the ageing process is the individual lifestyle. To this end, what is certain is that being physically active and doing exercise are strong predictors of healthy ageing (World Health Organization [WHO], 2010; WHO, 2015). With this, to promote physical activity (PA) and exercise in a largely inactive older adult population is of great importance. In this thesis I will present a study that used modern technology, text-messaging, to support older adults from an upper-middle income country, Malaysia, to exercise. In this first chapter I provide some background to the research problem.

1.2 Population Ageing

1.2.1 Global Trends

Population ageing is a phenomenon of the 21st century that will likely continue (Christensen, Doblhammer, Rau, & Vaupel, 2009; Rowe, 2015). For example, 841 million or 11.7% of the global population were 60 years or older in 2013. In 2050, however, experts projected that over 2 billion people (21.1%) will be at least 60 years old (United Nations, Department of Economic and Social Affairs, Population Division, 2013).

Conceptually, population ageing occurs when fertility decreases and life expectancy increases. This leads to a demographic shift in the composition of a population with a smaller share of children and a larger share of adults as well as older adults (Bloom, Canning, & Lubet, 2015). Table 1.1 displays the global fertility and life expectancy trends from 1950 to 2050. The numbers clearly indicate that fertility decreases and life expectancy increases. With this, in 2047, for the first time in history older adults aged 60 years and older will outnumber children (United Nations, Department of Economic and Social Affairs, Population Division, 2013).

Table 1.1: Global Fertility and Life Expectancy Trends (United Nations, Department of Economic and Social Affairs, Population Division, 2013)

Time period	Fertility (children per women)	Life expectancy (years from birth)
1950-1955	5	Developed regions: 65 Less developed regions: 42
2010-2015	2.5	Developed regions: 78 Less developed regions: 68
2045-2050	1.8 - 2.2	Developed regions: 83 Less developed regions: 75

Further, health care quality in many countries increased. As a consequence, older adults are also growing older (Bloom et al., 2015). For example, life expectancy at the age of 60 rose from about 18.2 years in 1990 to about 20 years in 2012. This trend is responsible for accelerated population ageing (WHO, 2014).

According to the United Nations (UN, 2013) and the WHO (2014) population ageing is especially fast in countries other than high-income countries (HICs) with 83% of the global older adult population residing in such countries by 2050.

1.2.2 Population Ageing in Malaysia

Malaysia is an upper-middle income country that shows accelerated population ageing. The current population of Malaysia is about 30 million, and with an annual population growth of 1.3% (2015 to 2020), it is one of the fastest growing societies in the Western-Pacific Region (Tey et al., 2015; WHO, 2014). The Department of Statistics Malaysia (2012) projected that in 2040, Malaysia's population will have increased to 38.6 million. Increased wealth has brought improvements to the medical and hygiene sectors in Malaysia (Noor Safiza et al., 2008) thus people are living longer, with older adults making up one of the largest segments of the population. In 2015, 5.8%, or 1.8 million people, in the total population of Malaysia were 65 years or older. It is estimated that by the year 2040 the proportion of older adults will almost double and reach 11.4%, about 4.4 million people (Department of Statistics Malaysia, 2012). Further trends underpinning the accelerated population ageing in Malaysia are shown in Table 1.2. With this, the Department of Statistics Malaysia (2012) anticipates that in 2021 Malaysia will be an ageing society.[1]

[1] Based on the United Nations, an aging society is present when the population aged 65 and over achieves 7% of the total population.

Table 1.2: Population Ageing Indicators for Malaysia

Life expectancy at birth (years)	**Life expectancy at age 60 (years)**	**Healthy life expectancy at birth (years)**
1990: 71 2012: 74	1990: 17 2012: 19	2012: 64

Note: Healthy life expectancy at birth refers to the years a person is expected to live without disability (WHO, 2014).

1.3 Consequences and Opportunities of Population Ageing

According to Christensen et al. (2009) the "gain in life expectancy stands out as one of the most important accomplishments of the 20th century" (p. 1196). However, the steep increase in the proportion of older adults will affect current and future societies (Bloom et al., 2015; Rowe, 2015). First, problems might occur to support the growing older population (Bloom et al., 2015). This can mean increased stress for family members and/or national pension systems (Ezeh, Bongaarts, & Mberu, 2012; United Nations, Department of Economic and Social Affairs, Population Division, 2013). Second, public and private health expenditures might rise because the prevalence of non-communicable diseases (NCDs), disability, and complex health problems is likely to increase when a population is ageing (Christensen et al., 2009; Rechel et al., 2013; Rowe, 2015). For example, total expenditure on health in Malaysia increased from 3.0% of the gross domestic product (GDP) in 2000 to 3.8% in 2011 (WHO, 2014). Denton and Spencer (2010) attributed such an increase partly to population ageing. Third, Bloom et al. (2015) explained that workforce participation decreases with increasing age. Additionally, an increase of burden of disease in the growing older population reduces workforce participation further. This might lead to slow or even reversed economic growth.

However, there is also compelling support for the notion that population ageing bears many opportunities and advantages if societies adapt appropriately to the changing demographic landscape (Rowe, 2015). First and foremost, longer lives can mean that more people are able to meaningfully contribute to society (Rechel et al., 2013; Rowe, 2015). This presupposes that older age is accompanied by good health because people who age healthily have a strong drive to develop skills, volunteer, and remain in the workforce (Christensen et al., 2009; Rechel et al., 2013). Thus, older adults can be an economic asset and a valuable resource (Bloom et al., 2015). Rechel et al. (2013) who conducted in depth research on ageing and its impact on economies and health care systems in the European Union (EU) argued that ageing is not necessarily a "drain on health care resources…if increased life expectancy is accompanied by a similar proportion in good health" (p. 1314, 1315).

Healthy ageing is therefore in the interest of the individual as well as the society. This was underpinned by Dr. Margaret Chan, Director General of the WHO when she identified demographic change as a major priority of the WHO: "Good health must lie at the core of any successful response to ageing. If we can ensure that people are living healthier as well as longer lives, the opportunities will be greater and the cost to society less" (WHO, 2012, p. 3).

1.4 Successful Ageing

Healthy ageing is often tied to successful ageing, a concept that was popularized by Rowe and Kahn in 1987. According to the researchers, successful ageing has three criteria, "avoidance of disease and disability, maintenance of high physical and cognitive function, and sustained engagement in social and productive activities" (Rowe & Kahn, 1997, p. 439). With this, successful ageing encompasses more than only physical health. Although this normative concept is not without shortcomings (Martinson & Berridge, 2015), it represents what older adults desire for themselves and what benefits societies the most. Therefore, successful ageing serves as a reference for ageing research and practice. This was underpinned by Martinson et al. (2015) who found that the majority of ageing researchers accepts Rowe and Kahn's model.

Later, Kahn (2003) emphasized that ageing successfully cannot be understood as a status that is existent or not, but it should be recognised as a process that older adults can influence when they engage in health promoting behaviours. To this end, Depp and Jeste (2006) reviewed 28 large studies and identified PA and exercise as important as well as modifiable behaviours that predicted individual successful ageing. This finding was supported by Sargent-Cox, Butterworth, and Anstey (2015) who noted that "regular PA is associated with many successful ageing domains" (p. 121) such as physical and psychological health. Finally, Ziegelmann and Knoll (2015) suggested that PA including exercise is one of the most important proximal health behaviours for older adults because it is directly linked to physiological processes that are responsible for improved health.

1.5 Effects of Physical Activity and Exercise in Older Adults

The effects of PA and exercise on successful ageing, especially in terms of health and functioning are well documented in the research literature (Macera, Cavanaugh, & Bellettiere, 2015; WHO, 2015). For example, Baker, Meisner, Logan, Kungl, and Weir (2009) assessed the role of PA on successful ageing based on the three criteria of Rowe and Kahn (1987) in 12,042 older Canadians. They showed that highly active older adults were

2.74 times, and moderately active older adults 1.83 times more likely to age successfully compared to their inactive contemporaries.

Södergren (2013) conducted a review on the predictors of healthy ageing in men and found that extended life expectancy, accompanied by good health and lowered probability of disability, was strongly associated with PA. Vogel et al. (2009) and others reported that PA and exercise positively impacted a number of metabolic risk factors for cardiovascular diseases, e.g., lipid profile, body composition, type 2 diabetes, and hypertension (Holme & Anderssen, 2015; Mazzeo & Tanaka, 2001; Petrella, Lattanzio, Demeray, Varallo, & Blore, 2005). Moreover, researchers from the American College of Sports Medicine (ACSM) noted that the total body fat mass can be reduced by up to 3.4% via moderate- to vigorous-resistance activities in previously not exercising older adults, and up to 4% can be lost with aerobic exercise training over a training period of 2 to 9 months. The authors also highlighted that higher intensities account for stronger effects. Finally, they pointed out that resistance training in older adults lead to increases in muscular strength that ranged from 25% to more than 100% (Chodzko-Zajko, Proctor, Singh, Salem, & Skinner, 2009). Further, PA and especially exercise in older adulthood benefit the immune system by increasing telomere length, the most important factor in biological ageing (Cherkas et al., 2008), preventing viral infections (Martin, Pence, & Woods, 2009), and increasing vaccine efficiency (Kohut et al., 2004).

Effects of PA and exercise can be also observed in terms of brain plasticity and cognitive functioning (Erickson, Gildengers, & Butters, 2013). For example, researchers have shown that exercising older adults have more brain volume than their inactive contemporaries (Colcombe et al., 2006). More specifically, hippocampal volume was up to 2% higher in older adults with increased fitness levels compared to less fit individuals (Erickson et al., 2009). This is important because increased hippocampal volume is significantly associated with better memory functions that normally decline with increasing age (Erickson et al., 2011). Interestingly, Colcombe et al., (2006) reported these effects also in older adults who only started recently to exercise.

Finally, PA and exercise affect mental health in older adults in terms of increased life satisfaction and well-being (Elavsky et al., 2005), protection against depressive and anxiety disorders (Pasco et al., 2011), and effective antidepressant for older adults with depression (Blumenthal et al., 1999). Drawing from the aforementioned studies, PA and exercise are integral, non-pharmaceutical ways towards successful ageing and an extended lifespan in good health (Chodzko-Zajko et al., 2009; Vogel et al., 2009).

1.6 Physical Activity and Exercise Recommendations for Older Adults

The ACSM and the American Heart Association (AHA) were the first to publish detailed recommendations on PA and exercise for older adults (Macera et al., 2015; Nelson et al., 2007). Later, the WHO recognised the positive health effects of regular PA for all age groups including older adults when they published their document on global PA recommendations for older adults in 2010. These recommendations were targeted at national policy makers and were intended to serve as a guide for a primary prevention approach for emerging NCDs. The WHO (2010) recommends older adults to perform a minimum of either 150 minutes of moderate aerobic activity per week or 75 minutes of vigorous aerobic activity weekly. A combination of both is also acceptable. Individuals not meeting these guidelines are considered insufficiently active. Further, it is vital that older adults engage in regular weekly muscle-strengthening exercises (ACSM, 2013; WHO, 2015).

It is important to emphasize that these recommendations constitute the minimum activity necessary to gain essential health benefits. The ACSM, AHA, and WHO urge older adults to exceed these recommendations in order to gain greater health benefits (Nelson et al., 2007; WHO, 2010). Accordingly, the optimal PA level is 300 minutes of moderate or 150 minutes of vigorous PA per week (or a combination of both). Structured exercise is one of the domains that should contribute to the overall PA. The only difference to the recommendations for adults is that the intensity of the activities for older adults is not absolute but subjective because of great individual differences in physical function and fitness (WHO, 2010).

1.7 Physical Activity and Exercise Levels of Older Adults

1.7.1 Global Physical Activity and Exercise Levels

Despite the global release of PA and exercise recommendations and the widespread promotion of PA and exercise participation in older age, PA and exercise prevalence is low (Macera et al., 2015). The authors of a recent systematic review included 53 studies that examined global PA levels in adults 60 years and older. The researchers provided some evidence on the low PA levels in older adults (Sun, Norman, & While, 2013). Although in most studies 20% to 60% of older adults met the various PA recommendations, researchers who used accelerometer data to make inferences about PA participation reported that only 0% to 17.2% met the recommendations. Since exercise is a subcategory of PA respective exercise levels are even lower. Similarly, a study group from the United States measured PA with accelerometers in a large cohort. In this study, older adults aged 60 to 69 years spent literally no time in vigorous intensity activities/exercise, whereas time in moderate activities ranged from 6 to 10 minutes per day. With this, only 2.3% of older adults were active at recommended levels (Troiano et al., 2008). A similar picture was drawn by researchers of a recent accelerometer study in Germany. The researchers found that older adults spent only 2% of their day in moderate or vigorous PA (Ortlieb et al., 2014). A study group in the United Kingdom also combined objective and subjective instruments to measure PA in 1,787 older adults aged 60 to 64 years. Accelerometer data indicated that energy expenditure from moderate PA approached zero, and virtually no time was spent in vigorous PA/exercise. Moreover, merely 2.2% of the total sample met the WHO PA guidelines (including strength training twice weekly) (Golubic et al., 2014).

Although there are some indications that PA is slightly increasing in some HICs (National Center for Health Statistics, United States, 2013), there is growing evidence that the adoption of a Western lifestyle in some regions is associated with declining PA and exercise levels (Peters et al., 2010). Abouzeid, Macniven, and Bauman (2008) undertook a comprehensive review on the PA levels in the Asia-Pacific. They reported that in almost all countries (21 out of 24) PA levels declined with increasing age. The authors also suggested that older adults were the least active age group.

I was not able to identify studies that provided data on exercise levels in older adults. However, as exercise is a subcategory of PA (Caspersen, Powell, & Christenson, 1985; Centers for Disease Control and Prevention [CDC], 2011) I conclude that exercise levels in older adults are lower than PA levels.

1.7.2 Physical Activity and Exercise Levels of Older Malaysians

There is not much published data on PA levels of older Malaysians, but data available confirms the general trend in the Asia-Pacific region. The Malaysia Adult Nutrition Survey provided data that indicated that Malaysian adults have an average PA level of 1.6 (total daily energy expenditure to basal metabolic rate; sedentary: 1.40-1.69, moderately active: 1.70-1.99, vigorously active: 2.00-2.40) and are therefore considered inactive. Further, only 16.2% of adults between 50 and 59 years were adequately active, defined as 20 minutes of PA 3 times a week (Poh et al., 2010). Researchers, who used the same data set reported that only about 54% of older adults, 55 years and older, adhered to the WHO PA recommendations (Teh et al., 2014). More recently, PA levels of 145 older men were assessed by Ibrahim, Karim, Oon, & Ngah (2013) using the short version of the International Physical Activity Questionnaire (IPAQ short) (Craig et al., 2003). The weekly median activity score was 90 (IQR = 149). The researchers derived this score by multiplying the weekly minutes of moderate PA and walking by one and the weekly minutes of vigorous PA by two. A score of 90 led the authors to the conclusion that older Malaysian men are insufficiently active according to the WHO guidelines. Finally, Kaur et al. (2015) confirmed this by reporting that 88% of older Malaysians lack PA and exercise. Hence, increasing the low PA and exercise levels of older Malaysians is an undertaking of great importance.

1.8 Problem Statement

Levels of PA and exercise in older adults are alarmingly low and declining with increasing age (Sun et al., 2013). Researchers who assessed PA levels in Malaysia confirmed this and reported that older adults are insufficiently active (Ibrahim et al., 2013; Kaur et al., 2015; Poh et al., 2010; Teh et al., 2014). This is problematic because PA and exercise are important factors of health and well-being in older adulthood. Further, increasing the PA and especially exercise participation in the older adult population is likely to reduce the burden on the health care system (Chodzko-Zajko et al., 2009). It is therefore crucial to develop, implement and evaluate interventions to promote PA and exercise participation in older adults.

1.9 Study Purpose

The purpose of my study is to examine the effect of mobile phone text messages on the effect of an exercise intervention on exercise frequency among older Malaysians in a randomized controlled trial (RCT).

1.10 Study Objectives

There are six objectives to this study. These are:

1. To examine the effect of mobile phone text messages sent over a period of 12 weeks on the effect of an exercise intervention on weekly exercise frequency in older adults.
2. To identify the strongest predictor of weekly exercise frequency from an exercise intervention in older adults.
3. To examine the effect of mobile phone text messages on weekly exercise frequency in older adults after adjusting for the effect of the strongest predictor of exercise frequency.
4. To examine the moderating effect of the strongest predictor of weekly exercise frequency in the relationship between mobile phone text messages and weekly exercise frequency in older adults.
5. To examine the effect of mobile phone text messages on weekly exercise frequency in older adults after removing the text messages.
6. To examine the effects of mobile phone text messages on the effects of an exercise intervention on secondary outcomes: exercise duration, exercise self-efficacy, PA-related energy expenditure, daily sitting time, body mass index (BMI), grip strength and lower body strength.

1.11 Significance of the Study

To my knowledge, this study is one of first that assesses the effects of encouraging text messages on exercise participation in older adults. It is also one of the first studies to examine a mobile health (mHealth) approach to promote exercise participation in a country other than a HIC (Vandelanotte et al., 2016).

1.11.1 Theoretical Contribution

Although there is some preliminary evidence suggesting that mHealth, and especially text-messaging approaches are successful (Buhi et al., 2013; Cole-Lewis & Kershaw, 2010), only a few trials recruited older adults and even less were conducted in a non-HIC (Müller & Khoo, 2014, Vandelanotte et al., 2016). Further, the only trial I could identify that used text messages in older adults to promote PA provided no information on the long-term maintenance of PA behaviour after removing the text messages (Kim & Glanz, 2013).

With my study I may inform the research community on the suitability and efficacy of an mHealth approach to support behaviour change, particularly exercise, in older adults residing in a non-HIC. The knowledge gained from my study might trigger new research efforts geared towards the assessment of the feasibility of text messages to impact other health behaviours in this age group and across other non-HICs. Further, with this study I provide information on the long-term effects of text messages on health behaviour in older adults. I also anticipate that the findings from my study will serve as an anchor for researchers who want to explore mechanisms of mHealth interventions in older adults and in non-HICs.

1.11.2 Practical Contribution

The findings from my study may be useful for the private and public health sectors and its representatives intending to implement a feasible, potentially effective, and inexpensive intervention to promote health behaviour in the growing older adult population. My study can further be a guide for respective intervention developers who plan to intervene on the population level. Finally, my study can lead to significant adjustments of the way behaviour health interventions are delivered in other non-HICs with limited resources.

1.12 Definition of Terms

1.12.1 Text Message

A text message, also called short message service (SMS), is a brief electronic message that can be sent from one mobile phone to another or several other mobile phones. New technological developments also allow text messages to be sent via the Internet. Although a text message contains maximum 160 characters, many messages can be combined in to a larger text message.

1.12.2 Exercise

The terms PA, exercise, and sport are often used interchangeably even though they are scientifically clearly distinct. PA is the umbrella term of human movement. The term is defined as any bodily movement that is produced by the skeletal muscles leading to energy expenditure (Caspersen, et al., 1985) above individual basal level (ACSM, 2013; CDC, 2011).

Exercise is a subcategory of leisure time PA and is defined as planned, structured, repetitive activity that is executed by individuals to either maintain or improve one or more components of physical fitness, performance or health (Caspersen et al., 1985; CDC, 2011). With this, despite obvious similarities to PA exercise is different from other PAs like housework or gardening because the latter activities are commonly not performed to increase fitness, performance or health (Caspersen et al., 1985). In this study I adopted the exercise definition as stated above because the intervention described in my study is a structured exercise programme and the text messages are supposed to support participants to exercise.

1.12.3 Older Adult

There is no clear age cut-off that defines an older adult because ageing is usually seen as a lifelong process starting from birth and ending with death (WHO, 2012). Generally, the UN and the WHO, in their population and health reports, refer to an older adult as a person who is 60 years or older (United Nations, Department of Economic and Social Affairs, Population Division, 2013; WHO, 2014). The Department of Statistics Malaysia (2012) uses 65 years as the cut-off age. However, for my study I chose the age of 55 years as the cut-off age because that was the official retirement age in Malaysia until 2013.

1.13 Organisation of the Thesis

My thesis consists of five chapters and I organised it in a conventional way. In the introductory chapter I provide the rationale for the study. Here I present the problem statement, the purpose of the research, and the research objectives. In Chapter 2 I discuss the literature relevant for my study. Essentially, I will inform the reader about the current research in terms of health behaviour change theories and techniques, and about the emerging field of mobile phone, especially text-messaging interventions for behavioural health with particular focus on PA and exercise studies. I will introduce the methods of my study in Chapter 3. In this chapter I included information on the study design, study intervention, study instruments, and data analysis. In Chapter 4 I will display the findings of my study. In the final chapter, Chapter 5, I will discuss the research findings in light of the current state of knowledge. The study limitations, the implications of my study, and suggestions for future research are also part of this chapter.

1.14 Summary

In this chapter, I first introduced the phenomenon of population ageing and its implications for individuals and societies. Second, I highlighted that successful and healthy ageing is of utmost importance to older adults, health care systems, and economies. Third, I pointed to the great importance of PA and exercise to preserve health and independence in older adults. Lastly, I presented recent studies suggesting that global and local PA and exercise levels among older adults are alarmingly low, and called for innovative approaches to promote PA and exercise in this population. Finally, I introduced the problem statement, research purpose, and research objectives before highlighting the significance of the study and defining relevant terms. In the following chapter I will discuss the literature relevant to my study.

CHAPTER 2: LITERATURE REVIEW

2.1 Introduction

Modern day PA and exercise research is relatively young (Müller, Ansari, Ale Ebrahim, & Khoo, 2015) and can be traced back to 1953 when Morris and Heady published their seminal paper on the positive associations between work-related PAs and lower risk of cardiovascular disease as well as all-cause mortality in the British Journal of Industrial Medicine. Their findings were later confirmed by researchers from the United States (Leon & Blackburn, 1977; Paffenbarger, Wing, & Hyde, 1978). In addition, scholars from The Netherlands provided initial evidence on the relationship between habitual walking, cycling, and gardening and reduced risk of heart diseases (Magnus, Matroos, & Strackee, 1979). Based on these early research efforts and accumulating evidence on the health benefits of PA and exercise over the following decades, several consensus statements and recommendations were issued that served as guides for PA and exercise adoption. However, PA levels were in decline and prescription based PA and exercise programmes that were thought to be a remedy for inactive individuals did not yield the desired outcomes (Dunn, Andersen, & Jakicic, 1998).

Since then various approaches to increase different types of PAs were systematically designed, implemented, and evaluated by a growing number of researchers. The knowledge gained from the respective studies built the basis for current interventional PA and exercise research. Of special importance to the development of interventions was the integration of psychological and particularly behaviour change theories. This was coupled with the emergence of the field of exercise psychology within the American Psychological Association (APA) in the 1980s, a crucial impulse for interventional PA and exercise research (Baranowski, 2004; Dunn et al., 1998). The use of behavioural theory that comprises psychological, social, educational, and other theories as well as relevant constructs has since become common practice for interventionists that seek to change PA and/or exercise levels in the general population (Baranowski, Anderson, & Carmack, 1998; Dunn et al., 1998). For example, one of the first research groups who applied behavioural theory to change PA employed the Health Belief Model (Hochbaum, Rosenstock, & Kegels, 1952; Rosenstock, 1974) to encourage 124 firefighters to exercise (Lindsay-Reid & Osborn, 1980).

In this chapter I provide the reader with an overview of the relevant research related to my study. A brief literature review on self-efficacy as a key predictor of PA and exercise behaviour for all age groups (Williams & French, 2011) including older adults (McAuley, 1992) will be followed by a description of four major behaviour change theories and models that include self-efficacy as one of their key predictors of behaviour change (Ashford, Edmunds, & French, 2010). With this section I want to give the reader some background on how health behaviour change can be explained. I will then introduce the recently emerging behaviour change techniques (BCTs) (Abraham & Michie, 2008; Olander et al., 2013; Williams & French, 2011). These techniques are supposed to lead to actual health behaviour specifically PA and exercise, and diet. In the final section of this chapter I will focus on the use of mobile phone technology, particularly text-messaging as a means to promote health behaviour, especially in the realms of PA and exercise. In accordance with the target population of my study I will primarily focus on older adults whenever possible.

2.2 Self-Efficacy as Key Predictor of Physical Activity and Exercise Behaviour Change

In his 1977 article, Albert Bandura stressed that cognitive theories are central to the explanation of behaviour. He also described the central role of self-efficacy in behavioural change processes by refuting earlier beliefs that behaviour can be primarily predicted by outcome expectations. Bandura (1997) defined self-efficacy as "the belief in one's capabilities to organize and execute the courses of action required to produce given attainments" (p. 3). With this, self-efficacy determines the activities an individual chooses, the effort he expends, and the persistence he/she shows when obstacles arise. Bandura (1997) further proposed four sources of self-efficacy, (1) performance accomplishments, (2) vicarious experience, (3) verbal persuasion, (4) physiological or affective states, and explained that there are methods to influence efficacy beliefs.

Self-efficacy has since emerged as the central construct of major theoretical models within health psychology and within the realms of health behaviour research (Ashford et al., 2010). In terms of exercise behaviour change, McAuley (1992) suggested that self-efficacy is "the belief that one is capable of successfully adopting and maintaining a regular exercise regimen" (p. 66). He further highlighted that exercise self-efficacy is of pivotal importance to behaviour change. This conclusion was mainly drawn from earlier correlational research reporting on the strong predictive qualities of self-efficacy on PA and exercise adoption and maintenance in adults (Sallis et al., 1986; Sallis, Hovell, & Hofstetter, 1992). Other researchers confirmed these findings for different populations including employees (Kaewthummanukul & Brown, 2006), university students (Rovniak, Anderson, Winett, & Stephens, 2002), adolescents (Plotnikoff, Costigan, Karunamuni, & Lubans, 2013), and ethnic minorities in the United States (Sharma, Sargent, & Stacy, 2005). Further, researchers who conducted experimental research showed that PA and exercise adoption and maintenance were significantly mediated by self-efficacy beliefs in formerly sedentary adults (Darker, French, Eves, & Sniehotta, 2010; McAuley, 1992) and older adults (McAuley, Jerome, Elavsky, Marquez, & Ramsey, 2003; van Stralen, Vries, Mudde, Bolman, & Lechner, 2009). Finally, others have shown that exercise self-efficacy decreases with increasing age, thus, underscoring the importance of targeting exercise self-efficacy in interventions with older adults (Anderson-Bill, Winett, Wojcik, & Williams, 2011).

2.3 Major Behaviour Change Theories

Over the last few decades researchers developed many continuum and stage-based behaviour change theories and models, that incorporate self-efficacy as a key construct. Most of these theories have been applied in interventions that focussed on increasing PA and exercise behaviour across a number of populations (Schwarzer, 2008). Here, I will introduce four theories that are commonly applied in interventional PA and exercise research (Müller & Khoo, 2014; O'Brien, N. et al., 2015; Williams & French, 2011). These theories are rather generic and not targeted towards a specific age group as suggested by Ziegelmann and Knoll (2015). However, whenever possible I discuss research conducted with older adults.

2.3.1 Social Cognitive Theory (SCT)

Social Cognitive Theory (SCT) was initially developed as a social learning theory that explained how people learned in a social context (Bandura, 1977b, 1986). The earlier theory posits that learning and behaviours are primarily acquired through observation. In addition, the later SCT suggests that current behaviour is the result of personal (e.g., age, sex, ethnicity, cognitions like self-efficacy), behavioural (especially self-regulation), and environmental (especially social support) factors which continuously interact with each other (see Figure 2.1 for a simplified version of SCT).

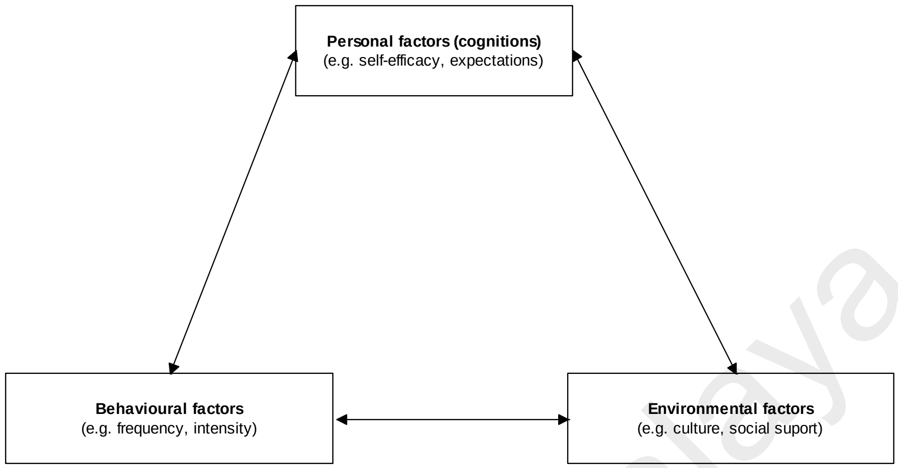

Figure 2.1: Triadic Reciprocally Model of Social Cognitive Theory

According to SCT, learning or behaviour acquisition can be accomplished by observing relevant models (including people, media, and texts). In order for the observations to be effective, the individual must pay attention, retain important information for later use, execute the behaviour, and be motivated. Further, the individual must be introduced to the expected positive and negative consequences of the behaviour (outcome expectations) and the likelihood of attaining them. Self-efficacy, as I defined earlier, is another construct that affects the translation of observations into own behaviours. Additional constructs that are important within the SCT are goal setting, self-regulation, coping, reinforcement, behavioural capabilities, and social support.

Recently researchers conducted a meta-analysis where they examined the predictive power of SCT on PA in all possible populations (Young, Plotnikoff, Collins, Callister, & Morgan, 2014). The authors of the meta-analysis used Bandura's SCT model that was specifically designed for health behaviours (Bandura, 2004) (see Figure 2.2).

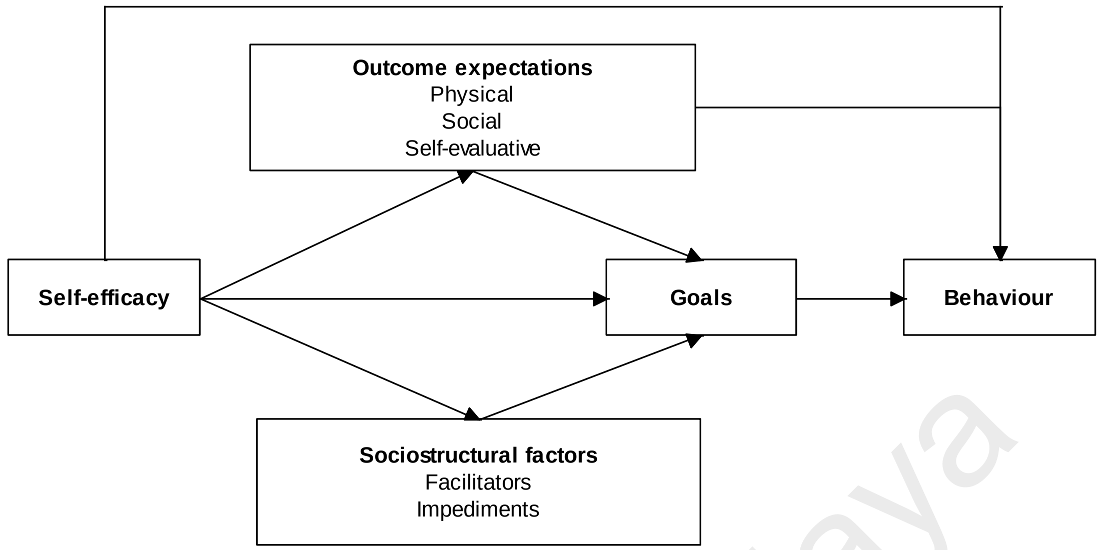

Figure 2.2: Social-Cognitive Theory Model for Health Behaviours (Bandura, 2004)

From this model one can see that self-efficacy and outcome expectations are proposed to have a direct impact on behaviour. Hence, the researchers included correlational studies that included self-efficacy and outcome expectations as primary predictors of PA. From the analysis of 55 models (in 44 studies) SCT explained 31% of the variance in PA ($p < .001$). Further analysis revealed that self-efficacy and goals (including behavioural goals/intentions and self-regulatory skills) were consistent predictors of PA whereas outcome expectations and socio-structural factors were not. In addition, most studies that specifically focussed on older adults reported that self-efficacy and self-regulation are primary predictors of PA whereas social support seems to also have an impact.

The findings from this meta-analysis were confirmed by researchers who conducted a cross-sectional study (Anderson-Bill, Wojcik, Winett, & Williams, 2006). The authors examined the psychosocial determinants proposed in the SCT in terms of PA behaviour in a sample of 999 adults and older adults in the United States. Figure 2.3 displays the model the researchers tested via structural equation modelling.

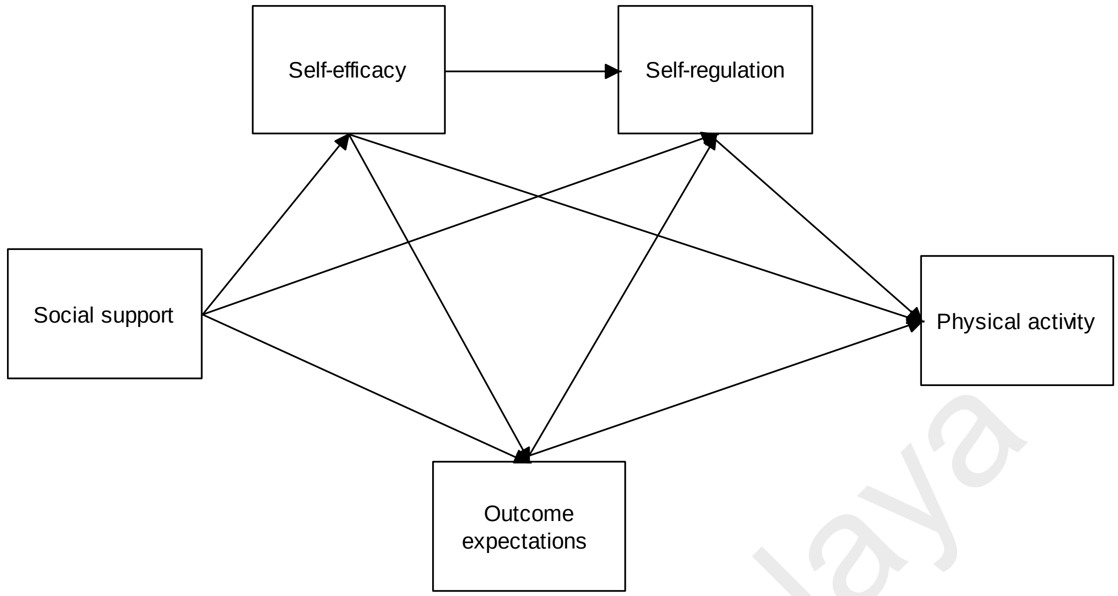

Figure 2.3: Social-Cognitive Model for Physical Activity (Anderson-Bill et al., 2006)

The researchers reported that perceived social support, self-efficacy and self-regulation contributed significantly to PA. Self-regulatory strategies (e.g., planning and scheduling PA) had the strongest impact on PA. Partially contradictory to the proposed model, self-efficacy had little impact on PA but contributed strongly to self-regulation and was thus considered to be indirectly related to PA. Social support, however, had an even stronger effect on self-regulation and also influenced self-efficacy significantly (Anderson-Bill et al., 2006). In a later study on older adults Anderson-Bill et al. (2011) confirmed these results. They reported that social support strongly related to self-efficacy and self-regulation. Further, self-efficacy directly affected PA and self-regulation, whereas self-regulation moderately predicted PA. The authors also evaluated an SCT-based intervention and found that increased self-efficacy levels acquired during the intervention were mainly responsible for maintaining PA behaviours.

In summary, the results from the meta-analysis and the individual studies suggest that self-efficacy, social support, and self-regulatory skills are important predictors of PA in older adults. Researchers should target these constructs in interventions if possible.

However, despite these SCT constructs explaining a large proportion of the overall PA variance most interventions fall short in including all relevant constructs. Moreover, strategies that are meant to affect these constructs vary (Baranowski et al., 1998). Additionally, to my knowledge, no review has been published that examined the effects of SCT-based interventions on PA and exercise, and hence, precise causal inferences of the utility of SCT to promote PA and exercise behaviour in interventions are difficult to make.

2.3.2 Transtheoretical Model of Health Behaviour Change (TTM)

The Transtheoretical Model of Health Behaviour Change (TTM) is a stage-based model. In this model changes in behaviour are not of abrupt nature and are unlikely to be explained by a single theory (DiClemente & Prochaska, 1982; Schwarzer, 2008). Prochaska and DiClemente developed the TTM based on therapeutic literature, different theoretical approaches in psychotherapy (Prochaska & Velicer, 1997), and their own studies on smoking cessation (DiClemente & Prochaska, 1982; Prochaska & DiClemente, 1983; Prochaska & DiClemente, 1986).

After extensive research, several amendments, and the inclusion of new stages and other constructs the contemporary TTM consists of five core constructs: six stages of change, ten processes of behaviour change, decisional balance, self-efficacy, and temptation (Prochaska & Velicer, 1997). According to the founding authors an individual progresses through qualitatively different stages of behavioural change over time. The stages and their characteristics are displayed in Table 2.1.

Table 2.1: Stages of Behaviour Change in the TTM (Prochaska & Velicer, 1997)

Stage of Behaviour Change	Characteristics
Precontemplation	Individual has no intention to change behaviour for the next six months
Contemplation	Individual has intention to change behaviour within next six months
Preparation	Individual has intention to take action in immediate future usually within one month
Action	Individual has changed behaviour during last six months
Maintenance	Individual works towards preventing relapse for six months to 5 years
Termination	Individual has 100% confidence that he/she will stick to behaviour in any circumstances

Progress through stages is influenced by 10 processes of change that people use to alter cognitions, affects, and behaviours. The processes that are considered important for interventions are: consciousness raising, dramatic relief, self-re-evaluation, environmental re-evaluation, self-liberation, social liberation, counterconditioning, contingency management, stimulus control, and helping relationships. Different processes of change operate at different stages of change and processes might also differ in importance depending on the behaviour. Cognitive and affective processes were reported to be more important in earlier stages, whereas behavioural processes are more crucial in later stages (e.g., social support) (Nigg et al., 2011). Stage progression is also dependent on the decisional balance of individuals. According to Prochaska and Velicer (1997) for an individual to progress to the next behavioural stage it is necessary to develop a positive decisional balance in the form of reducing negative perceptions (cons) and increasing positive perceptions (pros) of changing behaviour (e.g., reduce the perception that exercise is difficult and increase the perception that exercise is good for health). The construct self-efficacy as conceptualised by Bandura (1977, 1997) is also seen to be an essential determinant of stage progression. Self-efficacy needs to increase to enable progression to the next stage but its importance decreases in higher stages (Nigg et al., 2011). Finally, the fifth construct of TTM, temptation, is the opposite of self-efficacy and refers to the commitment of an individual to the health promoting behaviour in the face of challenges/temptations (e.g., sticking to exercise when one's favourite TV show is on). Temptations need to decrease to enable stage progression (Nigg et al., 2011).

Initially developed for addictive behaviours (Prochaska, DiClemente, & Norcross, 1992), many researchers applied the TTM in research and practice of health behaviours including PA and exercise (Bridle et al., 2005; Hutchison, Breckon, & Johnston, 2009; Marshall & Biddle, 2001). Marshall and Biddle (2001) who conducted an early meta-analysis of 71, mainly cross-sectional, PA and exercise studies confirmed, overall, the theoretical notion of TTM that stage membership is associated with different levels of behaviour, self-efficacy, pros and cons as well as processes of change. For example, exercise and PA increased with stage progress with the largest effect size from 'preparation' to 'action' ($d = 0.85$). This transition is where cognitions like self-efficacy are proposed to be particularly important.

In addition to the predictive capabilities of TTM in terms of health behaviour, Prochaska and colleagues argued that the TTM is especially useful for interventions. Interventions can easily be matched with the current behaviour stage of individuals to enhance effectiveness (Nigg et al., 2011; Prochaska & Velicer, 1997). For example, individuals in the preparation stage can be exposed to a cognitive intervention targeting self-efficacy. The effectiveness of stage-based approaches on health behaviour change was examined by Bridle et al. (2005). The researchers found that in only 11 out of 42 cases the TTM based interventions were more effective in changing health behaviour compared to non-stage-based interventions, usual care, or no-interventions (one of five in older adults). For PA, only one of eight comparisons favoured the TTM-based intervention. The researchers reported similar results for stage progression, indicating that TTM-based interventions are insufficiently effective in promoting health behaviour and stage progression. Interestingly, after the publication of the research by Bridle et al. (2005) it seems that not many additional studies were conducted using the TTM for PA and/or exercise behaviour change interventions (Nigg et al., 2011). The lack of evidence regarding the effectiveness of the TTM to promote PA and exercise behaviour might be related to the fact that TTM was initially developed for a different behaviour, smoking cessation. Arguably, PA and exercise behaviour change are more complex compared to smoking cessation (Nigg et al., 2011). It is also likely that other strategies and techniques need to be used to affect stage progression and PA.

In sum, the TTM is useful in explaining potential behaviour change processes in a generic manner but its usefulness for promoting PA and exercise behaviour is questionable.

2.3.3 Theory of Planned Behaviour (TPB)

The Theory of Planned Behaviour (TPB) (Ajzen, 1991) is an extension of the Theory of Reasoned Action (Fishbein & Ajzen, 1975). According to the developer of TPB, behavioural intentions can be predicted by three types of cognitions: attitude toward behaviour, subjective norm, and perceived behaviour control (PBC). The developed intentions are then thought to lead to behaviour (see Figure 2.4).

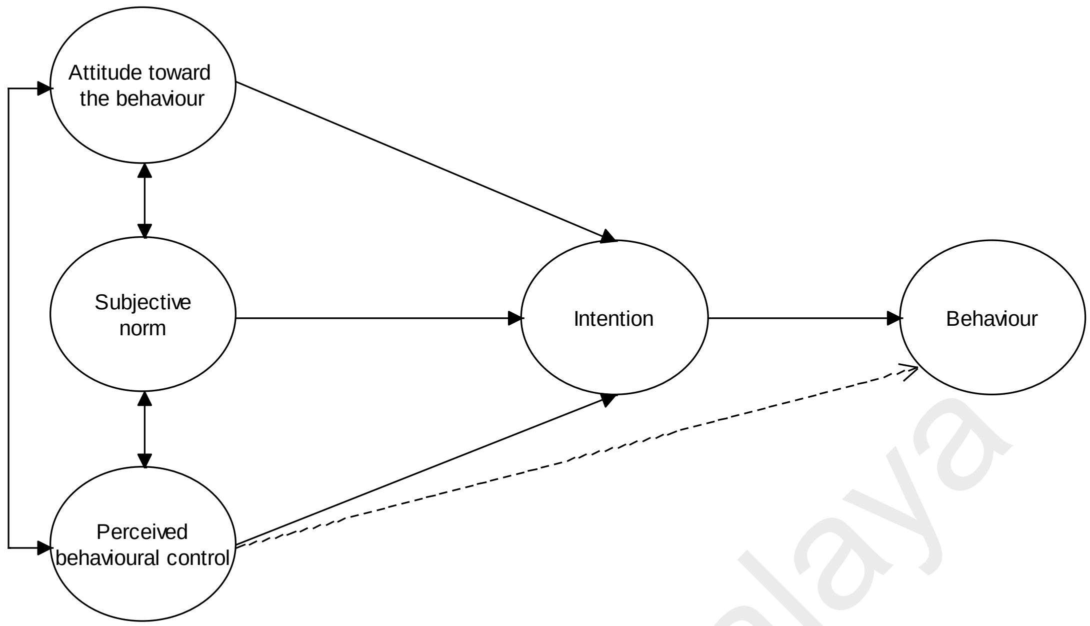

Figure 2.4: Model of the Theory of Planned Behaviour (Ajzen, 1991)

Behavioural attitudes are related to behavioural beliefs like outcome anticipations of the behaviour in question and feelings towards behaviour. This means that how people appraise behaviour determines how strong their intentions are. Subjective norms describe the social influence that others like family and friends have on individual behaviour. People who feel that others approve or even encourage behaviour develop stronger intentions. The construct PBC in the TPB derived from Bandura's self-efficacy (Bandura, 1977a) and is based on control beliefs (perceived capabilities of performing a specific behaviour). The more a person feels that he/she has the skills and resources to perform behaviour the stronger the behavioural intentions. Additionally, as can be seen in Figure 2.4, PBC is also a direct predictor of behaviour. This implies that PBC (self-efficacy) is particularly important because it affects behavioural intentions and behaviour.

The TPB is one of the most popular theories in health behaviour research (Armitage & Conner, 2001; Darker et al., 2010; Sniehotta, 2009). Many researchers reported on the predictive capacity of the TPB on PA and exercise intentions and behaviour in different populations (Armitage, 2005; Hagger, Chatzisarantis, & Biddle, 2002; Plotnikoff et al., 2013; Rhodes & Nigg, 2011). However, the studies conducted by the respective researchers were largely correlational and involved primarily younger people (Sniehotta, Presseau, & Araújo-Soares, 2014).

Although researchers often claim to apply the TPB, Hardeman and colleagues (2002) reported in their systematic review that TPB was seldom explicitly used in developing health behaviour interventions and that there is a lack of evidence on its effectiveness on impacting health behaviour. Within their review none of the three studies that applied TPB to promote PA or exercise behaviour reported results on actual behaviour and one study reported decreased exercise intentions. Others also criticised the lack of experimental evidence of TPB for promoting PA and exercise and called for rigorous testing (Rhodes & Nigg, 2011). Only Sniehotta (2009) conducted such experimental testing of TPB in the realm of PA. He systematically tested (1) whether the manipulation of behavioural, normative, and control beliefs affect the underlying constructs, (2) whether the changes in attitudes, subjective norm and PBC affect intentions, and (3) whether these changes in intentions translate into behaviour. He found that, although the manipulations affected cognitions and cognitions affected intentions, these intentions were not translated into behaviour. Only control beliefs (self-efficacy) significantly affected PA behaviour directly supporting the role of self-efficacy in PA and exercise behaviour interventions (Bandura, 1977a, 1997). The lack of evidence on the effectiveness of the TPB to promote health behaviour across populations was confirmed later by Sniehotta et al. (2014).

In conclusion, TPB is a theory that can be used to explain behaviour change. However, from the results of interventional studies TPB has limited potential to increase actual PA and exercise behaviour with only self-efficacy having some impact (Sniehotta, 2009). This led Sniehotta (2014) to question the utility of the TPB for behavioural health interventions.

2.3.4 Health Action Process Approach (HAPA)

The Health Action Process Approach (HAPA) developed by Ralf Schwarzer from the Free University Berlin, Germany is the most recent among the health behaviour change models, and it is gaining popularity (Schwarzer, 2008). The model is displayed in Figure 2.5. Schwarzer (2008) wanted to create a model that (a) is parsimonious, (b) bridges the intention-behaviour gap, (c) overcomes shortcomings of existing theories (e.g., TTM and TPB), and (d) is valid for different populations (Sheeran, 2002).

Schwarzer (2008) proposed that health behaviour change occurs in two broad phases: a motivational phase that leads to intentions and a volitional phase that translates intentions into actual behaviour. In addition to using a stage-based approach, HAPA also integrates distal behavioural determinants like risk perceptions, outcome expectancies, and self-efficacy that are supposed to predict stage progression or regression (Schwarzer, 2008). With this, before people intend to perform a behaviour they (a) must have some self-efficacy that they are able to perform the behaviour, (b) have expectations that the behaviour benefits them in some way, and (c) must perceive only limited risks when performing the behaviour. Self-regulatory skills in the form of planning are especially important to translate intentions into behaviour.

Schwarzer (2007) and others further recognised that self-efficacy is an essential determinant of behaviour change, but suggested that different modes of self-efficacy are important depending on the phase of behaviour change (Luszczynska, Mazurkiewicz, Ziegelmann, & Schwarzer, 2007). Figure 2.5 shows the different modes of self-efficacy in the respective behaviour change phases. In the motivational phase, pre-action self-efficacy is essential to generate intentions to behave (e.g., belief to be able to exercise regularly). Maintenance self-efficacy refers to an individual’s beliefs about his/her capabilities to continue with the behaviour in the face of barriers. The level of maintenance self-efficacy is important when translating intentions into behaviour (when plans for the behaviour and for how to deal with obstacles are developed) and when behaviour is initiated. Recovery self-efficacy is the perceived competence of re-starting the intended behaviour after relapsing. This is important when a behaviour is established but only when risks to relapse are present.

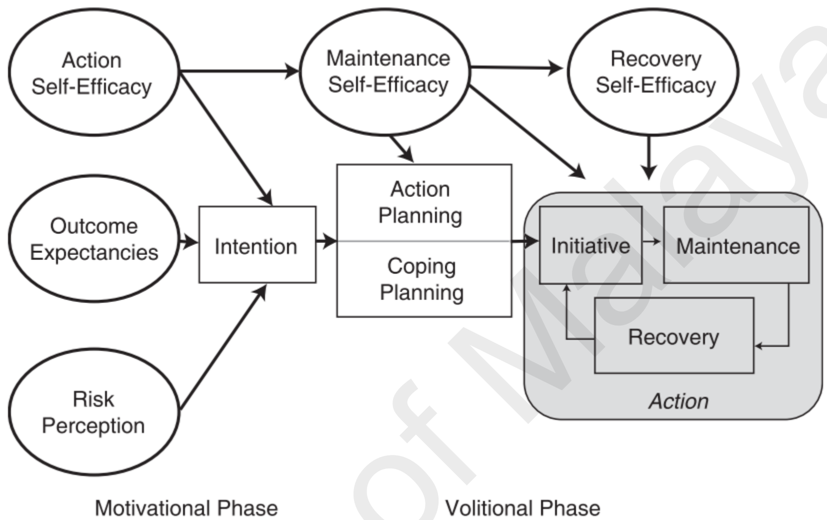

Figure 2.5*:* Model of the Health Action Process Approach (Schwarzer, 2008)

Schwarzer (2008) also provided initial evidence on the validity of HAPA for a number of health behaviours (e.g., exercise, diet, and seat belt use) and concluded that the model predicts behaviour well. Later, a number of other researchers who conducted studies on diet and PA/exercise provided further empirical support for the HAPA model (Barg et al., 2012; Lippke, Schwarzer, Ziegelmann, Scholz, & Schüz, 2010; Parschau et al., 2014; Wiedemann et al., 2009). For example, the HAPA model was tested in a cross-sectional study of obese adults and researchers showed that the proposed relationships between the constructs of the model were generally confirmed (Parschau et al., 2014). Similar results were reported by researchers who conducted a study on middle aged women (Barg et al., 2012).

In an experimental study, intenders who received a volitional intervention (they were asked to form PA plans) showed significant more stage progression than intenders who did not receive an intervention. The intervention effects on PA were significantly mediated by intentions and planning as proposed by HAPA. Additionally, the authors of this study reported that 77.8% of the theoretical predictions of HAPA were confirmed, thus, lending further support for the model (Lippke et al., 2010).

From the available evidence, the HAPA model is a useful theoretical framework because it integrates many important constructs of other theories (SCT, TTM, and TPB) into a single model. Despite this, researchers have shown that HAPA explains less than 25% variance of actual PA behaviour and specific studies in older adults are currently lacking (Barg et al., 2012; Lippke et al., 2010; Parschau et al., 2014). However, because the HAPA model is comparatively new, there are no systematic reviews and/or meta-analysis available that would provide more accurate information on its overall performance in promoting health behaviours.

2.4 Behaviour Change Techniques (BCTs)

Theories are ideally suited to explain behaviour change, and the application of theories to change health behaviour and its predictors within interventions is practical. Despite this, a number of researchers have highlighted shortcomings of the respective theories especially in terms of theory application in behavioural health interventions (Abraham & Michie, 2008; Bridle et al., 2005; Hutchison et al., 2009; Michie et al., 2011; Sniehotta, 2009; Sniehotta et al., 2014). For example, Sniehotta (2009) and Darker et al. (2010) cautioned that behaviour change theories suggest behavioural antecedents (e.g., self-efficacy or social support) but do fall short in specifying which Behaviour Change Techniques (BCTs) should be used to change these antecedents and to promote actual behaviour. Sniehotta (2009), after showing that the TPB has only a small impact on PA intentions but no impact on actual PA behaviour he suggested that the lack of tools and BCTs to change respective constructs and to promote behaviours makes the theory rather useless for behavioural health interventions. This might explain why many theories only explain a small amount of PA and exercise variance, especially in interventions.

Further, even though some theories do provide some guidance on which techniques interventionists should use to influence key constructs (for example SCT suggests using verbal persuasion to increase self-efficacy, (Bandura, 1977a)) researchers have reported that other BCTs than those suggested by the theories might be better suited to affect behavioural antecedents and promote behaviours (Ashford et al., 2010). With this, as I noted earlier, theories are helpful in explaining behaviour change and in providing guidance to describe behavioural change mechanisms in interventions, but that accurate BCTs are needed to influence behaviour.

2.4.1 Taxonomies of Behaviour Change Techniques

BCTs are the "active ingredients" that affect behaviour (Michie et al., 2013, p. 82). However, it is currently difficult to clearly identify which BCTs are effective because documentation of interventions are mostly imprecise and ambiguous (French, Olander, Chisholm, & Mc Sharry, 2014; Hutchison et al., 2009; Michie et al., 2011; Michie et al., 2013; Olander et al., 2013). For example, the strategy 'counselling' does not indicate which specific BCTs have been used to affect behaviour change (different BCTs, such as initiating self-monitoring, setting graded tasks, and general encouragement could be used for counselling). Further, the terminology used to describe BCTs varies and some researchers might give the same label to different BCTs (Michie et al., 2011) making it impossible to identify which BCT led to respective behavioural outcomes (Michie et al., 2013). Precisely labelling BCTs that are responsible for actual behaviour acquisition is therefore important. The absence of a vocabulary of specific BCTs, that would allow the scientific community to separate effective from ineffective techniques in respective domains, and that would enable practitioners to translate research findings, is unacceptable (Abraham & Michie, 2008).

Responding to the call for a comprehensive labelling system of BCTs for health behaviour interventions (Foster, Hillsdon, Thorogood, Kaur, & Wedatilake, 2005; Michie, 2008), Abraham and Michie developed a specific taxonomy of BCTs in 2008. After several systematic iterations, the first taxonomy consisted of 26 theory-linked BCTs. Subsequent tests of the BCT taxonomy by coding intervention studies were conducted by the researchers. Coding was based on a manual that defined the BCTs. Two researchers used this manual to identify the BCTs used in interventions. They did this to ascertain whether BCTs can be reliably identified. There was a 93% agreement between the researchers.

Michie et al. (2011) later refined this taxonomy in an effort to "improve its comprehensiveness, ease of use and reliability, by clarifying definitions and labels and identifying and adding additional techniques" (p. 1482). The resultant Coventry, Aberdeen & London - Refined (CALO-RE) taxonomy consists of 40 clearly labelled BCTs for PA/exercise and healthy eating interventions (see Table 2.2). The researchers recommended experimental research to identify which BCTs are effective in specific populations and for specific domains, and they encouraged the subsequent application of BCTs in interventional studies (Michie et al., 2011; Olander et al., 2013). There is a more current version of this taxonomy. The Behaviour Change Technique Taxonomy Version 1 (BCTTv1) consists of 93 BCTs that are hierarchically clustered into 16 categories (Michie et al., 2013). This taxonomy encompasses an even greater number of BCTs for most health behaviours. However, the CALO-RE taxonomy was specifically developed for PA/exercise and healthy eating and is therefore more relevant to my study.

Table 2.2: CALO-RE Taxonomy of Behaviour Change Techniques for Physical Activity and Healthy Eating (Michie et al., 2011)

Number	BCT
1	Provide information on consequences of behaviour in general
2	Provide information on consequences of behaviour to the individual
3	Provide information about others' approval
4	Provide normative information about others' behaviour
5	Goal setting (behaviour)
6	Goal setting (outcome)
7	Action planning
8	Barrier identification/Problem solving
9	Set graded tasks
10	Prompt review of behavioural goals
11	Prompt review of outcome goals
12	Prompt rewards contingent on effort or progress towards behaviour
13	Provide rewards contingent on successful behaviour
14	Shaping
15	Prompting generalization of a target behaviour
16	Prompt self-monitoring of behaviour
17	Prompt self-monitoring of behavioural outcome
18	Prompting focus on past success
19	Provide feedback on performance
20	Provide information on where and when to perform the behaviour
21	Provide instruction on how to perform the behaviour
22	Model/ Demonstrate the behaviour

Table 2.2 continued

Number	BCT
23	Teach to use prompts/ cues
24	Environmental restructuring
25	Agree behavioural contract
26	Prompt practice
27	Use of follow up prompts
28	Facilitate social comparison
29	Plan social support/ social change
30	Prompt identification as role model/ position advocate
31	Prompt anticipated regret
32	Fear arousal
33	Prompt self-talk
34	Prompt use of imagery
35	Relapse prevention/ Coping planning
36	Stress management/Emotional control training
37	Motivational interviewing
38	Time management
39	General communication skills training
40	Stimulate anticipation of future rewards

2.4.2 Identifying Effective Behaviour Change Techniques to promote Physical Activity and Exercise

Williams and French (2011) conducted an analysis of 27 PA and exercise interventions with the goal of identifying the most effective BCTs, to promote PA and exercise self-efficacy as well as actual PA and exercise behaviour. They included self-efficacy in the analysis because of its importance in promoting PA and exercise behaviour (McAuley, 1992, 1993; McAuley et al., 2011; McAuley et al., 2003). They reported that interventions using the BCTs 'action planning', 'reinforcing effort or progress towards behaviour' and 'provision of instructions' yielded significantly higher PA and exercise self-efficacy as well as PA and exercise effect sizes compared to interventions that did not include these BCTs. Table 2.3 provides detailed definition of these BCTs. The authors recommended using these BCTs for PA and exercise interventions to increase effectiveness.

Table 2.3: Definitions of the three Behaviour Change Techniques from the CALO-RE Taxonomy that Effectively Changed Self-Efficacy and Physical Activity in Adults (Michie et al., 2011; Williams & French, 2011)

BCT	Definition related to PA/exercise
Action planning	Detailed planning of a behaviour including specific information on when/in which situation, will what PA, at which place, be executed.
Prompt rewards contingent on effort or progress towards behaviour	Using praise or rewards for attempts at achieving a PA behavioural goal. These include efforts made towards achieving the behaviour, or progress made in preparatory steps towards the behaviour.
Provide instruction on how to perform the behaviour	Includes verbal or written advice on how to perform PA/exercise or preparatory behaviours, and instructions to follow a specific programme of PA/exercise.

2.5 Mobile Phone Technology to Promote Health Behaviour

Theories are important to explain behaviour change mechanisms and to identify which behavioural antecedents are important to target. BCTs provide researchers with the tools to affect behavioural antecedents and promote behaviour. The final building block is the delivery mode. In the next section I will focus on mobile phone text messages and its application in behavioural health interventions, especially targeting PA and exercise.

2.5.1 Brief History of Mobile Phone Technology

Mobile phones, as they now penetrate the lives of billions, are a recent invention. In April 1973, the American engineer Martin Cooper who was working for the company Motorola made the first wireless phone call in history with a mobile phone that weighed 1.1kg, was 25cm long and needed to be charged for 10 hours after about 20 minutes of talk time. Ten years later the first mobile phone, the Motorola DynaTAC 8000X was commercially available for about US$ 4,000. However, it was only in the late 1990s when mobile phones were widely available to the public with Nokia and Motorola being the pioneers in the mobile phone market. These companies provided mobile phones (e.g., the Nokia 6110, Motorola StarTac) that were small enough to be carried in pockets and were already equipped with the text-messaging function that was developed and refined between the 1980s and early 1990s (Agar, 2013; Goggin, 2012).

2.5.2 Current Mobile Phone Penetration

In 2014, 96% or 6.9 billion of the global population owned a mobile phone subscription with 121% of people in HICs (some people have more than one subscription) and 90% of people in non-HICs (3.6 billion people in Asia-Pacific) with subscriptions (International Telecommunication Union [ITU], 2014). This marked strong increments from 2000 (719 million people) and 2005 (2.2 billion people). Further, in many countries the number of mobile phones, including smartphones, is higher than the respective population which makes the mobile phone the most used information and communication technology (ITU, 2014). This also indicates that mobile phones have become an integral part of daily life for many people (Goggin, 2012). That is especially true in Asia which has recorded and will further record the largest number of subscriptions (ITU, 2014; Portio Research Ltd., 2013). For example, in 2012, the Asia-Pacific region contributed 51.3% to the global mobile technology subscriber base. In 2016 experts expect that this figure will increase to 54.3% (Portio Research Ltd., 2013).

The use of mobile phones is not limited to any specific age group as indicated by researchers of an early survey from the United Kingdom. They suggested that about 57% of older adults aged 65 - 74 years owned a mobile phone. Even though this appears to be low compared to younger age groups, the authors also highlighted the strongest increase of mobile phone usage in the group of older adults compared to all other age strata (United Kingdom, Office for National Statistics, 2004). Researchers analysing data from the 2011 United States National Health and Aging Trends Survey indicated that 75.9% of those aged 65 and older owned a mobile phone (N = 7,609 included in the study, representative sample), thus confirming the predicted increase of mobile phone ownership in older adults (Gell, Rosenberg, Demiris, LaCroix, & Patel, 2015). Also in Malaysia, the majority of older adults use a mobile phone (Malaysian Communications and Multimedia Commission, 2014). With this, the uptake of mobile phone technology in older adults is higher compared to past technologies (Gerber, Olazabal, Brown, & Pablos-Mendez, 2010). This trend seems to continue with some older adults reporting that their mobile phone has become very important (Hardill & Olphert, 2012). However, the frequency of mobile phone use depends largely on whether older adults perceive them as personally relevant, beneficial or necessary to their daily lives (Gell et al., 2015; Vroman, Arthanat, & Lysack, 2015).

2.5.3 Mobile Phone Technology for Promoting Health Behaviour

The use of mobile phone technology and especially text-messaging to promote health and particularly behavioural health has a short history, and according to Hall, Cole-Lewis, and Bernhardt (2015) related research is in its adolescence. From the systematic review by Head, Noar, Iannarino, and Harrington (2013) the first study that used mobile phone text-messaging for a health intervention was published in 2002 (Neville, Greene, McLeod, Tracy, & Surie, 2002). The evidence base has increased since then and was initially summarised in the first systematic review published in 2009 by Fjeldsoe, Marshall, and Miller. Although research has only been evolving for slightly more than a decade, the field is moving fast as there are now more than 20 systematic reviews and meta-analyses that focus on mobile phone delivered health interventions (Hall et al., 2015).

2.5.3.1 Advantages of Mobile Phones and Text-Messaging for Health Behaviour Interventions

The primary advantage of mobile phones is that they are affordable and people in almost all populations, including disadvantaged groups (e.g., older adults, and people with low socio-economic status) own a subscription (Krishna, Boren, & Balas, 2009). Hence, groups who are traditionally hard to reach with health behaviour interventions and those living in resource poor settings can be accessed (Fjeldsoe, Miller, & Marshall, 2010; Gell & Wadsworth, 2014; Muntaner, Vidal-Conti, & Palou, 2015; O'Reilly & Spruijt-Metz, 2013) leading to an increased equity in health care delivery (Cole-Lewis & Kershaw, 2010). With this, population-level behavioural health interventions can be implemented conveniently and cost-effectively, an advantage compared to traditional counselling or other face-to-face interventions (Buchholz, Wilbur, Ingram, & Fogg, 2013). Furthermore, mobile phones are usually carried by the person throughout the day, and this pervasiveness can be utilized in interventions as intervention content can be accessed at any time and at any place (Gell & Wadsworth, 2014; O'Reilly & Spruijt-Metz, 2013).

Mobile phone text-messaging is particularly relevant for behavioural health interventions and an increasing number of researchers recognise its inherent potential (Cole-Lewis & Kershaw, 2010; Krishna et al., 2009; Wei, Hollin, & Kachnowski, 2011). This is mainly because text-messaging is reported to be the mobile communication channel that is most frequently used with 8 trillion messages sent worldwide in 2013 (Liu, 2013). Table 2.4 displays the main advantages of using text-messaging for behavioural health interventions.

Table 2.4: Advantages of Text-Messaging for Health Behavioural Change Interventions

Advantages of text-messaging	**Implications for behavioural health interventions**
Popularity and frequent use of text-messaging across various populations and groups (Buchholz et al., 2013; Danaher, Brendryen, Seeley, Tyler, & Woolley, 2015; Sirriyeh, Lawton, & Ward, 2010)	• Population level interventions are possible (Gell & Wadsworth, 2014) • Minorities and disadvantaged groups can be reached • Familiarity with intervention delivery modality and hence, more comfort with potential interventions using text messages
Receiving text messages leads to unconscious pleasure induced by dopamine release (Weinschenk, n.d.)	• Behavioural interventions delivered via text messages are enjoyable and this can increase study retention

Table 2.4 continued

Advantages of text-messaging	Implications for behavioural health interventions
Non-invasiveness of text messages	• Intervention participants are not interrupted in daily routines compared to interventions that rely on face-to-face or phone-call contact (Fjeldsoe et al., 2010) • Intervention material can be accessed anytime and anywhere (Fjeldsoe et al., 2010; Gell & Wadsworth, 2014; Prestwich, Perugini, & Hurling, 2009)
No information overload due to brief intervention messages	• Increased intervention exposure
Text messages can be pre-programmed via online tools (Danaher et al., 2015; Sirriyeh et al., 2010)	• Participants and/or researchers can decide when an intervention is most crucial to influence behaviour (e.g., text message at lunch time to prompt a person to make healthy food choices) • Frequency of intervention text messages can be matched with individual preferences and needs
Specific and distinct audible signal upon text-message arrival (Danaher et al., 2015)	• Intervention content can be prompted to participants in a way that cannot be ignored (Danaher et al., 2015)

The characteristics of mobile phones, especially the text-messaging function, enable high-quality behavioural health interventions that can be delivered to a vast number of people at low cost (Gell & Wadsworth, 2014).

2.5.3.2 Overview of Mobile Phone and Text-Messaging to Promote Behavioural Health

Health interventions via mobile phones and especially text messages have been successful in various areas including, but not limited to, medication adherence, appointment keeping, medical test delivery, health information communication as well as disease and emergency tracking (Adler, 2007; Vodopivec-Jamsek, Jong, Gurol-Urganci, & Atun, 2012). Krishna, Austin Boren, and Balas (2009) were among the first to provide a comprehensive evidence-base on mobile phone interventions to promote health outcomes (including behavioural health outcomes) and processes of care. They reported that 80% of the 25 included studies identified a significant difference in health outcomes between participants in mobile phone interventions and control condition participants in favour of the former. Health behaviour was positively changed in 8 of 10 studies (e.g., smoking cessation, medication adherence, and stress management). Buhi et al. (2013) conducted a review in which they specifically evaluated behavioural health interventions via mobile phones. Of the 34 included studies the majority found significant positive behavioural changes following the mobile phone interventions.

In their conclusions, both author teams supported the use of mobile phones for health and behavioural health interventions. However, they could not infer the particular impact of text messages because none of the two reviews focussed specifically on text-messaging.

This gap was addressed by authors of seven reviews who included studies that used text-messaging as a mode of intervention delivery (Cole-Lewis & Kershaw, 2010; Fjeldsoe et al., 2009; Head et al., 2013; Militello, Kelly, & Melnyk, 2012; Siopis, Chey, & Allman-Farinelli, 2014; Vodopivec-Jamsek et al., 2012; Wei et al., 2011). The earlier reviews provided mainly narrative analyses of the effects of text-messaging on various health behaviours and clinical outcomes. The authors of these reviews reported that the text-message interventions were mostly successful. For example, Fjeldsoe et al. (2009), in their initial review, found that 8 of 14 included studies reported significant behavioural changes following a text-messaging intervention. The authors also reported that effect sizes ranged from $d = 0.09$ to $d = 1.38$. Similarly, Cole-Lewis and Kershaw (2010) found that eight out of nine adequately powered studies showed that outcomes related to disease management and preventive behaviours were significantly influenced by respective text-message interventions compared to control interventions. The superiority of the majority of text-messaging interventions compared to several other control interventions was confirmed in the remaining reviews that focussed on adults (Vodopivec-Jamsek et al., 2012; Wei et al., 2011), and children and adolescents (Militello et al., 2012).

Due to the increased scale of research on text-messaging for health behaviour in recent years later review authors were able to conduct meta-analysis procedures. Head et al. (2013) quantified the impact of text-messaging interventions on various health behaviours. The overall weighted mean effect size was $d = 0.33$, 95% CI [0.274, 0.385], $p < .001$. This led the authors to the conclusion that text-messaging is as effective as interventions delivered via different modes (e.g., print and Internet), but that they are less costly and, therefore of higher value for interventionists. Siopis et al. (2014) provided further support for text messages as a means to promote behavioural health in their meta-analytic review. They reported a mean weight loss difference of 2.17kg in text-messaging intervention participants compared to participants who were not exposed to text messages (95% CI [-3.41kg, -0.93kg], $p = .001$).

Most recently, researchers from the United States attempted to generate an overall evidence base of the impact of text-messaging on health behaviours and synthesized the results of 15 reviews describing 89 unique studies (Hall et al., 2015). Although the researchers were not able to clearly indicate which intervention components (e.g., text-message frequency, content, or intervention length) were efficacious in promoting health behaviour they reported that most interventions lead to a statistically significant and also clinically meaningful effect on respective health behaviours.

From these reviews, text messages have a strong impact on health behaviour. However, the effectiveness of such interventions on PA and exercise behaviour is unclear because only one study group meta-analysed the effect sizes of merely three studies (d = 0.51, 95% CI [0.236, 0.781], p < .001) (Head et al., 2013). In the following sections I will provide specific information on mobile phone text-messaging for PA and exercise promotion.

2.5.3.3 Effects of Mobile Phone Text Messages on Physical Activity and Exercise

From the published reviews on mobile phone technology to promote PA and/or exercise (Buchholz et al., 2013; Fanning, Mullen, & McAuley, 2012; Head et al., 2013; Muntaner et al., 2015; O'Reilly & Spruijt-Metz, 2013) and online searches conducted in several data bases I could identify only ten studies that used text-messaging as a primary mode to promote PA and/or exercise. These studies were conducted across different age groups, and I will discuss them hereafter.

(a) Effects of Mobile Phone Text Messages on Physical Activity and Exercise in Children and Adolescents

Three study groups targeted PA behaviour in children and/or adolescents, the age group that most frequently uses mobile phones and text-messaging (Krishna et al., 2009). Shapiro et al. (2008) conducted a 3-arm trial. A total of 58 children aged 5 to 13 years with one parent were randomised into a text-messaging, personal diary, and control condition. Participants in the text-messaging condition received a mobile phone for the 8-week study and were required to send daily text messages related to specific behavioural goals (diet, exercise, and screen time self-monitoring). A feedback text message was then sent via an automated system. Although the intervention resulted in more self-monitoring and less drop-out compared to the other conditions, no within- and between-group differences for exercise were reported.

Similarly, researchers who conducted a 12-week study with 78 diabetic adolescents found that a pedometer plus text-messaging intervention did not change daily step counts significantly (p = .40). However, the participants were already meeting the behavioural goal of 10,000 steps at baseline. Hence, it is not possible to make inferences about the effectiveness of the interventions in less active adolescents (Newton, Wiltshire, & Elley, 2009).

A more balanced sample of adolescents (active and inactive) was recruited by Sirriyeh, Lawton, and Ward (2010) in their two-week trial. All participants (N = 120) received text messages. However, content (affective, instrumental, and a combination of both versus neutral) and frequency (once per week versus once per day) varied. Overall, the interventions led to a significant 31.5 minutes increase of MVPA. However, when analysed separately, only inactive participants increased MVPA significantly compared to active participants. From these studies, there is mixed evidence on the effectiveness of text messages on PA and exercise promotion in children and adolescents.

(b) Effects of Mobile Phone Text Messages on Physical Activity and Exercise in Adults

A systematic review by Buchholz, Wilbur, Ingram, and Fogg (2013) summarised the scientific literature on interventions that applied text messages to promote PA in adults. The authors included 10 primary studies. However, three of these studies used text-messaging only as a minor adjunct, two others focussed primarily on weight management and diet whereas one study recruited only patients. With this, only four studies reported on the unique effects of text-messaging on PA and/or exercise in healthy adults. I will discuss these and two more recent studies in the following paragraphs.

Fukuoka, Vittinghoff, Jong, and Haskell (2010) conducted a three-week, one-group, pre-post study (2010) targeting the increase of daily steps in sedentary women with a mean age of 48.4 years. After a brief face-to-face counselling session, participants received daily text-message prompts encouraging them to monitor and increase step counts measured with a pedometer. Upon completion of the intervention, average daily step count increased by 816 steps, $p < .001$. However, the study was primarily conducted to examine the feasibility of using mobile phones to collect step-count data. Further, due to the small sample size (N = 41) and the less rigorous study design, I am cautious to make clear inferences about the effectiveness of the text messages on step counts.

Prestwich et al. (2009) designed a complex rigorous trial examining the effect of implementation intentions (formulating plans when, where and how to exercise) (Gollwitzer & Sheeran, 2006; Sheeran, Milne, Webb, & Gollwitzer, 2005), exercise reminder text messages, and implementation intentions plus exercise reminder text messages on exercise behaviour in university students (N = 155). They also had two control conditions. After the four-week intervention, exercise frequency increased more in both text-messaging conditions compared to the non-text-messaging conditions (p = .02).

Further, the effect of the implementation intentions were only significant when combined with text messages (p = .03). This indicates that text messages are potentially effective in promoting exercise. In a later study with 149 university students, Prestwich, Perugini, and Hurling (2010) confirmed this finding when they reported that implementation intentions plus different text messages lead to significant more increase in days with adequate levels of PA compared to a control condition. It therefore appears that theory-guided interventions can be successfully delivered using text messages, although the researcher did not specifically test this.

The 12-week text-messaging trial by Fjeldsoe et al. (2010) that aimed at PA promotion in postnatal women (N = 88) can be referred to as the gold standard, because (a) the primary outcome was PA, (b) a strong research design, RCT, was employed to examine the effect of the text messages versus a valid control, (c) the development of the text messages was based on formative research and further informed by theory, and (d) the published paper provides detailed information on the complete text-messaging intervention, thus, allowing replication. At baseline, all participants received a PA counselling session and PA information material. Participants randomised into the text-messaging condition also received a goal-setting refrigerator magnet, a counselling call after six weeks, and 42 text messages with behavioural change strategies based on SCT. Additionally, participants were asked to send one weekly text message indicating their progress towards PA behaviour goals from which tailored responses were generated. They were also encouraged to find a support person. This person then also received text messages that provided advice on how to support the research participant in increasing PA. Compared to the controls, participants randomised into the text-messaging condition greatly increased their weekly MVPA frequency between baseline and 6 weeks, and between baseline and 12 weeks (p = .003, d = 0.69; p = .001, d = 0.93, respectively). A similar pattern was reported for the variable walking for exercise. The researchers also interviewed the participants in the text-messaging condition after the intervention. Most participants indicated that the text messages had a strong impact on their decision to be active when they were not motivated to do PA. In their more recent publication, Fjeldsoe et al. (2015) reported on the effects of a similar intervention with the same population (but more participants). The text-messaging intervention in the newer study was developed via formative research (Fjeldsoe, Miller, O'Brien, & Marshall, 2012). The intervention was also more intense (participant handbook, more information on study website, more tailoring, more specific selection of support person, study Facebook group) and intervention components included SCT constructs that were translated into BCTs (Michie et al., 2011). This trial was an adequately powered nine-month RCT. Data was collected at baseline, immediately after the text-messaging intervention (3 months post baseline) and after a six-month period without the text messages (9 months post baseline). Despite the significant effect of the text-messaging intervention on self-reported PA (frequency, duration, and meeting PA guidelines) compared to the controls at three months, these effects were not maintained after nine months. The authors reported no significant and clinically meaningful between-group effects when accelerometer obtained PA data was analysed.

Finally, Gell and Wadsworth (2014) conducted a 24-week text-messaging RCT in working women that targeted the increase of step counts. All participants (N = 87) had similar access to walking maps and walking opportunities (they all worked in the same university). They were also given access to an educational website. In addition, participants in the text-messaging condition received three weekly text messages. The content of the text messages varied but was meant to motivate and support the participants to increase their daily step counts. Pedometer measured step counts and self-efficacy data were collected at baseline, and at Weeks 12 and 24. The researchers also assessed satisfaction with the text messages. An Analysis of Covariance (ANCOVA; baseline as covariate) revealed that step counts were significantly different between the research conditions at Week 12 (d = 0.38, p = .01). This was mainly because the control condition reduced step counts compared to the text-messaging condition that maintained step counts. At Week 24, there were no significant differences in step counts between the research conditions mainly because the control condition increased step counts (d = 0.30, p = .06). Self-efficacy levels were maintained in the text-messaging condition but decreased significantly in the control condition (continuous drop from baseline to Week 12 and Week 24). The authors concluded that text messages might be a useful adjunct to multicomponent interventions but are not sufficient to promote PA.

From the available evidence, encouraging text messages sent to adults are likely to affect PA and exercise behaviour in the short-term (as measured via self-report instruments and pedometer), but more studies are needed that assess if the effects last when the text messages are removed. Further, although the respective interventions were primarily delivered via text messages five studies included numerous other intervention components (e.g., counselling phone calls, handbooks, and pedometers) and hence, the effect of the text messages is not entirely clear. Moreover, text-message characteristics (e.g., content, timing, frequency, and unidirectional versus bidirectional) varied greatly between studies. It is thus not clear how to best design respective interventions (Hall et al., 2015).

(c) Effects of Mobile Phone Text Messages on Physical Activity and Exercise in Older Adults

Using text messages to promote health behaviour is also suitable for older adults because older adults are especially keen to use mobile phone features when they enable communication (Gell et al., 2015) and also benefit health (Kurniawan, 2008; Mikkonen, Va¨yrynen, Ikonen, & Heikkila¨, 2002; Parker, Jessel, Richardson, & Reid, 2013). A further advantage of using mobile phone text-messaging for health interventions in older adults is that no great technological expertise is needed for sending and receiving text messages. Finally, among all mobile phone features, older adults use the text-messaging feature most often (Gell et al., 2015; Zhou, Patrick Rau, & Salvendy, 2014).

In order to examine the evidence of text messages to promote PA and exercise in older adults I conducted a systematic review that was published in 2014 (Müller & Khoo, 2014). I decided to include all studies that have implemented a non-face-to-face approach in their interventions. A systematic search for relevant scientific papers published between January 2000 and May 31, 2013 in six databases was conducted. None of the 16 studies included in my review used text messages to promote PA and/or exercise behaviour.

Only Muntaner et al. (2015) who reviewed intervention studies that have used mobile devices to promote PA (studies published until December 31, 2013 were included) identified one study that examined the effects of text-messaging on walking and leisure-time PA in older adults (Kim & Glanz, 2013). Kim and Glanz (2013) conducted a six-week RCT with 45 African-Americans aged between 60 and 85 years. All participants received a pedometer and a walking manual. Participants randomised into the text-messaging condition also received three motivational text messages per day on three week days. Completer analysis was conducted on 36 participants with $n = 26$ in the text-messaging and $n = 10$ in the control condition. The analysis revealed that only the text-messaging condition participants showed a significant increase in step-counts, $F(1, 35) = 18.79$, $p = .001$ ($d = 0.35$) leading to a significant condition by time interaction ($p < .05$, $\eta^2 = .26$). Leisure-time PA increased significantly in both conditions, $p = .01$, but the condition by time interaction indicated that participants who received the text messages increased significantly more ($p < .05$, $\eta^2 = .13$).

From this study, there is some preliminary evidence that text messages to promote PA and potentially also exercise in older adults are feasible and effective. However, the authors highlighted that future studies should be conducted that, (a) have adequate statistical power for analysis, (b) examine the role of covariates on the respective PA outcomes, and (c) investigate if the effects of the text messages can be maintained when the text messages are removed, which is important for potential research translation (Fjeldsoe, Neuhaus, Winkler, & Eakin, 2011). Moreover, they recommended to design the content of intervention text messages based on past theoretical and empirical research, and highlighted that it is crucial to ensure that all text messages are delivered to the participants (this was not the case in the previous study).

2.6 Summary

In this chapter I provided the basis for my study. I highlighted that self-efficacy is an essential and stable predictor of health behaviour, particularly PA and exercise, in all the theories in which the construct is incorporated. However, despite this, when behaviour change theories are used as a framework for health behaviour change interventions, particularly PA and exercise, they only explain a very limited amount of variance in actual PA and/or exercise behaviour. As a result, Abraham and Michie (2008) suggested that it is necessary to apply BCTs that actively influence behaviour. With the application of such BCTs interventions can be delivered effectively. I then introduced the BCTs from the CALO-RE taxonomy (Michie et al., 2011) that were found to significantly affect exercise self-efficacy and actual PA and exercise behaviour in adults: action planning, reinforcing effort or progress towards behaviour, and provision of instructions (Williams & French, 2011).

Finally, I introduced mobile phone text-messaging as a promising mode to promote behavioural health. Mobile phone text-messaging appears to be an ideal channel for intervention delivery because of its various advantages compared to traditional approaches. Further, this least advanced technology is also suitable for older adults, the target population of my study. From the literature, the evidence concerning the effectiveness of text messages to promote PA and exercise is mixed. Moreover, I could identify only one small-scale study that used text messages for PA promotion in older adults (Kim & Glanz, 2013). Although the authors of this study reported that the text messages affected step-counts and PA positively, the trial was not adequately powered, no covariate and moderation analyses were conducted, and no information on long-term effects, after the text messages ceased, was provided. In the next chapter I will describe the methods I used to address some of the gaps in the existing literature on PA/exercise promotion in older adults using mobile phone text messages.

CHAPTER 3: METHODS

3.1 Introduction

The primary purpose of my study was to examine the effects of mobile phone text messages on the effects of an exercise intervention on weekly exercise frequency in older adults. In this chapter I will describe the methods used in my study. I will discuss the pilot studies, study participants, study measures, sample size calculation, study procedures as well as data analysis.

3.2 Pilot Studies

I conducted two formative pilot studies to inform the design of my study and to gain an understanding of how to recruit and retain research participants (Yardley, Morrison, Bradbury, & Muller, 2015).

(a) *Pilot Study 1*

I conducted the first pilot study in January 2014 at the premises of an urban residential association. Seven older adults between 55 and 72 years old voluntarily attended the initial meeting which lasted 90 minutes. This meeting was conducted as a workshop themed 'physical activity for health'. The aim of the workshop was to deliver some information on the benefits of PA and on how to increase PA. Additionally, I wanted to gain insights on how far a sole text-messaging intervention to promote PA and exercise is feasible in this age group. During the meeting, I introduced the concept and benefits of PA and explained options to be more active. After that I asked the participants to make (develop and write down) some detailed plans for being active in the coming week. I then asked participants for their mobile phone number. During the following week, text messages were sent to the mobile phones of the participants (via a bulk SMS service) to remind them to do PA. The content of the text messages included a phrase that was intended to remind participants on the PAs they wanted to do.

A week later I conducted a follow-up meeting. During this meeting I asked the participants for feedback about their PA experiences during the past week and to comment on the text messages they received. Furthermore, I asked the participants what I should do to make the intervention more feasible and effective. Finally, we discussed recruitment options for the main study (Gul & Ali, 2010).

Participants suggested that it would be more beneficial to have a clear guide of what PAs and exercises could be performed because they had limited knowledge on how to exercise and they did not know what was appropriate for their age. They could only think of walking as an option. Although most of the participants already walked for exercise, they mentioned barriers such as weather, limited access to proper walkways and safety concerns which sometimes prevented them from going out. They preferred an intervention that included health promoting and enjoyable exercises that can be performed at home. With this, the participants recommended that I should provide an exercise booklet for every study participant because they thought it would be easier to have a visual exercise guide. They also suggested that I should demonstrate the exercises during the initial meeting because older adults would likely not know how to do the movements.

In this pilot study I also collected overall PA data using IPAQ (short version) (Craig et al., 2003). The participants found it difficult to fill up the questionnaire on their own and preferred some explanation on the concepts of moderate and vigorous PA. The participants also suggested conducting some physical assessments during the main study because they thought it would be interesting to know how strong and/or healthy they are. This could result in increased interest in the research.

The participants opined that the text messages were helpful and should be used as a reminder, but they also stated that motivational message would be more appealing. The pilot study participants suggested that a combination of a "push" and motivational content would be suitable. They suggested this because they felt that older adults sometimes needed to be pushed to exercise, but they also want to feel motivated.

From the literature, I knew that recruiting and retaining suitable participants was a major threat to the main research. I highlighted this in the meeting and asked the participants to provide some suggestions. One pilot study participant was trying to invite other community members for the pilot study, but found that those who are generally not very active were not interested in a study that promotes PA and/or exercise. As a result she suggested recruiting older adults into the main study who are at least interested in some exercise. Additionally, some participants said that there is a general mistrust towards strangers resulting from increasing crime rates. They opined that this is another factor that could influence recruitment. Two participants recommended that I should approach other community centres, senior citizen associations, and churches, mosques, and temples in order to increase recruitment success.

(b) ***Pilot Study 2***

On April 24, 2014 I conducted a second pilot study to trial the revised study procedures and to receive feedback on my planned recruitment and retention strategies. Two participants (55 and 60 years) who also participated in Pilot Study 1 took part in this study. First, I presented the changes I made to the study procedures. Then, I obtained demographic information via an interview. After this, I used IPAQ (short version) to assess overall PA. The questionnaire was interviewer administered (I asked participants) and I used an intensity scale (0 - 10) to explain the concepts of moderate and vigorous PA as suggested by the participants in Pilot Study 1. Participants perceived this as more feasible than self-administration. As per suggestions from the participants of Pilot Study 1, I administered two physical assessments, the 30 seconds chair-stand test (Jones, Rikli, & Beam, 1999) and a grip strength test. I measured grip strength with a dynamometer (North Coast Hydraulic Hand Dynamometer, North Coast Medical Inc, Morgan Hill, CA, USA). Participants opined that both physical assessments were appropriate and interesting.

I then introduced a draft version of the $_{my}$PAtHS exercise programme booklet (see Appendix A for the final version) and we discussed options to facilitate (introduce and demonstrate) the exercises. This booklet contained 12 exercises that could be performed without any equipment (more details in Section 3.5). The pilot study participants suggested that it would be best if I introduce the exercise programme by going through every page of the booklet to avoid confusion and to ensure participants have no problems following the exercises. Explanations, demonstration (by me), and the execution (by participants) of the 12 exercises took about 45 minutes. During the exercise session I asked both participants to share their thoughts. Their comments are as follows:

1. I need to explain to participants that they should feel muscular strain and not pain when doing the exercises.
2. Heavy Wings exercise: This exercise can be executed without additional weights (this also accommodates the needs of people with low fitness levels).
3. Paper Press exercise: Participants suggested that for the main study it should be mentioned that the strain should be felt between chest and shoulder.
4. Standing Eagle exercise: It is important to explain to the research participants not to lift the shoulders in order to feel the exercise in the appropriate area.
5. Chair Squat exercise: Participants with higher fitness levels can decide not to touch the chair when going down direction chair to increase intensity.

6. Back the Heel exercise: It is important to explain to main study participants that the buttock area should be active while doing this exercise.
7. Sitting Scissors exercise: Participants felt this exercise was difficult. They also mentioned that some people might have problems to execute it due to a lack of flexibility. During the main study, I was advised to highlight the key movements and explain that it is not important to do every exercise 100% correctly.
8. Belly Triangle exercise: Pilot study participants suggested providing the option to put the feet against a wall while doing this exercise to make it slightly easier to execute.

After the execution of each exercise, I asked the participants to fill up the $_{my}$PAtHS exercise diary to provide information on when they exercised, how long they exercised, how intense they exercised, and where they exercised (see Appendix A). Participants experienced no problems with this and suggested that most participants will be able to record their exercise routine using the diary. Lastly, the pilot study participants completed the exercise self-efficacy scale (EXSE) (McAuley, 1993). They felt it was an easy questionnaire to complete.

Finally, we discussed the motivational text messages. I introduced the participants to the content that was based on the research findings by Williams and French (2011). According to the researchers using instructions to exercise and reinforcing efforts towards exercise are most effective in increasing exercise self-efficacy and exercise behaviour. I incorporated these two BCTs into the content of the text messages. Although the pilot study participants considered this content to be suitable, they opined that it would be desirable to add some form of personalisation to the text messages. They considered using the participant's name in the text messages to be appropriate.

Overall, the pilot study participants suggested that the $_{my}$PAtHS exercise programme booklet, the text messages and the study procedures would be appropriate when the proposed changes will be made. I gave a token of appreciation, a mug and certificate, to the pilot study participants and they thought that this will too add to study commitment in the main study.

3.3 Study Design

I conducted my study as a stratified RCT with three assessments over a total period of 24 weeks between June 9, 2014 and January 3, 2015. This trial was registered at the US National Institutes of Health (ClinicalTrials.gov), registration number: NCT02123342, and was recently published in the Journal of Medical Internet Research (Müller, Khoo, & Morris, 2016). Participants were randomised into either the text-messaging condition (SMS) or the No-text-messaging condition (No-SMS). I collected data on weekly exercise frequency and duration using the exercise programme ($_{my}$PAtHS) at Weeks 12 and 24. Data on overall PA-related energy expenditure, sitting time, exercise self-efficacy, grip strength, and lower body strength was collected at baseline, and at Weeks 12 and 24. The study was part of the Malaysian Elders Longitudinal Research (MELoR) and all procedures have been approved by the Faculty of Medicine Ethics Committee, University of Malaya.

3.4 Study Participants

3.4.1 Participant Eligibility

The target population of my study were healthy older adults residing in urban Malaysia (Kuala Lumpur and Petaling Jaya). The eligibility criteria of the study were:

1. Aged between 55 and 70 years
2. Mobile phone user (this included using text messages)
3. Acceptable health that does not prevent exercise

4. Acceptable command of the English language (able to speak, read and understand)
5. Not doing more than once a week of structured exercise routine such as gym training or other structured programmes that include resistance training
6. Interested to participate in the exercise programme and study
7. Willing to schedule home visits at baseline, and at Weeks 12 and 24 from baseline

I chose the age of 55 years as lower cut-off based on (a) the target group of MELoR and (b) due to the fact that this was the age when a person could receive retirement benefits. In Malaysia, the retirement age was 55 years until 2013. Researchers reported that the transition from work to retirement influences exercise and PA behaviour, and this transition period is therefore an appropriate time for exercise and PA promotion interventions (Barnett, van Sluijs, Esther MF, & Ogilvie, 2012; Hobbs et al., 2013). The upper cut-off of 70 years was chosen because this age is related to decreasing functional capacity that affects many cognitive functions (Qiu, Kivipelto, & Strauss, 2009). Hence, including older individuals, older than 70 years, might have influenced the validity of the responses in the exercise diary. English language is widely spoken among older Malaysians because they received most of their education in English.

Individuals who performed regular, structured, planned, and purposive exercise more than once weekly were not included in the study. These activities included: gym training, exercise classes, and regular home exercise. Older adults, who were regular walkers, practiced light tai chi or qi gong were included.

3.4.2 Participant Recruitment and Retention

Recruitment refers to the selection process of participants from initial study notification to study enrolment, whereas retention means keeping recruited participants in the study (Gul & Ali, 2010). Both processes are essential in many respects: Low sample size or high drop-out rates can bias the research outcomes and lead to incorrect conclusions, increased time and costs, and possibly cause study termination (Coday et al., 2005; Patel, Doku, & Tennakoon, 2003). Coday and colleagues (2005) therefore emphasized that it is necessary to develop effective strategies for recruitment and retention. Gul et al. (2010) analysed common issues in recruitment and retention that need to be tackled for meaningful study results. The researchers highlighted that the Lasagna's Law or Funnel Effect, the overestimation of the pool of available study participants that are willing to take part is the most important pitfall in ineffective recruitment (van der Wouden et al., 2007). Problems with recruitment are related to (a) personal factors of the participants: e.g., age, education level, and distress, (b) contextual and environmental factors: e.g., culture, political situation, and funding and (c) research related factors: e.g., demands, discomfort, and treatment (Gul & Ali, 2010). There are general strategies to tackle these issues. Generally, appropriate adaptations in terms of cultural context, resources and, study goals are necessary.

In this study I recruited participants from urban residential organisations, community centres, religious facilities, and via word of mouth. All recruitment strategies were as active and as personal as possible because Mody et al. (2008) suggested that this can be up to 66.5 times more effective compared to passive recruitment strategies. I contacted representatives of the respective associations, organisations, clubs and religious facilities within the recruitment area and organised health talks for older adults. During these talks I highlighted the benefits of study participation (Coday et al., 2005).

After I obtained a list of potential participants I conducted initial eligibility screening via a telephone call (Jancey et al., 2006). During this call I informed the participants about my study. I also assessed the health status of participants with one screening question (Jancey et al., 2006). If potential participants answered “no” to “Do you have any medical condition or are there health concerns that would restrict you from doing regular exercise?" they were eligible to enter the study. In cases when participants answered "yes" I advised them to consult a medical doctor and excluded them from the study.

If eligible participants required time to consider their participation in the study, I called them back after a few days (Jancey et al., 2006). A few weeks after the calls I visited participants at the agreed day and time for an initial face-to-face home visit. During this visit I explained the study procedures, including potential risks and benefits, and provided an information sheet with relevant information (see Appendix B) (Patel et al., 2003). After participants provided signed informed consent (see Appendix C) I conducted baseline measurements.

3.4.3 Participant Randomisation

Researchers conduct intervention studies to evaluate the effects of an independent variable on one or a set of dependent variables. To draw valid conclusions about respective effects, randomisation of study participants into research conditions has become the gold standard for interventional research (Schulz & Grimes, 2002). According to the Cochrane Handbook for Systematic Reviews "Randomisation is the only way to prevent systematic differences between baseline characteristics of participants in different intervention groups in terms of both known and unknown (or unmeasured) confounders" (Higgins & Green, 2011, p. 90). With randomisation, these confounders are likely equally distributed. The variable of interest, the independent treatment variable, will then be the only difference between the research conditions. Thus, with randomisation researchers can make reliable inferences about intervention effects (Singh, 2006). In contrast, interventionists who do not apply randomisation procedures are more likely to report results that are contaminated, and they also tend to overestimate the effects sizes of interventions (Schulz & Grimes, 2002).

To ensure appropriate randomisation, two requirements need to be met: random participant allocation, and allocation concealment (Higgins & Green, 2011). Further, researchers should conduct random allocation after obtaining informed consent and baseline data collection.

In the current study, participants were randomised either into the text-messaging (SMS) or no text-messaging (No-SMS) condition via stratified randomisation. Stratification was based on whether participants entered the study with or without their life partner. Some participants joined as a couple, and because strong experimental evidence exists that older adults who join an exercise intervention with their life partner exercise more than those who do not, I decided to stratify participants based on this variable (Gellert, Ziegelmann, Warner, & Schwarzer, 2011). Within strata, randomisation using the chit method was conducted after baseline assessment to avoid assessor bias during the initial assessment (see Figure 3.1). I presented the participants/couples a set of sealed opaque envelopes. Every envelope contained a chit with "SMS_R" or "$_{my}$PAtHS" written on it. I asked the participants to select one envelope and return it to me to open. Participants were assigned to the SMS condition (SMS_R chit) or the No-SMS condition ($_{my}$PAtHS chit) depending on what was written on the chit. Envelopes were not replaced to ensure balanced groups, and participants were not informed about the real purpose of selecting envelopes.

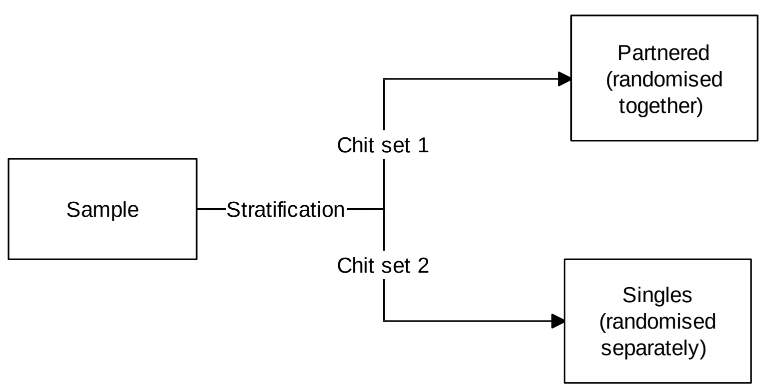

Figure 3.1: Randomisation Procedure

3.4.4 Blinding

Participants were blinded as they were not aware that there was a condition assignment in my study. Hence, they did not know that there were two conditions that differed. Further, I reduced assessor bias (I wanted to avoid me knowing to which condition a participant is likely to be assigned to) by creating a standard operation procedure for the home visits. I did not make any further blinding attempts.

3.5 Study Intervention

I visited all eligible participants at home for baseline data collection in June and July 2014. During this visit, I also introduced the $_{my}$PAtHS exercise programme booklet (see Appendix A). The booklet and its content were informed by the results of the pilot studies and specifically designed for this study. It contained the following:

1. A cover page: Participants could fill in their name on this page.
2. Outline of the content of the booklet.
3. Introduction: This part contained information about the benefits of PA and exercise as well as the rationale of designing an exercise programme for older adults.
4. Structure of the exercises: It was highlighted that there is no equipment needed to do the exercises, and most exercises can be done at any place and time. I provided information on the suitability of the exercises for older adults to ensure the participants felt that they were capable of exercising. Additionally, I introduced the four exercise categories (arms and shoulders, neck and back, legs and hips, and abdominal muscles) with three exercises each.
5. Self-management approach: In this section I explained that participants are supposed to self-manage their exercise routine. This means that there was no guide on frequency, duration, and intensity of exercise programme. However, I provided

some general advice on how to best stick to regular exercise with the programme. I also highlighted that higher frequencies lead to better results. This was done to allow for variability in the outcome measures.

6. Introduction into the diary to record exercise participation: Here I stressed that it is important to record every exercise session conducted with the $_{my}$PAtHS programme in the exercise diary. This part also contained a guide on how to fill up the exercise diary accurately.
7. Safety information: I provided some safety advice to prevent injuries and promote responsible behaviour.
8. The exercises: The first section of the exercise section provided some options for a light three to five-minutes warm-up (e.g., walk on the spot). The following 12 pages contained the 12 exercises. I categorised the exercises into the categories (arms and shoulders, neck and back, legs and hips, and abdominal muscles) and provided three exercises per category. Each exercise was described on a single page with an illustrative name (e.g., Touch the Sky for a shoulder exercise), pictures of key movements and positions, and explanations about the key movements and positions below the respective pictures. The pictures were of me demonstrating the exercises. Additionally, there was a small box on every page that described at which part of the body the exercise should be felt. I included this box to increase the accuracy of the execution of the exercises. Three simple cool-down exercises concluded the programme.
9. Diary: The last part of the booklet contained the exercise diary. Here I provided an example on how to fill up the diary.

The booklet was designed by a semi-professional designer to make it appealing to the research participants. After going through the $_{my}$PAtHS exercise booklet, I demonstrated each exercise and asked the participant to repeat the respective movements. I then provided corrective feedback on the execution of the exercises by the participants. Finally, I provided the participants with the exercise booklet and a study token ($_{my}$PAtHS mug). The initial booklet was exchanged with a new one during the Week 12 home visit. I collected this new booklet at the Week 24 home visit and returned the initial one to the participants. During this final home visit, I gave every participant a certificate of appreciation for their participation. I also asked them if they were interested in the data I collected from them. Those who were interested provided me with their email or postal address so that I could send them a brief report on their individual results. I sent this two to three-pages report shortly after the final home visit.

3.5.1 SMS Condition

During the 12-week period following the initial home visit, SMS condition participants received 60 text messages (5 text messages per week). The text messages were sent via an online tool that was developed by a programming expert. This tool allowed me to schedule text messages and to also monitor if the participants received them (see Appendix D). Participants were not required to reply to the text messages because Head et al., (2013) showed that uni- or bi-directional text-messaging are equally effective in promoting health behaviour. I personalised the text messages in the form of using the participant's name for the greeting. I did this because Head et al. (2013) in their meta-analysis on text-messaging for health behaviour reported that studies that used this form of personalisation were significantly more effective than studies that did not apply personalisation. The pilot study participants had also suggested doing this. Further, each text message contained an instruction to execute the $_{my}$PAtHS exercises and a phrase that praised/reinforced the participants' effort to exercise. I used these contents because researchers reported that providing instructions and reinforcing efforts of progress toward exercise behaviour are effective BCTs for promoting exercise self-efficacy as well as actual exercise behaviour (see Section 2.4.2) (Williams & French, 2011). An example of a text message sent to participants is provided in Table 3.1, and the content of all text messages can be found in Appendix E. Participants received the same text message maximum 3 times over the 12-week period. I decided to send text messages for 12 weeks because researchers who conducted a study in 2010 reported that a certain automaticity for health behaviours can be achieved after a median time period of 66 days (range: 18-254 days). However, they also suggested that exercise automaticity requires more time (Lally, van Jaarsveld, Cornelia, Potts, & Wardle, 2010). Since this was the only trial providing information on behavioural automaticity of exercise behaviour outside a laboratory setting (Verplanken & Orbell, 2003) I used the reported information to decide to send the text messages for 12 weeks.

Text messages were sent in the morning between 8 a.m. and 11 a.m. based on the participant's preference. Sending text messages in the morning was to make sure the participants have enough time to plan and do the exercises during the day (Gell & Wadsworth, 2014). I sent a test text message to each participant one day or several hours before the baseline home visit. During this visit I asked the participant whether he or she received the text message. I did this to ensure that the respective mobile phone number is in service and the person is able to retrieve text messages.

Table 3.1: Example of the Text Message Content

Tailoring	Instruction	Praise/Reward	Closing
Hello Mr. Wong, I hope you are well.	Please do the ${}_{my}$PAtHS exercises regularly.	Thumbs up for your effort.	Have fun!

3.5.2 No-SMS Condition

Participants randomised into the No-SMS condition did not receive text messages during the 12-week period following the initial home visit. I only provided them with the ${}_{my}$PAtHS exercise booklet that was exchanged for a new during the Week 12 visit. With this, the only difference between the two research conditions was the receipt of the text messages.

3.6 Measures

During the baseline home visit, I obtained data on the demographic characteristics of the participants (see Appendix F). These included date of birth, sex, highest educational level (no formal education, primary, secondary, post-secondary, college/university), ethnicity (Malay, Chinese, Indian, or other), current work (yes, no) and marital status. Additionally, I used one question to assess the participants' perceived health status in comparison to their contemporaries. Answer options were poor, fair, good, very good, and excellent. Many researchers used self-rated health assessments in their studies, and Idler and Benyamini (1997) reported that self-rated health is a valid indicator of the health status of a person. I also included a question on participants' previous exercise and/or sports participation (except school physical education, PE) because researchers showed that previous exercise participation influences exercise adherence (Koeneman, Verheijden, Chinapaw, & Hopman-Rock, 2011).

I collected quantitative and qualitative data to address the research objectives stated in Chapter 1. Quantitative measures included data from the myPAtHS exercise diary (exercise frequency and duration), the IPAQ (short version, PA-related energy expenditure, daily sitting time), the Exercise Self-Efficacy Scale (EXSE, exercise self-efficacy), a scale and measuring tape for weight and height measurement to calculate BMI, a grip strength dynamometer (grip strength), and the 30 seconds chair-stand test (lower body strength). In addition, I conducted semi-structured interviews to go beyond the quantitative data.

3.6.1 Exercise Diary

I used an exercise diary to measure the primary outcome of this study, which is the number of weekly myPAtHS exercise sessions (weekly exercise frequency). The diary was also used to collect data on time spent exercising (weekly exercise duration), exercise intensity and location of exercise sessions (see the diary in Appendix A). I collected this data at Weeks 12 and 24. I chose exercise frequency over exercise frequency as primary outcome because I anticipated that participants might not be able to provide reliable estimates of how long they exercised. The participants were required to provide answers to the following questions based on their exercise participation:

1. When did you do the myPAtHS programme (date and time)?
2. How long did you do the myPAtHS exercises?
3. How intense did you exercise (average per session between 0 – 10, Borg, 1990)?
4. Where did you do the myPAtHS exercises (choices: at home, outdoor, hotel, other place)?

The Borg Scale (Borg, 1970) has been frequently used by researchers to self-assess exercise intensity. In a study where researchers assessed the correlation between this scale and physiological measures of lactate and heart rate in 2,560 adults (age range: 18 to 83 years), perceived intensity significantly matched the physiological responses to exercise tasks ($p < .001$) (Scherr et al., 2013). In my study, asking participants to self-assess their exercise intensity was suggested by the pilot study participants. I did not analyse the data on self-assessed intensity. The location of where participants exercised indicated whether they exercised outside their homes and therefore, made use of the flexibility of the $_{my}$PAtHS exercise programme.

I included an example of a completed diary entry in the $_{my}$PAtHS exercise programme booklet. After practicing each exercise during the initial home visit, I asked the participants to record the exercise session they just did. I did this to ensure that participants are able to fill up the diary accurately.

3.6.2 Validity and Reliability of Physical Activity and Exercise Diaries

Although self-report instruments to measure PA and exercise are well accepted in research, they come with inherent problems, especially in terms of over- and under-reporting (Bollen, Dean, Siegert, Howe, & Goodwin, 2014; Burke, Wang, & Sevick, 2011; Schoo, Morris, & Bui, 2005). Bollen et al. (2014) pointed out that in home-based exercise programmes that are unsupervised, it is necessary to know whether the participants did what they reported. However, the authors also highlighted that different states of forgetfulness, self-efficacy, attitudes, mood states, and social-economic status (SES) affect what research participants report.

To avoid recall errors that are common when using questionnaires to asses PA and exercise participation, diaries have been widely applied (Crosbie, 2006). However, the validity and reliability of diary data can vary considerably (Crosbie, 2006), and therefore, identifying reliable methods that validate information given in exercise diaries is crucial, yet problematic (Burke et al., 2011). In a study published in 2004 researchers validated a newly designed questionnaire (LASA physical activity questionnaire [LAPAQ]) with a 7-day PA diary and a pedometer in older adults (Stel et al., 2004). The authors reported that the 7-day activity diary data was highly correlated with the LAPAQ data ($r = .68$, $p < .001$). The relationship was even stronger for sport activities ($r = .71$, $p < .001$). Pedometer data were moderately correlated with the 7-day activity data ($r = .54$, $p < .001$). In the same study the researchers also established construct validity and found significant small to medium correlations between the 7-day activity data and the physical performance tests, handgrip strength and leg-extensor strength. However, for my study I used a specific exercise diary that was designed to capture information on exercise participation over a longer period of time (12 weeks). I conducted a thorough literature search to allocate additional studies that would have provided detailed information on reliability and validity of exercise diaries, or that would have provided suggestions on how to cope with under- and over-reporting. Unfortunately, I was unsuccessful in finding relevant studies. However, most researchers who used exercise diaries reported that they solely relied on the data from the diaries, while occasionally acknowledging that data accuracy relies on participants' commitment and that accurate data on compliance remains challenging (Ludewig, 2003). Yet, Crosbie (2006) discussed some methodological issues pertaining to diary studies and offered some solutions concerning detail and accuracy of diary data. For example, he recommended that researchers collect activity diaries themselves to avoid data loss. He further suggested to thoroughly explain the diary and to demonstrate how to fill them up. Although this might prevent some error, the author also highlighted that it is not possible to entirely rule out under- and/or over-reporting.

To establish whether the data obtained from the diary were valid I asked the participants during the baseline home visit to only fill in information when they exercised, and not to add other activities (PA or exercise that was not part of the $_{my}$PAtHS programme). Further, during the semi-structured interviews that took place at Weeks 12 and 24, I asked participants how often they normally exercised per week. This provided me with some information on whether the data provided in the diary were reasonably accurate.

3.6.3 International Physical Activity Questionnaire (IPAQ)

The IPAQ was developed by an international working group between 1998 and 2000 with the goal to create an instrument that can assess PA of people between 15 and 69 years across the globe (Craig et al., 2003). The questionnaire is available in 21 languages and its long and short versions can be interviewer- or self-administered. The long version of IPAQ has 27 items. It assesses PA in the following domains: (a) recreation, sport, leisure time PA, (b) housework, house-maintenance, caring for family, (c) transportation PA, and (d) job related PA. Two items assessing sitting time are also included.

The short version of IPAQ that I used in my study consists of seven items. Respondents are required to indicate frequency (days per week) and duration (hours and minutes per day) of vigorous PA, moderate PA and walking during the previous week. However, only PA and walking of at least 10 minutes are counted. Time spent sitting on a normal weekday is also assessed (see Appendix G).

In my study, IPAQ (short version) was administered at baseline, and at Weeks 12 and 24. I asked participants first about their vigorous and moderate PAs. The term vigorous PA was explained as activities that take hard physical effort and make the person breathe much harder than normal including heavy lifting, digging/heavy gardening, hard exercise, and fast bicycling. Moderate PAs were described as activities that take moderate physical effort and make the person breathe somewhat harder than normal (excluding walking). I used the examples of carrying light loads, moderate exercise, bicycling at a regular pace, and tai chi for this category. To assess walking, I asked participants about (a) any walking at home or at work, (b) walking to travel from place to place, and (c) walking solely for recreation, sport, exercise, or leisure. Sitting time included sitting during day time at home and at work or at any other place. I provided the examples of sitting at a desk, taking meals, visiting friends, reading, sitting or lying down to watch television, and resting.

I used the total number of MET-minutes per week, an indicator of overall PA-related energy expenditure, for data analysis. First, I multiplied weekly frequency of vigorous PA, moderate PA, and walking by the respective duration in minutes. Second, I multiplied these values by the respective MET (metabolic equivalent for task) level. For vigorous PA this was 8 METs, for moderate PA this was 4 METs, and for walking this was 3.3 METs. Third, I summed up the resulting MET-minutes per week of each activity category to obtain a score of the total MET-minutes per week (Craig et al., 2003). I used the following equation to calculate this value: $Total\ MET\ \frac{minutes}{week} = Vig(METs * mins * days) + Mod(METs * mins * days) + walk(METs * mins * days)$.

3.6.4 Validity and Reliability of the International Physical Activity Questionnaire

Craig et al. (2003) established reliability and criterion validity of IPAQ (short and long version) in 12 countries. A total of 1,974 participants completed the IPAQ (short form) twice within 7 days. From the Spearman correlation coefficients test-retest reliability for the PA-related variables was acceptable with 75% being above r = .65 (overall range of r: .32 –.88). The authors reported similar results for the sitting time variable. Criterion validity was established against accelerometer with 781 subjects who were required to wear the device for 7 days. There was moderate agreement between PA-related data from IPAQ (short version) and accelerometer data with pooled ρ = .30, 95% CI [.23, .36]. Moderate agreement was also reported for sitting time.

Others assessed test-retest reliability and criterion validity of IPAQ (short version) in 122 older adults in South Africa (Kolbe-Alexander, Lambert, Harkins, & Ekelund, 2006). MET-minutes per week correlated significantly between the two measurements that took place three to five days apart (men: r = .54, p < .001; women: r = .60, p < .001). Similar results were reported for sitting time. The researchers used accelerometers to establish criterion validity. In men, significant, yet small to medium correlations between IPAQ-measured energy expenditure and accelerometer counts were observed for vigorous PA (r = .05, p = .05), moderate PA (r = .31-.37, p < .05), and walking (r = .56-.57, p < .001) but not for overall MET-minutes per week. Significant correlations were also reported between sitting time and accelerometer counts. In women, only energy expenditure related to walking measured via IPAQ was significantly correlated with the accelerometer data (r = .32-.42, p < .05). Sitting time correlated significantly with accelerometer data.

3.6.5 Exercise Self-Efficacy Scale (EXSE)

The EXSE was developed by Edward McAuley in 1993 for assessing exercise maintenance predictors in older adults. EXSE is used to assess the belief of an individual to be able to exercise 3 times per week with moderate intensity for 40 minutes or more in the future. For my study, I modified the EXSE to assess the beliefs of study participants to be able to do the $_{my}$PAtHS exercises in the future (e.g., for the next week, next two weeks, next three weeks etc.).

Research participants were required to indicate the strength of their belief (I also used the word confidence as this was better understood by some research participants) to execute the $_{my}$PAtHS exercises in the future without quitting it (e.g., "I am able to do the $_{my}$PAtHS exercise programme without quitting for the NEXT 4 WEEKS”). Response options ranged from 0% (not at all confident) to 100% (highly confident) with 10% increments (see Appendix H). To derive a total exercise self-efficacy score for each participant I summed the ratings and dividing them by the respective number of items (eight items). The maximum self-efficacy score was 100% (McAuley, 1993). Exercise self-efficacy was assessed at baseline, and at Weeks 12 and 24.

3.6.6 Validity and Reliability of the Exercise Self-Efficacy Scale

The EXSE has been used extensively in research on exercise and PA in older adults (McAuley et al., 2011; McAuley et al., 2003). Validity of the instrument has been examined by researchers who assessed the predictors of exercise adherence in older adults (McAuley, 1993; McAuley et al., 2003). From the results of these studies, EXSE was significantly correlated with the Barriers Self-Efficacy Scale (McAuley, 1992) that was used to assess the confidence to exercise in the future despite occurring barriers (r = .88; r = .72). Further, EXSE scores correlated strongly with exercise related outcomes (exercise frequency and exercise duration) and therefore, EXSE is a valid instrument (McAuley et al., 2003).

Internal consistency of the EXSE was established by many researchers, and all reported Cronbach alpha coefficients of .90 and above (McAuley et al., 2011; McAuley et al., 2003; Motl, McAuley, Snook, & Gliottoni, 2009; Taylor-Piliae, Haskell, Waters, & Froelicher, 2006).

3.6.7 Body Mass Index (BMI)

I measured body weight to the nearest 0.1 kg using the Seca Clara 803 Digital Personal Scale (Seca GmbH & Co. KG, Hamburg, Germany). Participants were instructed to step on the scale, stand still with hanging arms, and look straight until I finished recording the weight. I measured body height to the nearest 0.5 cm using standard measuring tape, with participants standing with their backs against a wall. For both measurements, participants were lightly dressed and did not wear shoes. I calculated the BMI in kg/m^2 from the obtained measures using the following equation: $BMI = \frac{weight(kg)}{[height(m)]^2}$. I measured body weight and calculated BMI at baseline, and at Weeks 12 and 24.

3.6.8 Grip Strength

I assessed maximum grip strength in kg force of the dominant hand using the North Coast Hydraulic Hand Dynamometer (North Coast Medical Inc, Morgan Hill, CA, USA) at baseline, and at Weeks 12 and 24. This device has been frequently used in research involving older adults (Landi et al., 2013; Taylor et al., 2013). I selected the grip strength test because it is an easy to administer field test. Further, researchers showed that grip strength is a predictor of overall health and is associated with health-related quality of life in older adults (Rantanen et al., 1999; Sayer et al., 2006). I instructed participants to perform the grip-strength test with the hand that they normally use for writing, throwing, and heavy tasks. For all participants, I set the handle at the second position. The participants performed the grip-strength test in the standing position, with arms close to the upper trunk and the elbow of the dominant arm (test side) flexed to 90°. Upon the signal “ready, go” the participants squeezed the device as strong as they could. To avoid arm movement I kneeled in front of the participants to ensure the dynamometer remains in the initial position. The test was performed three times with about three to seven seconds rest that allowed me to reset the peak-hold needle of the dial to zero. I used the average of the three measurements for analyses.

3.6.9 Validity and Reliability of Grip Strength Dynamometers

Roberts et al. (2011) published a systematic review where they summarised reliability and validity data of grip-strength dynamometers used in 43 individual studies. The authors concluded that grip-strength dynamometers have excellent inter-instrument reliability. Wang and Chen (2010) conducted test-retest analyses of dynamometer measured grip strength with 77 older adults from Taiwan. The interclass correlation coefficient (ICC) between the two measurements that were seven days apart was excellent (ICC = .97). Concurrent validity of grip-strength dynamometers with known weights was excellent with $r > .96$ (Roberts et al., 2011).

3.6.10 Lower Body Strength

I assessed lower body strength using the 30 seconds chair-stand test at baseline, and at Weeks 12 and 24. This test was specifically developed for studies involving older adults. It is easy to administer and provides valuable information on the overall fitness of older adults (Jones et al., 1999).

I used a chair without arm rest for the test. In the original test procedure Jones et al. (1999) used the same folding chair with a seat height of 43.2 centimetres for all research participants. However, due to different heights of the participants in my study I opted against a standardised seat height. Instead, I asked participants to provide a test chair that is appropriate for their height (a chair they frequently use) and that allows them to place their feet on the floor with a knee angle between 95° and 100°. The test chair for each participant was the same throughout the study.

I placed the test chair against a wall to prevent it from moving during the test. I then instructed the participants to sit in the middle of the chair slightly towards the edge with a straight back, feet shoulder-width, and arms either crossed against the chest or on their hips.

Upon the signal "ready, go" participants rose from the chair to a full stand (erected body and straight) and then returned to the initial seating position. The goal was to repeat this procedure as often as possible in 30 seconds. While monitoring the performance of the participants and correcting them if necessary, I silently counted the correctly executed repetitions. Before each test I demonstrated and explained the procedure, and participants were allowed to practice one to three times.

The test score was the total number of correctly executed stands. If a participant was half-way up at the end of the 30 seconds I counted the repetition (Jones et al., 1999).

3.6.11 Validity and Reliability of the 30 Seconds Chair-Stand Test

A great number of researchers have used the 30 seconds chair-stand test because it is a simple to administer field assessment of lower body strength (Frye, Scheinthal, Kemarskaya, & Pruchno, 2007; Nakamura, Tanaka, Yabushita, Sakai, & Shigematsu, 2007; Shumway-Cook et al., 2007). Test-retest reliability and validity were established with 76 community dwelling older adults in a laboratory environment (Jones et al., 1999). The test was conducted two times within two to five days. Correlation analysis showed that the test was reliable with ICC = .89, 95% CI [0.79, 0.93]. In terms of validity, the 30 seconds chair-stand test scores correlated well with the 1-RM leg press test results in the same sample (r = .77, 95% CI [0.64, 0.85]). The test also has appropriate discriminant validity. There was a significant decline in repetitions with increasing age ($p < .01$) and with decreasing PA levels ($p < .0001$).

Later, Macfarlane, Chou, Cheng and Chi (2006) conducted a study to examine construct and discriminant validity in a community setting. They did this in order to evaluate whether the 30 seconds chair-stand test is also valid outside the laboratory. A total of 143 older adults from Hong Kong executed the 30 seconds chair-stand test and 2 maximal effort isometric tests of lower body strength at their home. Correlation analysis revealed significant, yet weak correlations between the tests ($r = .42$, $p < .0001$; $r = .29$, $p < .0015$). The authors, however, confirmed the discriminant validity results reported by Jones et al. (1999) as they discovered that the number of repetitions decreased significantly with age and decreasing PA levels. The form I used to record the data on BMI, grip strength, and lower body strength can be found in Appendix I.

3.6.12 Short Interviews

At the end of the Weeks 12 and 24 home visits I asked all participants to take part in a short informal semi-structured interview to gain some in-depth insights into their experience with the intervention and to go beyond quantitative findings.

Leech (2002) opined that semi-structured interviewing is the middle-way between conversational and structured, Questionnaire like interviewing and provides valuable details from insiders on specific areas of interest. Such interviews can lead to insights that were not considered initially. In my study I was especially interested to determine what the intervention meant to the participants and how they perceived and handled the text messages (SMS condition only) (Christensen, Johnson, & Turner, 2010). The interview structure and technique I used were based on the suggestions by Leech (2002) and Christensen et al. (2010).

After participants gave permission to be interviewed, I started the interviews with a grand tour question that asked the participants to give an overview of their feelings, thoughts and experiences of the past weeks regarding the $_{my}$PAtHS exercise programme. For example, I asked participants to share what happened over the last 12 weeks in terms of the exercises. Depending on the response of the participants some aspects were discussed in more detail to gain a better understanding. For example, if a participant indicated that he or she faced many barriers to exercising I asked what these barriers were. I also prepared a list of guiding open-ended questions that were categorised according to themes of interest (see Appendix J). These questions were related to (a) when, where and how participants normally exercised, (b) exercise barriers, (c) perceived effects of the exercises, and (d) participants' suggestions regarding the exercise programme.

For Weeks 1 to 12, I was mainly interested in the exercise routine of the participants and the barriers they encountered. My aim was to find out how easy or difficult it was to exercise throughout the 12 weeks. I prepared some additional questions for the SMS condition participants with the aim of understanding how far they perceived an impact of the text messages. I specifically wanted to know if they thought that the text message had an effect on their exercise routine and how the text messages helped them to exercise, if the text messages had an impact. I also asked what the participants felt about the content and frequency of the text messages, and what they did with the text messages.

During the Week 24 home visit I was primarily interested in the differences the participants perceived compared to Weeks 1 to 12. I wanted to know if there were changes in terms of when, where and how they exercised, motivation, and barriers to exercise. I also asked participants' about their future plans to continue with the exercises. For SMS condition participants I asked additional questions on the perceived difference between receiving and not receiving text messages. I did this mainly to understand (a) whether participants thought they needed the SMS for a longer period and (b) whether participants thought that not receiving the text messages made a difference in terms of their exercise routine. I digitally recorded all interviews with permission from the participants.

3.7 Sample Size Calculation

I calculated the required sample size a priori using PS Power and Sample Size Calculations (version 3.0.43). With a significance level of .05 and a statistical power of .80, 18 participants per condition were required to detect a between-group difference of 1 exercise session (SE = 0.26 session) per week with an independent *t*-test (Cohen, 1992; Fjeldsoe et al., 2010). As I anticipated a dropout of 10 - 15% my aim was to recruit 21 participants per condition (*N* = 42 for the whole study).

3.8 Analysis

3.8.1 Statistical Analysis

(a) *Introductory Remarks*

Conducting statistical tests is a skill and the test one choses depends on the research context and the nature of the variables, and often decisions are made pragmatically (Field, 2013). For the data analysis in my study I took several steps to make informed but also pragmatic decisions on which statistical procedures to apply. First, I have consulted the respective literature to gain insights into the statistical procedures available and to understand what are the assumptions and conditions underlying the respective tests (Bland & Altman, 2015; Field, 2013). Second, I have plotted my data and conducted some explorative tests to understand the characteristics of the data I collected. Third, I consulted established researchers in the field of health psychology and behavioural science to discuss the appropriateness of the procedures I intended to use. After some deliberation I made an informed choice about the set of statistical procedures to analyse my data. Before embarking into the description of the statistical procedures I will provide some explanations on how I approached the analysis.

I only conducted completer analysis. That means I only analysed the data of participants with complete data at Weeks 12 and 24. Hence, I decided against any intention-to-treat procedures that would have required me to apply imputation procedures. I made this decision because imputation procedures in small samples can bias the results considerably (Field, 2013).

The sample in the current study is small and hence, some violations of test assumptions were unavoidable. Specifically, I have checked the assumption of normality (for the respective tests) using histograms, p-p plots, q-q plots, skew- and kurtosis values, and the Kolmogorov Smirnov test. I also checked homogeneity of variances and conducted specific other tests for the respective statistical procedures. Taking together the information from these checks I found signs of violating the assumption of normality in a number of cases. I mostly encountered problems with skew and kurtosis. To increase the accuracy of my results I applied two procedures. Where possible I have used Bias Corrected and Accelerated (BCa) bootstrap 95% CIs. Bootstrapping procedures treat the sample as the population and draw several smaller bootstrap samples (I used 1000) from it. The parameter of interest in each bootstrap sample will be calculated. From these values the 95% CIs of the parameter can be calculated. The resulting bootstrap CIs will not be affected by the distribution of scores in the sample and provide a more precise estimate of the population effect compared to the p - significance values (Efron & Tibshirani, 1994; Field, 2013). For procedures where I could not use BCa 95% CIs (regression models) I conducted log- and square root transformation. These transformations did not yield the desired effects. As a result, I decided to work with the untransformed data. This was also recommended by Field (2013) who cautioned that transformations can have worse effects than using untransformed scores.

Due to the small sample size the statistical power was reduced. Hence, effects that might genuinely exist in the population might not turn out to be significant in my study. In cases where I had good reasons to assume that the *p*-value did not cross the .05 threshold because of a lack of statistical power (plots and/or effect sizes suggested effects) I conducted follow-up measures and/or reported respective effect sizes. I acknowledge that this procedure is not ideal and likely subjective, but it allowed me to actively engage with the data I collected.

(b) ***Description of Statistical Analysis***

I conducted data coding and analyses using the Statistical Package for the Social Sciences (SPSS) version 20 (IBM Corp. Armonk, NY). For all analyses, significance was established if $p \leq .05$. However, I also report confidence intervals to provide the reader with information on the respective effects. All statistical procedures were informed by Field (2013) as well as Bland and Altman (2015).

At baseline, I compared categorical data (e.g., sex, ethnicity) between the two research conditions using χ^2-test with Fisher's exact test due to the small sample size and expected frequencies less than five in the respective contingency tables. I compared baseline data of the continuous variables between the research conditions using independent samples *t*-tests.

For the analysis of the Week 12 data, I employed independent samples *t*-tests to determine whether there was a significant difference between research conditions in terms of weekly exercise frequency and weekly time spent exercising. Further, I split the data to obtain mean values of three 4-week chunks which I compared between research conditions using independent samples *t*-test. I applied two-way mixed model Analysis of Variance (ANOVA) to examine whether there was a condition (SMS/No-SMS) by time (4 weeks, 8 weeks, 12 weeks) interaction on weekly exercise frequency and weekly time spent exercising. Main effects were followed-up with Bonferroni post hoc tests, and interaction effects were follow-up with contrast analysis. I plotted line-graphs to visualise the results.

I then conducted bivariate correlations to identify significant predictors of weekly exercise frequency. Following this, I entered significant and meaningful predictors into a hierarchical regression model. I entered condition (SMS/No-SMS) first into the model, before, in a second step, the remaining predictors were entered in a forward stepwise manner. With this analysis I was able to determine the strongest predictor of exercise frequency. Using an ANCOVA I adjusted for the strongest predictor of exercise frequency (exercise self-efficacy at baseline) to determine the unique relationship between condition (SMS/No-SMS) and exercise frequency. In a final step I performed moderation analysis to examine whether the relationship between condition (SMS/No-SMS) and weekly exercise frequency was moderated by exercise self-efficacy at baseline. I plotted simple slopes to visualise the results.

For the analysis of weekly exercise frequency and weekly time spent exercising at Week 24, I conducted two-way mixed model ANOVAs to examine main and interaction effects of condition (SMS/No-SMS) by time (Week 12, Week 24). Interaction effects were followed-up with simple effects analysis. I plotted line-graphs to visualise the results.

For the remaining secondary outcomes I converted the data into two change variables, one between baseline and Week 12 and one between baseline and Week 24. I then conducted mixed between-within subjects 2(time) by 2(condition) ANOVAs on the change scores for each variable to assess the pattern of change between research conditions and across time points. In each model I entered baseline values of each variable as covariate. I conducted independent *t*-tests to follow-up significant interactions. Graphs were plotted and can be found in Appendix K.

3.8.2 Interview Analysis

I applied inductive analysis and creative synthesis to analyse the interview data. I did this in order to "immerse in the details and specifics of the data to discover important patters, themes and interrelationships" (Christensen et al., 2010, p. 345). In a first step I transcribed the interviews and categorised the responses into broad pre-defined themes. I further divided these themes into sub-themes that were partly derived from the responses of the participants. This concluded the exploring data stage. In a second step, confirming data and analysis stage, I extracted direct quotations from participants to exemplify the synthesis derived from the interviews. In a final step, creative synthesis stage, I authored the synthesis (Christensen et al., 2010). Pseudonyms were used to conceal participants' identity.

Although I asked the research participants about their overall experience with the exercise intervention, the main focus of the interview analysis was on their experiences with the text messages and their impact on exercise frequency.

3.9 Summary

The purpose of my study was to examine the effects of mobile phone text messages on the effects of an exercise intervention on weekly exercise frequency in older adults. In this chapter I provided a detailed overview of the study methods. Briefly, I recruited older adults in churches and residential organisations, and screened them for study eligibility during an initial home visit where I also collected baseline data. I randomised eligible participants into an exercise booklet plus text-messaging condition (SMS) and an exercise booklet without text-messaging condition (No-SMS). My primary study outcome was weekly exercise frequency measured with an exercise diary. Secondary outcomes were weekly exercise duration, exercise self-efficacy, PA-related energy expenditure, BMI, grip strength, and lower body strength. After 12 weeks, I visited participants again to collect outcome data and to conduct short interviews. During Weeks 13 to 24 no text messages were sent to the SMS condition participants. I revisited all participants at Week 24. Outcome data were collected and short interviews were conducted.

I calculated between-group differences for the variables weekly exercise frequency and weekly time spent exercising over Weeks 1 to 12 using independent samples *t*-tests. Further, to examine the unique effect of the text messages on exercise frequency I used an ANCOVA to adjust for the strongest predictor weekly exercise frequency (exercise self-efficacy). Finally, I conducted moderation analysis to examine the moderating effect of exercise self-efficacy at baseline on the relationship between text-messaging and weekly exercise frequency.

To examine the long-term effects of the text messages I conducted two-way mixed model ANOVAs for the exercise frequency and exercise duration variables. I analysed the remaining secondary outcomes by conducting two-way mixed model ANOVAs on the change scores while controlling for baseline scores.

The study flow chart is displayed in Figure 3.2. The study results will be reported in the following chapter.

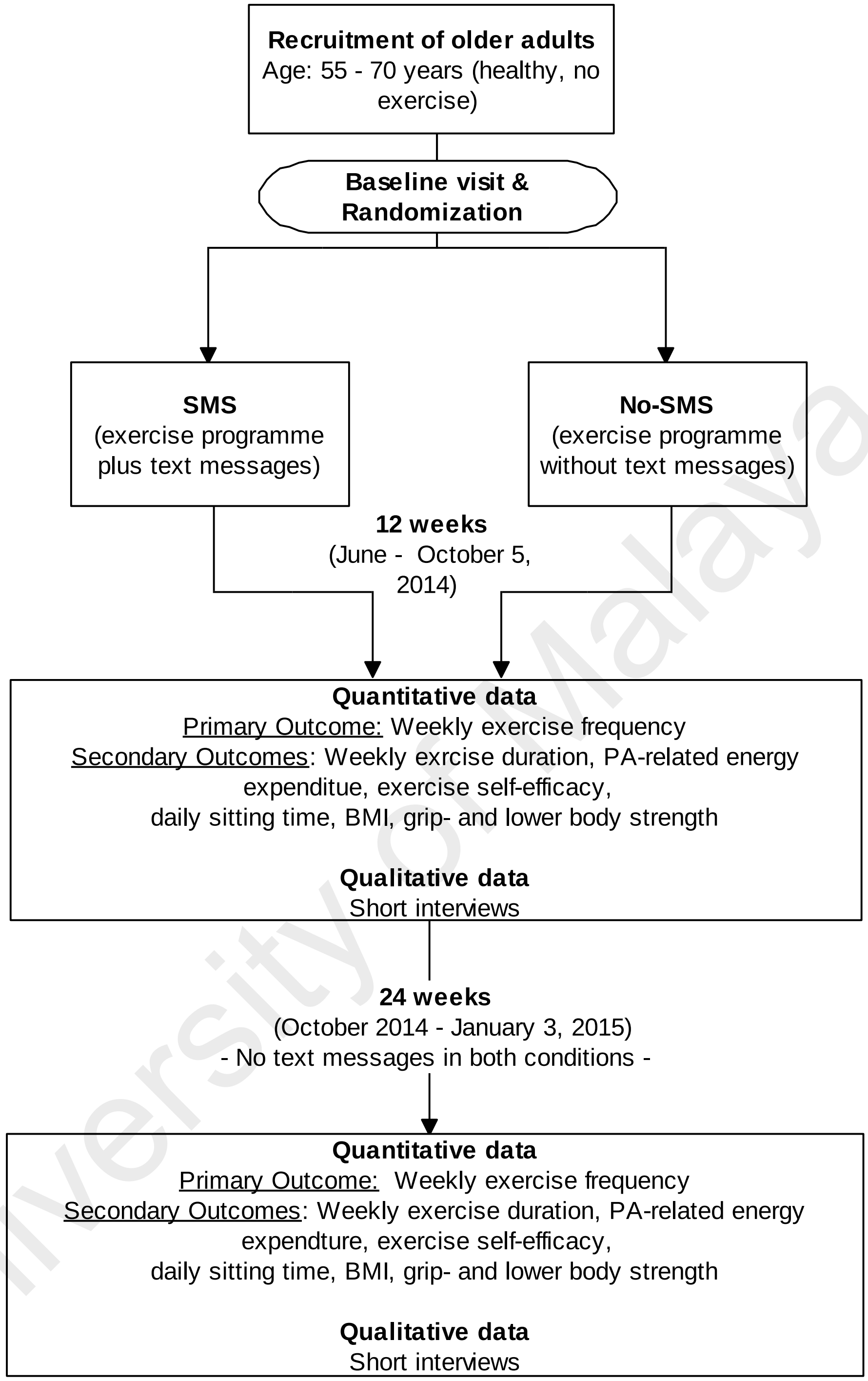

Figure 3.2: Flow Chart of the Study

CHAPTER 4: RESULTS

4.1 Introduction

In this chapter I will present the results of my study. The chapter consists of four broad sections. First, I will present the baseline data, including data on demographic characteristics of the study sample. I will also provide study retention information. Second, I will present the data analysis regarding the weekly exercise frequency variable. Third, I will show the results from the analysis on the secondary outcomes. Following the results from the quantitative analyses I will present the findings from the short interviews for each home visit separately (Weeks 12 and 24).

4.2 Baseline

A total of 89 older adults were interested in taking part my study. I conducted initial study eligibility assessment via telephone calls, and this resulted in 45 older adults being excluded. The most common reason for exclusion was that participants were too old or too young to join the study. I excluded one more person during final eligibility assessment (baseline home visit). This person was not in adequate health to take part in the study. Reasons for exclusion are displayed in Figure 4.1. With this, 43 participants entered the 24-week RCT at baseline.

4.2.1 Study Retention

Retention in my study was high with four and two participants dropping out during Weeks 1 to 12 and Weeks 13 to 24, respectively. Total retention was 86%. Sacket, Straus, Richardson, Rosenberg, and Haynes (2001) suggested that drop-out rates under 20% should not threaten the validity of a trial and the results can generally be trusted.

Drop-out occurred only in the SMS condition but was unrelated to the intervention. From Week 1 to Week 12 four participants dropped out after experiencing an injury that was not related to my exercise intervention. Injuries did not permit these participants to continue exercising (e.g., slipped disc). The respective participants notified me via telephone call of the injury. Another participant lost interest in the study and dropped out during this period, but I was allowed to collect the exercise booklet to obtain the data from the diary (exercise frequency and duration). I could not collect secondary outcome data from this participant.

I was unable to reach one participant at Week 24. After several calls, text messages, and voice messages this participant was considered a drop-out. Figure 4.1 presents the participant flow of the study. There were no significant differences between participants who dropped-out and those who completed the study ($p > .05$ for continuous and categorical variables at baseline). I conducted the Week 12 and Week 24 analyses only with the data of participants with complete outcome data.

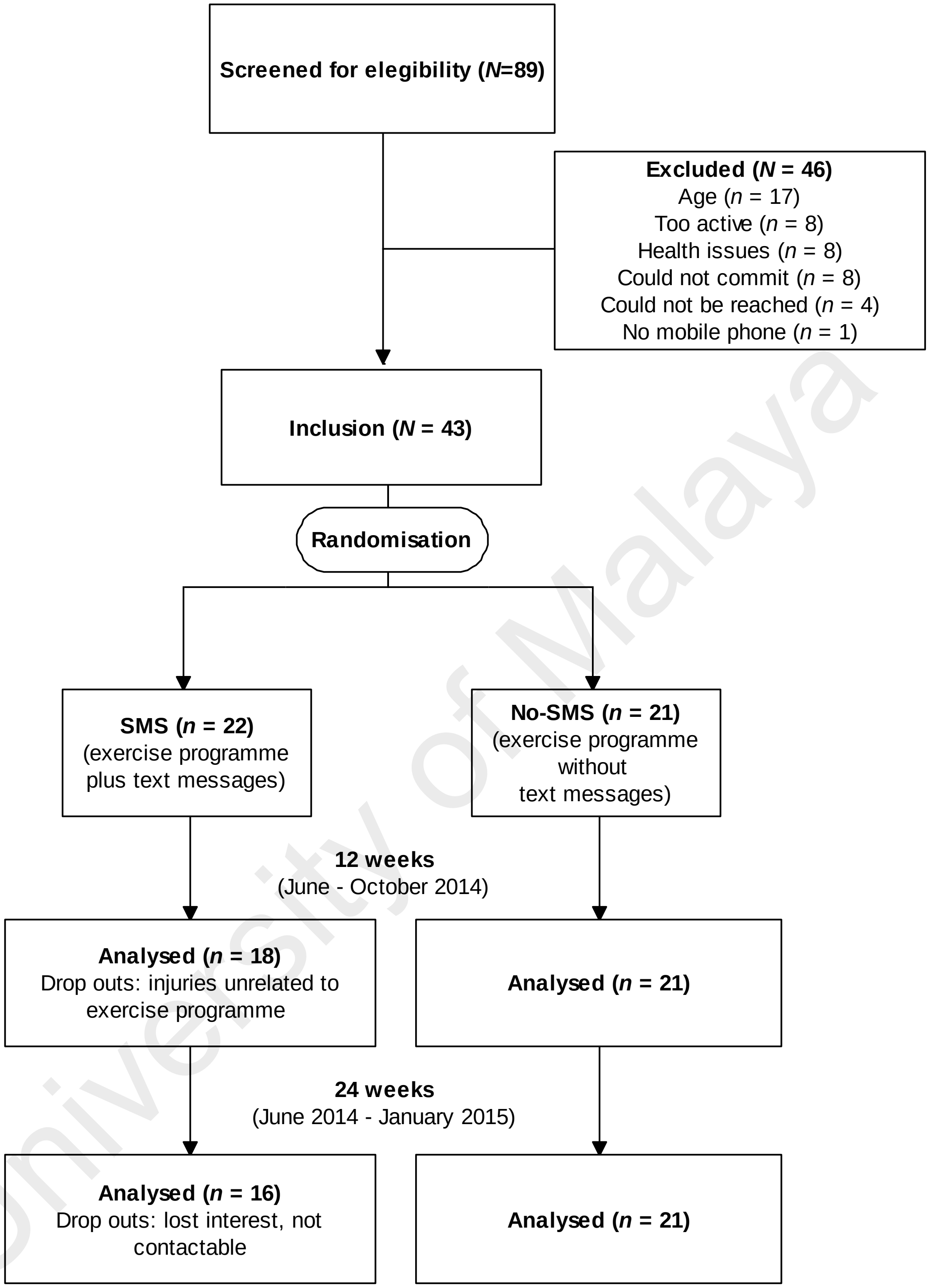

Figure 4.1: Participant Flow of the Study

4.2.2 Overall Sample Characteristics (*N* = 43)

The mean age of the overall sample was 63.3 years (SD = 4.5 years). The mean BMI was 23.06kg/m^2 (SD = 3.1kg/m^2) which is considered to be within the normal range based on the WHO cut-offs for adults (WHO expert consultation, 2004). As can be seen in Table 4.1 the majority of study participants were female (74.4%), Chinese-Malaysians (83.7%), married (81.4%), college or university educated (67.4%), not working (76.7%), had no prior exercise or sport experience except for PE in school (67.4%), and were in at least good health (83.7%).

Table 4.1: Demographic Characteristics of the Overall Study Sample (*N* = 43)

Demographic characteristics	Frequency	Percentage
Sex		
Male	11	25.6
Female	32	74.4
Ethnicity		
Malay	7	16.3
Chinese	36	83.7
Highest educational level		
Secondary	10	23.3
Certificate/Skill (Postsecondary)	4	9.3
College/University	29	67.4

Table 4.1 continued

Demographic characteristics	Frequency	Percentage
Marital status		
Single	5	11.6
Married	35	81.4
Divorced/Separated	1	2.3
Widowed	2	4.7
Working status		
Working	10	23.3
Not working	33	76.7
Health status compared to contemporaries		
Fair	7	16.3
Good	29	67.4
Very good	5	11.6
Excellent	2	4.7
Past exercise/sport experience (except for PE in school)		
Yes	14	32.6
No	29	67.4
Study enrolment		
With partner	14	32.6
Without partner	29	67.4

In the overall sample, the median total PA-related energy expenditure (in weekly MET-minutes) was 579.0 (IQR: 841.5). Therefore, the participants were considered to be inactive according to the respective cut-off of 600 MET-minutes per week (Craig et al., 2003). Table 4.2 displays the values of the remaining secondary variables. The average number of stands in the 30 seconds chair-stand test, 14.3 (SD = 3.7), was comparable to the normative data of older adults (14.0, SD = 2.4 stands) (Jones et al., 1999). The average grip-strength values for males (36.0kg, SD = 5.0kg) and females (22.1kg, SD = 3.9kg) were reasonably similar to those measured in 2,646 older adults in Finland (41kg, SD = 11kg for males, 23.0kg, SD = 7kg for females) and greater than the respective cut-offs for older adults with mobility limitations (Sallinen et al., 2010).

Table 4.2: Secondary Outcome Measures of the Overall Study Sample at Baseline (*N* = 43)

Variable	Minimum, Maximum	Mean	Standard deviation
Daily sitting time (hours)	3, 14	7.9	2.7
Exercise self-efficacy score	42.5, 100	81.0	18.0
30s chair-stand test repetitions	9, 25	14.3	3.7
Grip strength (in kg)			
Male	28.3, 45.3	36.0	5.0
Female	14.0, 29.2	22.1	3.9

4.2.3 Comparing Research Conditions at Baseline (*N* = 43)

Of the total sample of 43 participants, 22 were randomised into the SMS condition and 21 into the No-SMS condition. To check whether the randomisation produced balanced groups, I compared both conditions on the covariates. This is important because if research conditions vary significantly on the covariates, experimental effects will be confounded and no firm conclusions can be drawn about the effects of the manipulation (Field, 2013). To test for differences of categorical variables, I used χ^2- test with Fisher's exact test because of the small sample size and expected frequencies < 5 in the contingency tables. As can be seen in Table 4.3 there were no statistically significant differences between the research conditions at baseline for the categorical variables.

Table 4.3: χ^2- test with Fisher's Exact Test for Comparing Categorical Data at Baseline between the two Research Conditions

Variable	χ^2	***df***	***p***
Sex	0.07	1	1
Education	1.41	2	.57
Work	0.42	1	.72
Ethnicity	1.37	3	.41
Marital status	3.21	3	.54
Health	2.63	3	.52
Previous exercise experience	0.30	1	.75
Individual or Partnered participant	0.30	1	.75

For the continuous variables, I conducted independent samples *t*-tests with BCa 95% CIs to account for deviations from normality. For all continues variables I found no statistically significant differences between the SMS and the No-SMS condition at baseline (see Table 4.4).

Table 4.4: Independent Samples *t*-tests for Comparing Parametric Data at Baseline

Variable	**Condition**						**BCa 95% CI of Mean Difference**		
	SMS			**No-SMS**					
	M	***SD***	***n***	***M***	***SD***	***n***		***t***	***df***
Age (years)	63.6	4.6	22	62.9	4.5	21	-2.1, 3.4	0.53	41
BMI (kg/m^2)	23.7	3.3	22	22.4	2.8	21	-0.5, 3.2	1.39	41
Total PA (weekly MET-minutes)	641.4	503.2	22	968.7	322.8	21	-1210.4, 217.1	-0.98	41
Daily sitting time (hours)	7.3	3.1	22	8.5	0.5	21	-2.7, 0.5	-1.47	41
Exercise self-efficacy score	80.4	18.9	22	81.5	3.8	21	-11.8, 10.1	-0.20	41
30s chair-stand test repetitions	13.7	3.6	22	14.9	0.8	21	-3.4, 1.3	1.09	41
Grip strength (kg)	25.8	8.4	22	25.5	1.4	21	-4.0, 4.5	0.15	41

Overall, there were no statistically significant differences between the research conditions on all relevant covariates. Hence, the randomisation was successful in producing balanced groups and it is unlikely that confounding is of concern when conducting further statistical procedures.

4.3 The Effect of the Text Messages on Weekly Exercise Frequency at Week 12

Irrespective of the research condition, participants exercised mostly at home. However, a number of participants recorded that they occasionally exercised outdoors, in a hotel, and at other places.

To examine the effect of the text messages on weekly exercise frequency at Week 12, I conducted independent samples *t*-tests to compare the exercise frequency between the two research conditions. Data from the diary allowed me to compare the weekly exercise frequency for every 4-week interval in addition to the overall 12-week analysis.

Table 4.5 shows the means and standard errors of weekly exercise frequency for both research conditions, and the results from the analysis. On average, from Weeks 1 to 12, the SMS condition participants exercised more frequently per week (M = 3.7, SE = .32) compared to the No-SMS condition participants (M = 2.5, SE = .40). This difference, 1.2, BCa 95% CI [0.15, 2.28], was significant $t(37) = 2.30$, $p = .027$ and represented a medium to large effect, $d = 0.76$. However, due to the unexpectedly large standard errors within the research conditions the desired statistical power of .80 was not reached, although I adhered to the references from the literature that guided my decision on how many participants to recruit (Fjeldsoe et al., 2010). Instead, I obtained a statistical power of .615 and therefore, my study was underpowered and in only about 61.5% of the experiments the test statistic will reveal a significant effect (Cohen, 1992).

Further, weekly exercise frequency between research conditions was significantly different between Weeks 9 and 12, $p = .015$, $d = 0.82$ favouring the SMS condition. Exercise frequency per week was not significantly different between the research conditions for the other two intervals, however, I observed medium effect sizes ($d = .65$ for Weeks 1 to 4; $d = .57$ for Weeks 5 to 8).

Table 4.5: Independent Samples *t*-test for Comparing Weekly Exercise Frequency between Research Conditions from Week 1 to Week 12

Weekly exercise frequency	Condition						BCa 95% CI for Mean Difference			
	SMS			No-SMS						
	M	*SE*	*n*	*M*	*SE*	*n*		*t*	*p*	*df*
Overall (Weeks 1 - 12)	3.7	0.32	18	2.5	0.40	21	0.15, 2.28	2.3	.027[1]	37
Weeks 1 - 4	4.2	0.34	18	3.1	0.42	21	-0.02, 2.24	2.0	.053	37
Weeks 5 - 8	3.6	0.36	18	2.5	0.47	21	-0.15, 2.30	1.8	.084	37
Weeks 9 - 12	3.4	0.38	18	2.0	0.42	21	0.30, 2.61	2.6	.015[2]	37

Note: [1]$d = 0.76$. [2]$d = 0.82$.

To examine whether there was a condition (SMS/No-SMS) by time (Week 4, Week 8, Week 12) interaction on weekly exercise frequency I conducted a two-way mixed model ANOVA, and effects were followed-up with Bonferroni post hoc tests. Assumptions of linearity, equality of variances, and normal distribution were met. Table 4.6 displays the main analysis.

Table 4.6: Two-Way Mixed Model ANOVA Exploring the Interaction of Research Condition by Time Interval on Weekly Exercise Frequency

Main effects			
Research condition			
	df	***F***	***p***
SMS: 3.7 (*SE* = 0.39) No-SMS: 2.5 (*SE* = 0.36)	1, 37	5.31	.027
Time interval			
	df	***F***	***p***
4 weeks: 3.6 (*SE* = 0.28) 8 weeks: 3.1 (*SE* = 0.30) 12 weeks: 2.7 (*SE* = 0.29)	1.59, 58.76[1]	10.20	< .001
Interaction effect			
Research condition by Time interval			
	df	***F***	***p***
SMS 4 weeks: 4.2 (*SE* = 0.41) SMS 8 weeks: 3.6 (*SE* = 0.44) SMS 12 weeks: 3.4 (*SE* = 0.42) No-SMS 4 weeks: 3.1 (*SE* = 0.38) No-SMS 8 weeks: 2.5 (*SE* = 0.41) No-SMS 12 weeks: 2.0 (*SE* = 0.39)	2, 74	0.52	.596

Note: [1]Mauchly's test indicated violation of the assumption of sphericity for the main effect of time interval, $\chi^2(2) = 10.812$, $p = .004$. Therefore the degrees of freedom were corrected using Greenhouse-Geisser estimates of sphericity ($\hat{\varepsilon} = .79$).

Apart from the significant main effect of the research condition that I reported in the previous paragraph there was a significant main effect of the time interval, $F(1.59, 58.76) = 10.20$, $p < .001$, indicating that weekly exercise frequency decreased over time in the overall sample. Post hoc tests revealed that there was a significant mean decrease of weekly exercise frequency of 0.57 sessions, 95% CI [0.19, 0.94], $p = .002$ from Week 4 to Week 8. There was also a significant decrease from Week 4 to Week 12, 0.92, 95% CI [0.31, 1.54], $p = .002$. However, there was no significant decrease of weekly exercise frequency from Week 8 to Week 12, 0.36, 95% CI [-0.17, 0.89], $p = .30$.

There was no significant research condition by time interval interaction on weekly exercise frequency, $F(2,74) = 0.52$, $p = .60$. This suggests that the drop in weekly exercise frequency over the 12 weeks was similar in both research conditions (see also Figure 4.2).

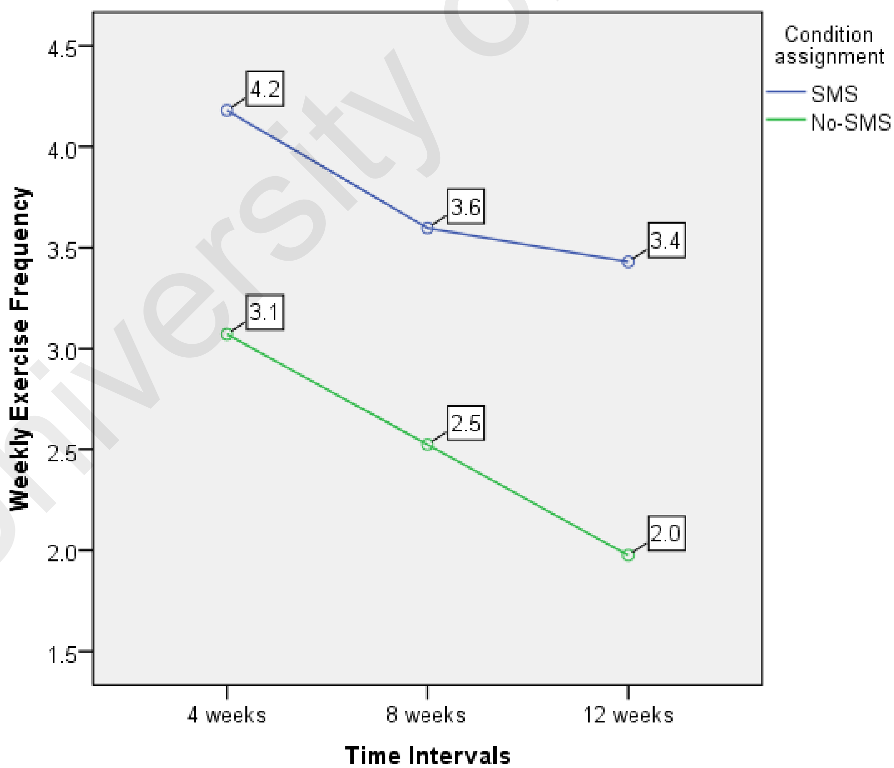

Figure 4.2: Research Condition by Time Interval Interaction of Weekly Exercise Frequency

4.3.1 Identifying the Strongest Predictor of Weekly Exercise Frequency at Week 12

In order to identify the strongest predictor of weekly exercise frequency that I wanted to adjust for in a later step, I performed two procedures. First, I conducted bivariate Pearson product-moment correlations to identify the factors that significantly correlated with weekly exercise frequency. These analyses revealed that, except of the research condition, four other variables were significantly correlated with weekly exercise frequency.

Weekly exercise frequency was significantly correlated with daily sitting hours, $r = -.35$, BCa 95% CI [-.58, -.06], $p = .03$, exercise self-efficacy at baseline, $r = 49$, BCa 95% CI [.25, .66], $p = .002$, exercise self-efficacy at Week 12, $r = .49$, BCa 95% CI [.16, .70], $p = .002$, and weekly time spent exercising, $r = .88$, BCa 95% CI [.81, .94], $p < .001$.

Second, to identify the strongest predictor of weekly exercise frequency I applied hierarchical multiple regression analysis. The variable research condition was forced into the model in the first stage. For Stage 2, I used a forward stepwise entry for the variables exercise self-efficacy at baseline, exercise self-efficacy at Week 12, and daily sitting hours at baseline. I chose these predictors to be included in the second step of the analysis because they showed significant bivariate correlations with weekly exercise frequency. In stepwise procedures predictors are entered and retained based on only mathematical criteria and many statisticians would argue against using them because they take some responsibility out of the researchers hand (Field, 2013). However, I was only interested in identifying the predictor that contributed most to the explanation of weekly exercise frequency while considering the explanatory value of some predictors that correlated highly with weekly exercise frequency. Hence, I only included variables that are theoretically important into the forward regression analysis. With this, the variable weekly time spent exercising that was also significantly correlated with the weekly exercise frequency was excluded from the analysis because it would not have added explanatory value.

There was a missing value for the variable exercise self-efficacy at Week 12 and thus, the data set of this person was not included in this analysis (list wise exclusion and hence, N = 38). From Table 4.7, the forward stepwise regression led to the removal of exercise self-efficacy at Week 12 and daily sitting hours at baseline.

Table 4.7: Stepwise Multiple Regression Model of Predictors of Weekly Exercise Frequency

	b [95% CI]	***SE B***	***ß***	***p***
Model 1				
Constant	5.11 [3.34, 6.89]	0.87		<.001
Research condition	-1.30 [-2.38, -0.21]	0.54	-.37	.021
Model 2				
Constant	1.18 [-1.63, 3.99]	1.39		.40
Research condition	-1.21 [-2.17, -0.25]	0.47	-.34	.015
Exercise self-efficacy (baseline)	0.05 [0.02, 0.07]	0.01	-.464	.002

Note: R^2 = .139 for Model 1 (p=.021), ΔR^2 = .214 for Model 2 (p=.002).

In the final model that explained 35.5% of the total variance of weekly exercise frequency the predictors exercise self-efficacy at baseline and research condition were retained. With this, the strongest predictor of weekly exercise frequency was exercise self-efficacy at baseline.

4.3.2 The Effect of the Text Messages on Weekly Exercise Frequency after Adjustment for Exercise Self-Efficacy

In order to obtain a purer effect of the text messages on weekly exercise frequency, I conducted an ANCOVA to adjust for the effect of the covariate exercise self-efficacy at baseline as the strongest predictor of weekly exercise frequency. After performing the respective assumption checks (independence of covariate and treatment effect, homogeneity of regression slopes, variance homogeneity, normal distribution; data not shown) I conducted the analysis (Field, 2013). The covariate, exercise self-efficacy at baseline, was significantly related to weekly exercise frequency, $F(1, 36) = 12.95$, $p = .001$, partial $\eta^2 = .27$. There was also a significant effect of the research condition on weekly exercise frequency after adjusting for the effect of exercise self-efficacy at baseline, $F(1, 36) = 6.806$, $p = .013$, partial $\eta^2 = .16$ (see Table 4.8). This indicates that the text messages had an even stronger effect on weekly exercise frequency after the effect of exercise self-efficacy was adjusted for.

Table 4.8: Analysis of Covariance to Adjust for the Effect of Exercise Self-Efficacy at Baseline on Weekly Exercise Frequency

Variable	***df***	***F***	***p***	**Partial η^2**
Exercise self-efficacy (baseline)	1, 36	12.95	.001	.27
Research condition	1, 36	6.81	.013	.16

Note: R^2=.357.

4.3.3 The Moderating Effect of Exercise Self-Efficacy in the Relationship between the Text Messages and Weekly Exercise Frequency

In the next analytical step, I conducted a moderation analysis to examine whether the relationship between the research condition and weekly exercise frequency is moderated by exercise self-efficacy at baseline. Conceptually, I wanted to examine whether different levels of exercise self-efficacy at baseline were related to the effect that receiving or not receiving text messages had on weekly exercise frequency (see Figure 4.3).

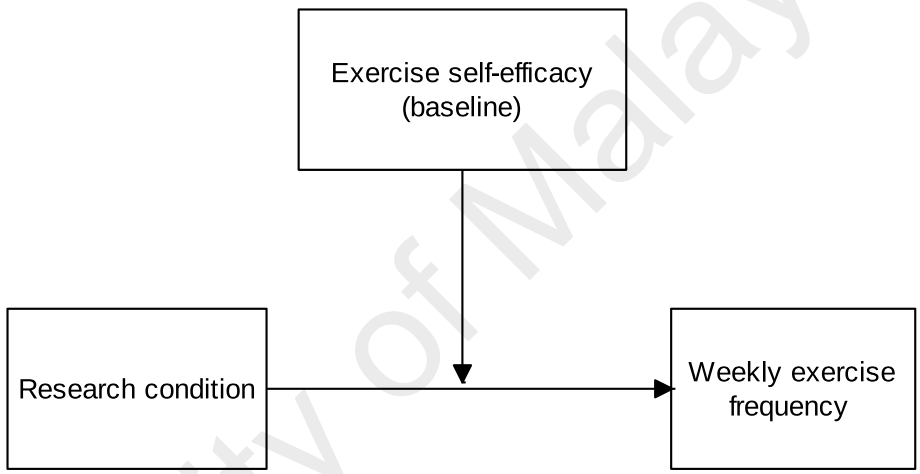

Figure 4.3: Potential Moderation of Exercise Self-Efficacy on the Relationship between Research Condition and Weekly Exercise Frequency

I conducted a moderation analysis using the *PROCESS* command in SPSS that was written by Andrew F. Hayes (Hayes, 2012, 2013). The *PROCESS* command can be downloaded and installed free of charge (http://www.afhayes.com/spss-sas-and-mplus-macros-and-code.html). From Table 4.9 it can be seen that the relationship between research condition and weekly exercise frequency is not significantly moderated by exercise self-efficacy at baseline. The interaction of research condition by exercise self-efficacy at baseline is not significant, b = 0.042, 95% CI [-0.040, 0.089], t = 1.86, p = .072. Hence, the strength and direction of the relationship between research condition and weekly exercise frequency is not significantly affected by the level of exercise self-efficacy. This indicates that receiving exercise-encouraging text messages is generally equally important at every level of exercise self-efficacy.

Table 4.9: Linear Model of Predictors of Weekly Exercise Frequency (Moderation Analysis)

	***b* [95% CI]**	***SE B***	***t***	***p***
Constant	3.09 [2.62, 3.56]	0.23	13.34	< .001
Exercise self-efficacy at baseline (centred)	0.048 [0.024, 0.072]	0.012	4.10	< .001
Research condition (centred)	-1.19 [-2.13, -0.26]	0.46	2.60	.014
Exercise self-efficacy at baseline by research condition	0.042 [-0.004, 0.089]	0.029	1.86	.072

Note: R^2 = .40.

However, the simple slope graph indicates that the lower the exercise self-efficacy at baseline the greater the difference in weekly exercise frequency between the conditions (Figure 4.4). Although this effect is not statistically significant it is likely meaningful.

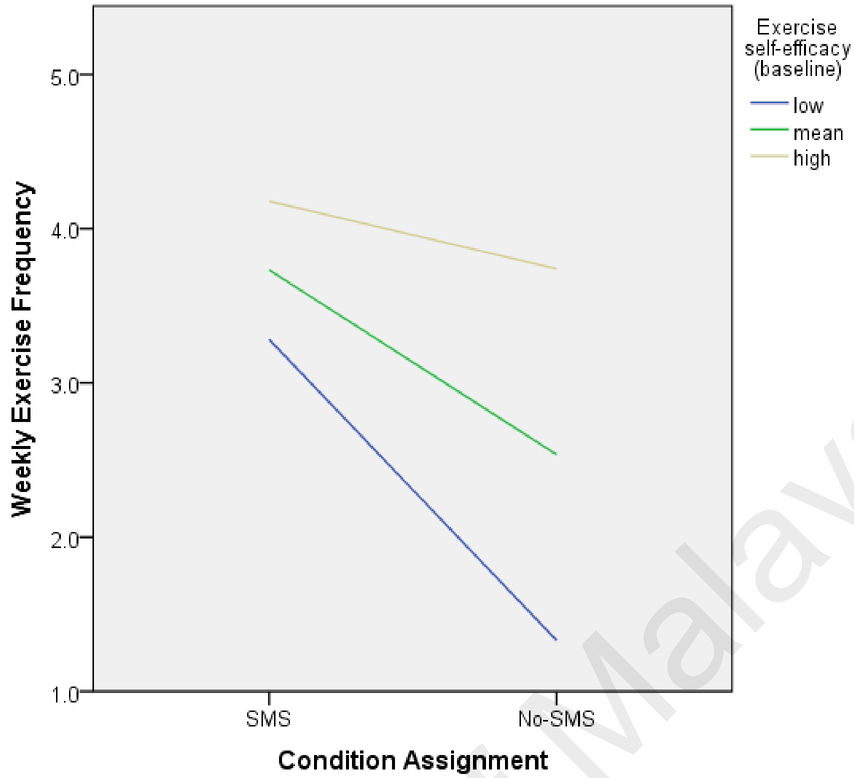

Figure 4.4: Simple Slopes Equations of the Regression of Weekly Exercise Frequency on Research Condition at the three Levels of Exercise Self-Efficacy at Baseline

4.4 The Effect of the Text Messages on Weekly Exercise Frequency after Removing the Text Messages (Week 24 Analysis)

I conducted a two-way mixed model ANOVA on the weekly exercise frequency data. There was a significant main effect of time, $F(1, 35) = 8.74$, $p = .006$ indicating that exercise frequency decreased from Week 12 to Week 24. The mean decrease was 0.47 sessions, 95% CI [0.15, 0.79].

There was no significant condition by time interaction on weekly exercise frequency, $F(1, 35) = 3.09$, $p = .087$. However, the graph in Figure 4.5 suggests that exercise frequency decreased more in the SMS (0.8 sessions) compared to the No-SMS condition (0.2 sessions). I conducted simple effects analysis to gain a better insight. This analysis revealed that exercise frequency decreased significantly from Week 12 to Week 24 in the

SMS condition $F(1, 35) = 9.79$, $p = .004$. There was no significant decrease in exercise frequency in the No-SMS condition, $F(1, 35) = .83$, $p = .37$. Hence, the significant reduction of weekly exercise frequency of the overall sample between Week 12 and Week 24 seems to be mainly influenced by the pronounced decrease in the SMS condition.

Further, an independent samples *t*-test revealed that, on average, participants in the SMS condition did not exercise significantly more often ($M = 2.9$, $SE = 0.27$) compared to No-SMS condition participants ($M = 2.3$, $SE = 0.42$) at Week 24. The difference between the two research conditions, 0.58, BCa 95% CI [-0.35, 1.55], was not significant $t(32.7) = 1.16$, $p = .256$ and represented a small effect, $d = 0.39$.

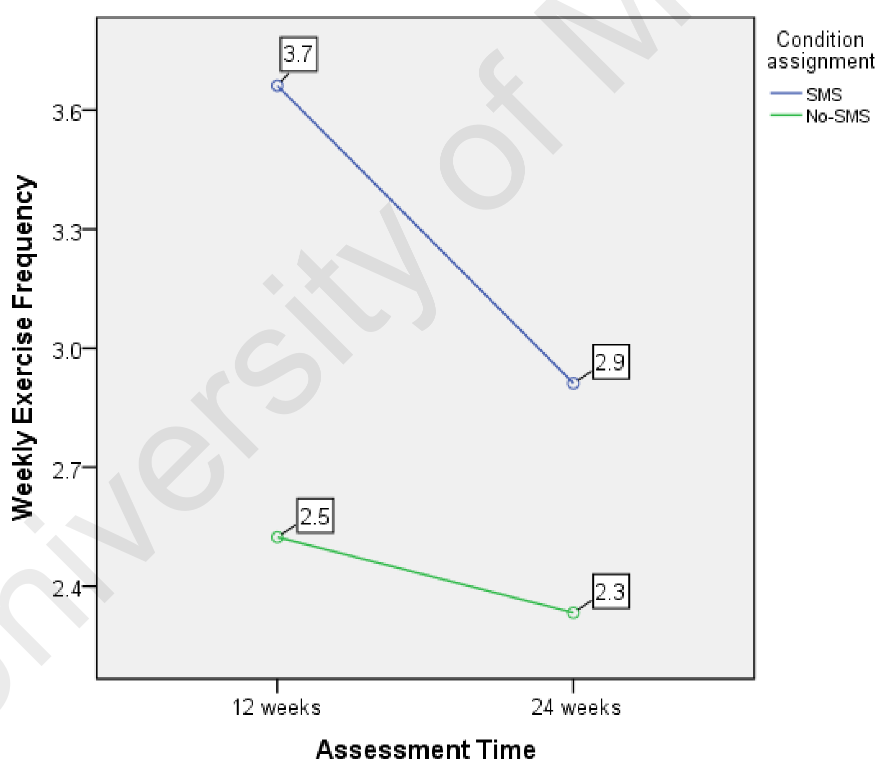

Figure 4.5: Weekly Exercise Frequency between Week 12 and Week 24 of the SMS and No-SMS Condition

4.5 Secondary Outcomes Analysis (*N* = 37)

4.5.1 Weekly Time Spent Exercising

For the Week 12 analysis I conducted independent samples *t*-tests to compare the weekly time spent exercising (in minutes) between the research conditions. I did this for the whole 12 weeks and for the three 4-week intervals. Table 4.10 displays the results of the analysis. On average participants in the SMS condition spent more time per week doing the exercises (*M* = 116.0 minutes, *SE* = 12.5 minutes), than participants in the No-SMS condition (*M* = 85.6 minutes, *SE* = 19.9 minutes). This difference, 30.4 minutes, BCa 95% CI [-13.06, 73.11 minutes] was not significant *t*(37) = 1.2, *p* = .22. However, it did represent a small to medium effect, *d* = 0.41. There were no significant differences in terms of time spent exercising between both conditions at any time point.

Table 4.10: Independent Samples *t*-tests for Comparing Weekly Time Spent Exercising (Minutes) between Research Conditions at Week 12

Weekly exercise minutes	Condition						BCa 95% CI for Mean Difference			
	SMS			No-SMS						
	M	*SE*	*n*	*M*	*SE*	*n*		*t*	*p*	*df*
Overall (1 - 12 weeks)	116.0	12.5	18	85.6	19.9	21	-13.1, 73.1	1.2	.22	37
Weeks 1 - 4	133.8	13.9	18	104.9	20.3	21	-18.3, 77.0	1.1	.26	37
Weeks 5 - 8	110.6	14.3	18	89.9	23.5	21	-32.1, 72.4	0.8[1]	.46	37
Weeks 9 - 12	103.5	14.0	18	63.2	18.9	21	-5.9, 83.2	1.7	.10	37

Note: [1]corrected for unequal variances.

To examine whether there was a condition (SMS/No-SMS) by time (Week 4, Week 8, Week 12) interaction on weekly time spent exercising I conducted a two-way mixed model ANOVA. There was a significant main effect of the time interval, $F(1.63, 60.07) = 9.61$, $p = .001$, indicating that weekly exercise frequency decreased over the 12 weeks. Post hoc tests revealed that there was a mean decrease of 19.11 minutes, 95% CI [4.23, 33.99 minutes], from Week 4 to Week 8, $p = .008$. There was also a significant decrease from Week 4 to Week 12, 35.95 minutes, 95% CI [12.54, 59.37 minutes], $p = .001$.

There was no significant research condition by time interval interaction on weekly time spent exercising, $F(2,74) = 0.72$, $p = .49$. This suggests that the drop in weekly time spent exercising over the 12 weeks was similar in both research conditions (see also Figure 4.6).

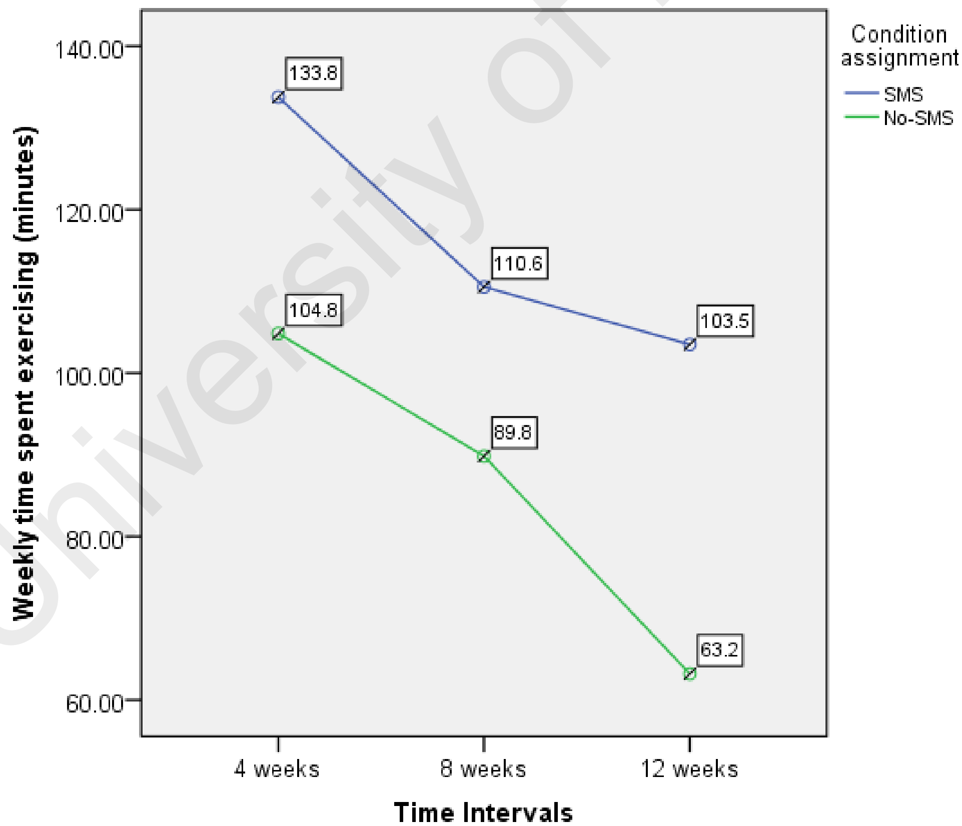

Figure 4.6: Research Condition by Time Interval Interaction of Weekly Time Spent Exercising

For the Week 24 analysis I conducted a two-way mixed model ANOVA. There was a significant main effect of time, $F(1, 35) = 13.74$, $p = .001$ indicating that time spent exercising decreased from Week 12 to Week 24. The mean decrease was 17.03 minutes, 95% CI [7.70, 26.35 minutes].

There was no significant condition by time interaction on weekly time spent exercising, $F(1, 35) = 1.87$, $p = .18$. However, the graph in Figure 4.7 suggests that exercise time decreased more in the SMS (23.3 minutes) compared to the No-SMS condition (10.8 minutes). I conducted simple effects analysis to gain a better insight. This analysis revealed that time spent exercising decreased significantly from Week 12 to 24 in the SMS condition $F(1, 35) = 11.33$, $p = .002$. In contrast, there was no significant decrease in exercise frequency in the No-SMS condition, $F(1, 35) = 3.17$, $p = .087$. Hence, the significant decrease of weekly time spent exercising of the overall sample seems to be mainly influenced by the strong decrease in the SMS condition. Further, an independent samples *t*-test revealed that, on average, participants in the SMS condition did not exercise longer ($M = 85.71$ minutes, $SE = 10.63$ minutes) compared to No-SMS condition participants ($M = 74.81$ minutes, $SE = 20.66$ minutes) at Week 24. The difference between the two research conditions, 10.89 minutes, BCa 95% CI [-34.64, 51.01 minutes], was not significant $t(35) = 0.43$, $p = .67$ and represented a small effect, $d = 0.10$.

The pronounced drop in weekly time spent exercising observed in the SMS condition mirrors the results from the weekly exercise frequency variable where the SMS condition also showed a significant decline.

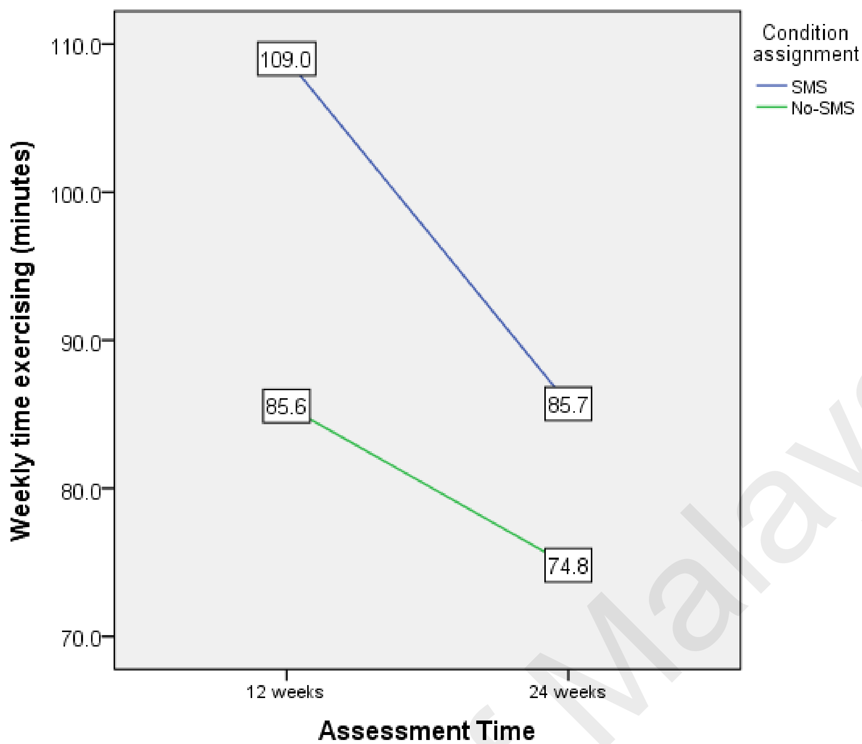

Figure 4.7: Weekly Time Spent Exercising (Minutes) between Week 12 and Week 24 of the SMS and No-SMS Condition

4.5.2 Exercise Self-Efficacy

For exercise self-efficacy there was no significant condition by time interaction, $F(1, 34) = 1.23$, $p = .28$, partial $\eta^2 = .035$. There were also no significant main effects of condition, $F(1, 34) = 1.57$, $p = .22$ and time, $F(1, 34) = 0.10$, $p = .75$. These results indicate that, although exercise self-efficacy decreased non-significantly in both conditions compared to baseline the pattern of decreases was not significantly different between both research conditions.

Table 4.11: Adjusted Mean Change of Exercise Self-Efficacy Score from Baseline to Weeks 12 and 24 and Result of the 2(Time) by 2(Condition) ANOVA

Variable	**Baseline mean (SE)**	**Change to Week 12**[†]	**Change to Week 24**[†]	***p***	**Partial** η^2
Exercise self-efficacy score					
SMS (*n* = 16)	82.73 (4.62)	-5.62 (5.02)	-1.76 (6.52)	.75[a]	.003
No-SMS (*n* = 21)	81.55 (3.83)	-9.94 (4.38)	-14.37 (5.69)	.22[b]	.032
				.28[c]	.035

Note: [†]=Adjusted for baseline values, [a]=time, [b]= condition, [c]=time by condition.

4.5.3 Physical Activity-Related Energy Expenditure

There was no significant condition by time interaction on weekly MET-minutes spent in PA, $F(1, 34) = 0.54$, $p = .47$, partial $\eta^2 = .016$. There were no significant main effects of condition, $F(1, 34) = 0.70$, $p = .41$ and time, $F(1, 34) = 0.61$, $p = .44$. However, there was some increase in PA-related energy expenditure from baseline. These results indicate that, although PA-related energy expenditure increased (non-significantly, but likely meaningfully) in both conditions compared to baseline the pattern of increases was not significantly different between both research conditions.

Table 4.12: Adjusted Mean Change of Physical Activity-Related Energy Expenditure (in Weekly MET-Minutes) from Baseline to Weeks 12 and 24 and Result of the 2(Time) by 2(Condition) ANOVA

Variable	**Baseline mean (SE)**	**Change to Week 12**†	**Change to Week 24**†	***p***	**Partial** η^2
Weekly MET-minutes in PA					
SMS (*n* = 16)	672.80 (132.12)	404.43 (215.51)	461.12 (185.61)	.44[a]	.018
No-SMS (*n* = 21)	968.71 (322.77)	367.18 (187.90)	163.22 (161.84)	.41[b]	.020
				.47[c]	.016

Note: †=Adjusted for baseline values, [a]=time, [b]= condition, [c]=time by condition.

4.5.4 Daily Sitting Time

There was no significant condition by time interaction on daily sitting time, $F(1, 34) = 0.07$, $p = .94$, partial $\eta^2 = .000$. There were also no significant main effects of condition, $F(1, 34) = 2.02$, $p = .17$ and time, $F(1, 34) = 3.92$, $p = .054$. However, the larger effect size of partial $\eta^2 = .103$ for time indicated that sitting time decreased over time, especially from baseline to Week 12. These results indicate that, although daily sitting time decreased (non-significantly, but likely meaningfully) in both conditions compared to baseline the pattern of increases was not significantly different between both research conditions.

Table 4.13: Adjusted Mean Change of Daily Sitting Time (in Hours) from Baseline to Weeks 12 and 24 and Result of the 2(Time) by 2(Condition) ANOVA

Variable	Baseline mean (SE)	Change to Week 12†	Change to Week 24†	*p*	Partial η^2
Daily sitting time (hours)					
SMS (*n* = 16)	7.50 (0.89)	-0.35 (0.54)	-0.03 (0.48)	.054[a]	.103
No-SMS (*n* = 21)	8.52 (0.48)	-1.21 (0.47)	-0.84 (0.42)	.17[b]	.056
				.94[c]	.000

Note: †=Adjusted for baseline values, [a]=time, [b]= condition, [c]=time by condition.

4.5.5 Body Mass Index

There was no significant condition by time interaction on BMI, $F(1, 34) = 0.09$, $p = .77$, partial $\eta^2 = .003$. There were also no significant main effects of condition, $F(1, 34) = 1.16$, $p = .29$ and time, $F(1, 34) = 0.20$, $p = .66$. These results indicate that there were no significant changes in BMI over time.

Table 4.14: Adjusted Mean Change of BMI (in kg/m^2) from Baseline to Weeks 12 and 24 and Result of the 2(Time) by 2(Condition) ANOVA

Variable	Baseline mean (SE)	Change to Week 12†	Change to Week 24†	*p*	Partial η^2
BMI (kg/m^2)					
SMS (*n* = 16)	24.09 (0.80)	0.17 (0.12)	0.07 (0.17)	.66[a]	.006
No-SMS (*n* = 21)	22.39 (0.61)	0.32 (0.11)	0.29 (0.15)	.29[b]	.033
				.77[c]	.003

Note: †=Adjusted for baseline values, [a]=time, [b]= condition, [c]=time by condition.

4.5.6 Grip Strength

There was no significant condition by time interaction on grip strength, $F(1, 34) = 0.38$, $p = .54$, partial $\eta^2 = .011$. There were also no significant main effects of condition, $F(1, 34) = 0.10$, $p = .76$ and time, $F(1, 34) = 1.47$, $p = .23$. These results indicate that there were no significant changes in grip strength over time.

Table 4.15: Adjusted Mean Change of Grip Strength (in kg) from Baseline to Weeks 12 and 24 and Result of the 2(Time) by 2(Condition) ANOVA

Variable	Baseline mean (SE)	Change to Week 12†	Change to Week 24†	*p*	Partial η^2
Grip strength (kg)					
SMS (*n* = 16)	26.09 (2.26)	0.27 (0.51)	1.53 (0.65)	.23[a]	.042
No-SMS (*n* = 21)	25.51 (1.38)	0.30 (0.44)	1.08 (0.56)	.76[b]	.003
				.54[c]	.011

Note: †=Adjusted for baseline values, [a]=time, [b]= condition, [c]=time by condition.

4.5.7 Lower Body Strength

There was no significant condition by time interaction on the number of stands in the 30s chair-stand test, $F(1, 34) = 0.53$, $p = .47$, partial $\eta^2 = .015$. There were also no significant main effects of condition, $F(1, 34) = 0.33$, $p = .57$ and time, $F(1, 34) = 3.82$, $p = .06$. However, the larger effect size of partial $\eta^2 = .101$ for time indicated that there was some increase in the number of stands (especially from baseline to Week 24). These results indicate that, although the number of stands in the 30s chair-stand test increased (non-significantly, but likely meaningfully) in both conditions compared to baseline the pattern of increases was not significantly different between both research conditions.

Table 4.16: Adjusted Mean Change of the Number of Stands in the 30s Chair-Stand Test from Baseline to Weeks 12 and 24 and Result of the 2(Time) by 2(Condition) ANOVA

Variable	Baseline mean (SE)	Change to Week 12[†]	Change to Week 24[†]	*p*	Partial η^2
30s chair-stand test (number of stands)					
SMS (n = 16)	12.56 (0.60)	2.89 (0.85)	4.31 (0.68)	.06[a]	.101
No-SMS (n = 21)	14.90 (0.83)	2.70 (0.73)	3.43 (0.59)	.57[b]	.010
				.47[c]	.015

Note: [†]=Adjusted for baseline values, [a]=time, [b]= condition, [c]=time by condition.

4.6 Results from the Short Interviews

4.6.1 Results from the Short Interviews at Week 12

The semi-structured interviews that I conducted with participants during the home visits at Weeks 12 and 24 lasted between 15 and 35 minutes. However, most interviews lasted approximately 20 minutes. Week 24 interviews were shorter than Week 12 interviews.

At Week 12, I first asked participants about their thoughts of the exercise programme (appropriateness/perceived difficulty of the exercises). Overall, 37 of the 38 interviewed participants indicated that the exercises are appropriate and the majority liked the programme. For example, one participant explained that she found the exercises not too difficult and not too easy, and concluded that the programme is useful for her age group. This was a common notion among the research participants. Another participant suggested that the exercise programme provides a balanced set of movements that are very doable. One participant highlighted that the exercises are interesting and enjoyable.

Although the programme was generally perceived as being appropriate, six participants highlighted exercises they did not like (static exercises, the bow, working neck (2 participants), belly exercises (2 participants)) because they felt uncomfortable when doing them. However, this did not impact how often they exercised. One participant perceived the programme as being slightly too easy and as a consequence, he added some exercises to his routine. In sum, the exercise programme was experienced as being appropriate for the participants.

During the Week 12 interview I also asked participants about their experience with the exercise diary. Participants indicated that they had no problems filling up the exercise diary because it was "easy" and "took just a few moments". Only two participants mentioned that they experienced some confusion in filling up the intensity column because they were unsure how intense they exercised. This data was not used for analysis and, hence, this was a rather minor issue. Overall, I conclude that the exercise diary was an appropriate instrument for measuring outcome data in my study.

4.6.1.1 Week 12 Analysis (SMS Condition)

At Week 12 I interviewed 17 participants in the SMS condition. One participant submitted the exercise diary but did not want to be visited.

All interviewed participants indicated that they did the $_{my}$PAtHS exercises throughout the 12 weeks. Most participants mentioned more than two beneficial effects of the exercise programme. These effects included improvements in strength and stamina, increased well-being and mood, improvements in health (including pain relief, weight reduction, and increased ease executing certain activities), and better appearance. Mary described her experience:

> I find that it [the exercise programme] really works for me. Previously when I squatted I used to have quite big problems… But after doing this exercise it's like WOW I could do it really easily… The other thing is, after starting this exercise we [she and her

husband] went a few times for mountain hiking… So, I find that the stamina is better and I can hike much better… I also feel just a bit more energetic.

Nancy said, "I reduced some weight here and there… I don't fall sick… And my back pain was gone after a while… My belly muscles improved."

Although the participants indicated that they exercised using the programme, not everyone felt it was easy to start and/or continue. Nine participants mentioned that they experienced few or no barriers to exercise throughout the intervention phase. Most of these participants were even able to establish a certain routine. For example, John said the following:

> I just had to make an effort to allocate another half an hour to do it… There was no real difference in terms of how I started and how it is now. I went straight into it… Usually I did it between 6 and 7 [in the evening before dinner]… During holidays I did it either in the morning or in the evening… but sometimes I couldn't… But after the holidays I went back to the same routine… It was generally easy to stick to it because I was self-motivated.

These participants were committed from the beginning to exercise using the programme. Sandra said, "Normally when I commit to something I will finish it… so, when I commit to something I have to do it… In the back of my head I knew I have to do it [the exercises]." For seven of these participants, the text messages had little or no impact on how often they exercised, and they indicated that the text messages were not necessary. They ignored the text messages after a while. Rebecca said that she would have probably performed similarly without the text messages. She read the text messages in the beginning and later took note but deleted them straight away. However, she perceived the content of the text-messages as being encouraging and opined that the text messages are probably best for people who need them. That was mirrored by Martin who summarised it as follows:

I find it a bit irritating [the text messages] because I don't need them… I honestly did not read them after a while [after the first or second day]… I do the exercises regularly… But SMSes might be good for others who are not so committed.

Two participants indicated that they experienced no barriers to exercising, but they also described that the text messages had an impact. Polly said that she was self-motivated from the beginning and established a stable routine. She also did not perceive any barriers to exercise. However, in terms of the text messages she experienced them as being very good and said, "This [text messages] is an encouragement… By the time I received the SMSes I had already done my exercise and felt satisfied when reading the message… Of course, I read all of them." Ralph also said that he had no problems to start and continue exercising but highlighted that the text messages were very supportive as they served as a reminder. He read all text messages and said about the content, "I felt that my effort was appreciated."

Eight participants experienced barriers to exercising. Commonly, these participants reported personal barriers such as overcoming laziness/tiredness, lack of opportunities to exercise, and motivational issues. For example, Jutta said,

In the beginning it was very difficult and I had to challenge myself… It was more about laziness. I just felt my body was so lazy sometimes… And when I am very busy I could not do it… When I am outside I have seminars and other things, and then I am so tired that I cannot do it… Sometimes I also forgot to do it.

Another participant was very enthusiastic at the beginning of the 12 weeks but found it difficult to continue exercising as time went on because of bad mood and a lack of motivation. Despite these barriers, participants were exercising throughout the 12 weeks without giving up. When I asked them about what helped them to keep exercising, without hinting at the text messages, seven participants mentioned that the text messages had an impact. Another participant indicated that the text messages had an effect after I specifically asked her. Two participants also asked if I could continue sending text messages after the 12 weeks. I then asked the participants to describe how the text messages impacted their exercise behaviour. The participants described different processes how the text messages supported them, and some described more than one process. Most often participants described that the text messages were a positive encouragement to exercise (five participants). They used words like "cheering", "hopeful" and "inspiring" to emphasize how the text messages supported them. Stephanie said,

> One of the things that helped me was your SMSes… Towards the end sometimes you become lazy… That is when your SMSes helped… They encouraged and inspired me to go on… The SMSes gave hope that I can do it.

Four participants suggested that the text messages "pushed" them to exercise. They explained that when they received the text messages they felt that they need to exercise despite some barriers. For example Hanna said, "When I felt lazy but then I saw the SMS I felt pushed to do it." Anna, despite experiencing many barriers that prevented her from exercising very regular, reported something similar. She explained that the text messages made her exercise at least a bit in spite of all the barriers she faced. Others said they felt guilty when they received the text messages and they were not intending to exercise. This made them exercise because they felt responsible (4 participants). They described this as being helpful because it made them aware that they were committed to it. Two participants highlighted the reminder function of the text messages. Hanna and Kathrin said that when there are so many things to do during the day, the text messages were like a positive interruption that reminded them to exercise. The importance of the text messages for the participants who experienced many barriers to continue exercising was also reflected in what they did with the text messages. All text messages were read and one participant even saved them.

Irrespective of whether the text messages impacted on exercise participation, the number of text messages (five text messages per week) was perceived as being too high by 13 participants. Four participants thought the number was appropriate. Some suggested implementing a regressive schedule (more text messages during the initial period) because they thought that after a while not so much support will be necessary.

Lastly, I asked the participants about alternatives to sending text messages to encourage exercise participation within their age group. The majority of participants who commented on this said that text messages are likely the best choice. Two participants suggested a telephone call after some time to receive some intermediate feedback, and another participant explained that the Internet (website, YouTube) might be useful to reach more people.

4.6.1.2 Week 12 Analysis (No-SMS Condition)

At Week 12, I interviewed all 21 participants of the No-SMS condition. Sixteen participants indicated that they were exercising with the programme throughout the 12 weeks. These participants experienced some benefits in terms of health, well-being, functional capacity, and mood that they attributed to the exercises they did. Ten of these participants experienced few or no barriers to exercising. They were determined and often developed an exercise routine. For example, Ruby described her experiences as follows:

> I would keep to a similar time… Usually, it was around six [evening]… That is my best time between six and seven… It has to be before dinner, definitely… It was not difficult to decide [to exercise]… It is a matter of discipline… In the beginning it was a forced kind of discipline… And as time went on it became like a want to do it, and I am going to do it.

When I asked the participants who experienced few or no barriers to exercising if they would have needed encouragement they indicated that this was not necessary. Carl explicitly said, “I do not need any support.” Ruby suggested that occasional phone calls would be a good option to remind and motivate people who are struggling.

Six participants experienced some barriers to exercising throughout the 12 weeks, however, they did not discontinue. Common barriers (similar to the SMS condition) were laziness/tiredness, lack of motivation, and forgetting to exercise. After I asked these participants if they would have potentially benefited from any additional support five indicated that some sort of a push or reminder would have been beneficial. One participant thought that sending reminder emails would be helpful, and two participants specifically suggested text messages or WhatsApp (smartphone messenger application) as a way to send reminders. Carol said, “A SMS or WhatsApp for a push and to remind us would be good… A push would help a lot.”

Five participants discontinued exercising after some time (after 3 to 8 weeks). These participants said that they exercised infrequently before they stopped exercising completely. Three of them highlighted that although they had very strong intentions to exercise at the beginning, they did not continue exercising because they did not make it a priority and they lacked determination. Rose described her struggle as follows: “I wanted to exercise badly… I overestimated the power of intentions…and underestimated how difficult it would be to be disciplined… I could just not make it happen… It was no priority I think.” She further suggested that some support in the form of group exercises and/or reminders might have helped her to continue exercising. Samantha also said that group exercises might have been supportive, whereas Betty indicated that some reminders would have been supportive. Finally, two participants explained that they were not very determined at the beginning and that they had limited intentions to exercise. However, they wanted to try the exercises to see if they can develop a routine. Robert, who exercised for a few weeks described that he struggled a lot to exercise. However, after not exercising for about three to four weeks he lost his motivation. He said, “My interest was not so strong.” but also highlighted “If I would be younger I would be doing it [exercise].” I asked him if he would have benefited from some support that encourages him to exercise. He replied that he had little hope that any form of support would make him exercise more. Marge, who lost her exercise booklet, described a similar scenario. She said, “I stopped after a week and my husband could not encourage me.” She said that she has no time to exercise and thought her occasional walks were enough. I asked her if she thought that some support or encouragement would have helped her. She indicated that almost nothing can encourage her.

4.6.2 Results from the Short Interviews at Week 24

4.6.2.1 Week 24 Analysis (SMS Condition)

At Week 24, I interviewed 16 participants in the SMS condition. One participant whom I interviewed at Week 12 could not be contacted at Week 24. Participants continued to follow the $_{my}$PAtHS programme throughout the Weeks 13 to 24. Most participants (12 of 16) reported some additional benefits to the ones acquired from Weeks 1 to 12. Improvements in health, functional capacity, well-being, and better appearance were common benefits mentioned by the participants. Two participants reported increased knowledge of and confidence in exercising.

The participants who experienced few or no barriers to exercising from Weeks 1 to 12 indicated that not much changed. However, three participants indicated that they exercised slightly less frequent but that they were still doing it as often as they can. Furthermore, these participants said that they intended to continue exercising in the future. For example, Paul explained,

> I was not so regular… I was quite busy during the last few weeks… But nothing has changed dramatically… I think I will do [the exercises in the future] because I have not much exercise except of a bit of walking.

I finally asked these participants if they perceived any differences in their exercise participation that is related to not receiving the text messages from Weeks 13 to 24 (compared to the Weeks 1 to 12). They all indicated that they did not really need the text messages initially, and that there were no differences with or without the text messages in terms of their exercise frequency. For example, Polly, who liked the text messages, continued exercising similarly without them.

Seven of the eight participants who indicated that they experienced barriers to exercising from Weeks 1 to 12 explained that barriers reduced during Weeks 13 to 24. They also could establish a reasonably stable routine. A few, however, indicated that they exercised less from Weeks 13 to 24. For example, Jutta pointed out, “It has become easier to stick to it… My routine changed a bit due to some travels, but it is generally stable… Laziness is not a barrier anymore.” These participants also indicated that they intended to continue exercising in the future. Some even established precise exercise goals like Hanna who wanted to exercise five times weekly. Additionally, Jutta and Peter described that the exercise programme has become part of their lives and they wanted to continue exercising as long as they can. In terms of the text messages, Kate, Stephanie, and Kathrin explained that the receipt of the text messages during Weeks 1 and 12 was helpful but that they were not needed during Weeks 13 to 24. In comparison, Peter and Hanna felt that the text messages would have also been helpful during Weeks 13 to 24. For example, Peter said, “It was a bit difficult without SMSes, especially initially… I slowed down a little bit without it because I did not get reminders." However, he further highlighted, "Now, the SMSes are not necessary anymore." Hanna described similar experiences. Finally, Anne said that the text messages were important to her during Weeks 1 to 12 but that she exercised more from Weeks 13 to 24 because she just decided to do so.

One participant reduced her exercise frequency considerably during Weeks 13 to 24 compared to Weeks 1 to 12 because she did not feel the push from the text messages. Tracy explained, "I did much less… I was too lazy… I did not feel the push and pressure from the SMSes… Without the SMSes it was very difficult to keep going… I would have needed at least one SMS per week." She also said that she feels no pressure to continue exercising in the future and concluded, "I am not sure if I will abandon it [the exercises]."

4.6.2.2 Week 24 Analysis (No-SMS Condition)

In the No-SMS condition I interviewed all 21 participants at Week 24. Compared to Week 12, the same 16 participants indicated that they were exercising throughout Weeks 13 to 24. Many of these participants indicated some improvements in health, well-being, fitness, and functional capacity that they attributed to their exercise participation. The 10 participants who experienced few or no barriers to exercising from Weeks 1 to 12 explained that nothing much has changed, although two admitted that they were exercising slightly less. They said that they intend to continue exercising in the future. Some participants even described that the exercises have become part of their daily lives. For example, Carla said that her routine is very stable and added, "Something is missing when I do not do it [exercising]."

Four participants who experienced a number of barriers to exercising from Weeks 1 to 12 said that they were still struggling to exercise. For example, Sally reported that the exercise barriers were still the same and that she exercised slightly less. However, she said that she intends to continue exercising. This was echoed by Carol, Sam, and Cindy. Susan and Melanie, on the contrary, experienced even more barriers to keep exercising during Weeks 13 to 24 compared to Weeks 1 to 12. As a consequence, they said that they exercised significantly less. They were also pessimistic about their future exercise plans. Susan said, “It was more difficult… I exercised less… In the future I will do it when necessary maybe once or twice per week.”

Finally, the five participants who discontinued exercising during Weeks 1 to 12 did not indicate any positive changes from Weeks 13 to 24. Samantha and Rose said that they exercised very few times, but stopped again after a short while. While Rose expressed optimism that she can exercise more in the future, Samantha explained, “I have no intentions to do it [exercise]… Maybe when I am older.” The remaining three participants did not exercise at all and indicated that it is unlikely that they will do it in the future.

4.7 Summary

In this chapter I presented the results of my study. Six participants, all from the SMS condition, dropped out over the course of the 24-week study. From the results, participants in the SMS condition exercised significantly more often throughout Weeks 1 to 12 compared to the No-SMS condition participants. However, the statistical power was only .615. Exercise self-efficacy at baseline was the strongest predictor of weekly exercise frequency. However, the text messages had an impact on exercise frequency regardless of exercise self-efficacy. This impact was pronounced in participants who had a low level of exercise self-efficacy at baseline. Exercise frequency decreased significantly in the SMS condition from Weeks 13 to 24 (when the text messages were removed) compared to Weeks 1 to 12, whereas No-SMS condition participants’ exercise frequency did not change significantly. As a result, there was no significant difference in weekly exercise frequency between the conditions at Week 24.

Throughout Weeks 1 to 12, SMS condition participants exercised non-significantly longer compared to No-SMS condition participants. Time spent exercising decreased significantly within the SMS condition from Weeks 13 to 24 compared to Weeks 1 to 12 but not within the No-SMS condition. Exercise self-efficacy and daily sitting time decreased non-significantly over time. PA-related energy expenditure and lower body strength increased non-significantly over time. There were no changes in BMI and grip strength.

The interview analysis revealed that, for Weeks 1 to 12, about 50% of the participants in the SMS condition indicated that they benefited from the text messages in terms of how often they exercised. Further, about 50% of the participants in the No-SMS condition said that they would have needed some support to exercising. Most SMS condition participants did not miss the text messages from Weeks 13 to 24, but some indicated that they would have needed them.

CHAPTER 5: DISCUSSION AND CONCLUSION

5.1 Introduction

With this study I wanted to examine the effect of mobile phone text messages on the effects of an exercise intervention on weekly exercise frequency in older Malaysians. I examined the short-term effects of text messages, and I also examined if the effects of the text messages were sustainable once they were removed. Additionally, I investigated how far different levels of exercise self-efficacy affected the relationship between the text messages and exercise frequency.

In this final chapter, I will discuss and contextualise the study results in light of existing research literature. Further, I will highlight limitations and strengths of the study, introduce implications for future research before presenting the concluding remarks.

5.2 Participant Recruitment and Retention

Recruiting enough research participants within a defined time frame is crucial in the research process. This is because an adequate number of research participants are needed to detect intervention effects in experimental trials (Patel et al., 2003). In my study, I recruited 43 study participants within a period of less than two months. My recruitment was hence successful because it is challenging to recruit participants for longitudinal interventions that require a long-term commitment (Gul & Ali, 2010; Patel et al., 2003; Watson & Torgerson, 2006). Additionally, researchers suggested that older adults are especially reluctant to be research participants (Jancey et al., 2006; Mody et al., 2008).

In order to overcome recruitment barriers, researchers recommended incorporating recruitment strategies into the research design. In my study, I applied many of the proposed strategies including discussing recruitment strategies with pilot study participants as suggested by Mody et al. (2008). The pilot study participants recommended recruiting older adults who were interested in exercise. As a consequence, I only enrolled participants who had intentions to exercise into my study. Additionally, Patel et al. (2003) and Mody et al. (2008) recommended working with advisors and representatives from potential recruitment communities because they possess insider knowledge. I approached one residential association to gain access to potential participants. The president of the association and I discussed ways of informing the community about the study, and how to recruit participants. We came to the conclusion that a health talk for older adults in the area would likely be successful. Representatives of the association helped me to advertise the event and allowed me to use their community hall for the health talk. More than 60 older adults attended the event. I used a similar strategy to recruit church-going participants.

Gul and Ali (2010) further recommended promoting the community benefits of study participation when working with Asian populations. During the health talks, I highlighted that study participation is essential because the results can inform later health interventions in the wider community. Finally, Mody et al. (2008) who summarized potentially effective recruitment strategies for intervention studies with older adults wrote that it is essential to minimise the participants' burden, especially in terms of costs and convenience. Participation in my study was free of charge and the participants were not required to travel to take part in the study as I conducted home visits.

Study retention was 86% after 24 weeks. This retention rate was similar to the study by Gell and Wadsworth (2014) who conducted a 24-week text-messaging trial with working women. Kim and Glanz (2013) who employed text messages to promote PA in older adults reported a retention of 80% after the six-week intervention (36 out of 45 participants completed the study). Overall, retention in my study was higher than the mean retention of 78% in various PA trials and comparable to PA and exercise studies with older adults (M = 85% retention) (Waters, Galichet, Owen, & Eakin, 2011).

Although it is desirable to retain all recruited participants to properly interpret study results, this is not always possible (Coday et al., 2005; Gul & Ali, 2010). However, generally, retention of at least 80% of study participants does not significantly bias the study results (Sackett et al., 2000). To inform the scientific community about effective retention strategies, Coday et al. (2005) conducted focus groups with researchers working in the area of behavioural science. The researcher reported, being flexible, emphasizing on study benefits and, persistence to get reluctant participants back into the study were the most successful strategies for older adult populations. I applied these and other retention strategies including providing a token of appreciation, minimising participant burden, and maintaining a participant tracking system. This likely led to the low drop-out in my study. The success of retention strategies was also evident in the studies by Fjeldsoe and colleagues (2010, 2015) who conducted text-messaging interventions to promote PA in postnatal women. In their 2010 study when they did not apply specific retention strategies, retention was rather low with 77% after 6 weeks and 69% after 12 weeks. In their later study, they reduced the burden of the participants by scheduling home visits. As a result, retention was much higher with 86% after 13 weeks and 70% after 9 months.

Despite the overall success of retaining participants in my study it is unfortunate that drop-out occurred only in the SMS condition (n = 6). Coday et al. (2005) and Gul and Ali (2010) suggested that if study drop-out is systematic then this would bias the generalizability of the results.

First, in my study I found that drop-outs and study completers were not significantly different in terms of demographic variables. This indicates that drop-out was random. However, there might have been unmeasured variables that differed systematically between drop-outs and study completers.

Second, it is unlikely that the experimental manipulation was responsible for the drop-outs because the only difference between the research conditions was receiving or not receiving text messages. Hence, the SMS condition participants should not have experienced additional difficulties compared to the No-SMS condition participants. The short interviews also indicated that participants in both conditions were equally satisfied with the exercise programme and the study procedures. Additionally, the four participants who dropped-out during the first intervention phase experienced an injury that was unrelated to the study.

With this, I conclude that the randomisation procedure did indeed produce balanced groups and that the drop-out was not systematic. However, randomisation of a larger sample probably leads to a more balanced drop-out.

5.3 The Effect of the Text Messages on Weekly Exercise Frequency

In this study, older adults who received text messages encouraging them to exercise did exercise significantly more than older adults who did not receive text messages. This is in accordance with previous PA text-messaging studies in adults (Fjeldsoe et al., 2010, 2015; Fukuoka et al., 2010; Gell & Wadsworth, 2014; Prestwich et al., 2009; Prestwich et al., 2010), and also older adults (Kim & Glanz, 2013). Further, the effect of the text messages in my study was medium to large (d = 0.76). This effect size is larger than the effect sizes reported by Gell and Wadsworth (2014) (d = 0.38), and Head et al. (2013) (d = 0.51) who meta-analysed three PA text-messaging studies. However, Fjeldsoe et al. (2010) reported an effect size similar to the one found in my study (d = 0.69).

Further, Kim and Glanz (2013) in their study with older adults also reported medium to large effect sizes for leisure time PA and step counts , respectively ($\eta^2 = .13$, $\eta^2 = .26$). With this, using text messages seems to be promising for the promotion of PA and exercise in older adults. This is also in light of the paper by Chase (2015) in which she meta-analysed PA intervention studies in older adults. The author reported an overall effect size of 0.18, 95% CI [0.10, 0.26], $p < .001$ which is smaller than the effects found in my study and in the one by Kim and Glanz (2013).

There are two groups of potential reasons why text messages are successful in promoting health behaviour, especially PA and exercise. The first is related to the text messages as intervention delivery modality, whereas the second is related to their content.

5.3.1 Text-Messaging as Intervention Delivery Channel

Buchholz et al. (2013) argued that most people are familiar with text-messaging and, hence, they feel comfortable with interventions that use text messages. This is also true for older adults who are regular users of text-messaging (Gell et al., 2015; Zhou, Patrick Rau, & Salvendy, 2014) and prefer to use technology for health promotion (Kurniawan, 2008; Mikkonen et al., 2002; Parker et al., 2013). In this study, many participants who received text messages had no problems retrieving them and felt that this was a good way to help them to continue exercising. This was also reported previously in a text-messaging study with middle-aged women (Gell & Wadsworth, 2014).

Another reason why text messages are effective was explained by Fjeldsoe et al. (2010). The authors suggested that exchanging text messages is commonly perceived as having a personal interaction with someone who cares. Thus, people generally have a positive attitude towards text messages and are inclined to pay attention to the content. For older adults, this social component could be particularly important (Gell et al., 2015; Lattimore et al., 2011; Vroman et al., 2015) as researchers have shown that social support has a strong effect on PA and exercise in older adults (Anderson-Bill et al., 2011; Gellert et al., 2011). One participant in the SMS condition specifically noted that the text messages made him feel as if his efforts were appreciated. Another participant mentioned "your SMSes helped", thus, indicating that she perceived some social interaction (the 'you') that helped her to exercise.

The audible signal when receiving text messages is likely to amplify the impact of the text messages because it functions as a prompt (Danaher et al., 2015). This prompt served as a reminder for a number of participants in my study. This prompting effect is probably most important for older adults who are forgetful and those who have busy schedules. Two participants explicitly said that the text messages interrupted them positively during busy days and made them remember the exercise programme.

Finally, using text messages to impact health behaviour is also practical because intervention material/encouragement is always at hand and can be accessed whenever and wherever it is needed (Danaher et al., 2015; Fjeldsoe et al., 2010; Gell & Wadsworth, 2014). This can affect the success of interventions because the intervention is present at all times but it is still partially controlled by intervention recipients, thus, it is likely not overburdening and annoying.

5.3.2 The Content of the Text Messages

The content of the text messages in my study was informed by the findings of Williams and French (2011). They reported that providing instructions to exercise and reinforcing efforts towards exercise were the most successful BCTs in promoting exercise self-efficacy and exercise behaviour in adults aged 18 to 65 years. They recommended incorporating these BCTs into interventions.

The BCT 'providing instructions on how to perform the behaviour' consists of two parts. The first part is about providing verbal or written advice on how to perform PA/exercise or on how to prepare for the PA/exercise behaviour (Michie et al., 2011).

Hence, it is initially important to inform intervention participants about the PA/exercise options and how they can become active (how they can do PA/exercise). In this study, I provided all participants with an exercise programme and demonstrated how the exercises should be performed. I also gave corrective feedback when the participants performed the exercises during the baseline home visit. With this, all participants received some form of instruction. This enabled them to exercise (Williams & French, 2011). As a consequence, the majority of participants exercised throughout the 24-week study period. The second part of this BCT is about providing instructions to follow a certain exercise programme (Michie et al., 2011). Participants in the SMS condition were exposed to text messages that instructed them to follow the $_{my}$PAtHS exercise programme. Hence, they received an additional instruction compared to the No-SMS condition participants. This additional instruction that directly prompted participants to use the specific exercise programme might be partially responsible for the significantly higher exercise frequency observed in the SMS condition. Interview data appears to confirm this conclusion as some participants explained that the content of the text messages pushed them to exercise using the programme.

I also incorporated the BCT ‘reinforcing efforts towards behaviour’ into the text messages. Michie et al. (2011) recommended providing rewards or praise for attempts to achieve a behaviour and also for the preparation of behaviour. Although I was not able to directly observe the behavioural progress of my research participants I designed the text messages in a way that they provided praise for participants who struggled to initiate the exercise behaviour. For example, the message ‘Thumbs up for your effort’ was intended to encourage steps that have been taken to exercise but might also have some impact on participants who were already exercising. Williams and French (2011) argued that this BCT is especially powerful in people who are still working on achieving the behaviour because it might encourage people to continue their efforts and enable them to exercise finally. In my study most SMS condition participants who faced barriers to exercising indicated that the text message content had such an effect. They used words like ‘inspiring’, ‘cheering’ and ‘hopeful’ to describe how the text messages helped and supported them. Participants who struggled to exercise were equally distributed in both research conditions but only the SMS condition participants were exposed to the reward and praise BCT, whereas participants in the No-SMS condition did not receive any such encouragement. While a number of the SMS condition participants felt support throughout Weeks 1 to 12, many No-SMS condition participants bemoaned the lack of support. Hence, this seems to be another important factor why, on average, the SMS condition participants exercised more frequently compared to the No-SMS condition participants.

Finally, the findings of the Week 12 analysis also seem to generally confirm the behavioural change processes proposed by the HAPA model (Schwarzer, 2008). In this model Schwarzer (2008) suggested that intenders (those who intend or are interested in performing a behaviour) need a plan to act upon their intentions. In this study, I only recruited participants who were interested in exercise (intenders). All participants received an exercise programme and some guidance on how to exercise. This constituted a plan to enact exercise behaviour. However, only participants in the SMS condition received text messages that instructed them to exercise. Thus, they were exposed to a reinforcement of the plan which might have led to a higher consciousness and self-regulation to actualise this plan (Gell & Wadsworth, 2014). Prestwich et al. (2009) reported a similar finding when they found that reminding people of their exercise plans via text messages was successful in increasing exercise behaviour.

5.3.3 The Impact of the Text Messages Throughout the 12 Weeks

I also analysed the time trend of exercise frequency to investigate when the text messages had the greatest impact. Overall, exercise frequency decreased significantly over the intervention period. From this, I conclude that over time participants struggled to continue exercising as often as at the beginning.

Exercise frequency decreased in both research conditions. However, what I found was that exercise frequency was significantly different between the two conditions only from Weeks 9 and 12. This suggests that the text messages had the strongest impact on exercise frequency towards the end of the intervention phase indicating that the decrease in exercise frequency was decelerated through the text messages. However, during the first 8 weeks exercise frequency was also higher in the SMS condition. Although these differences between the research conditions were not significant, the effect sizes indicated that the text messages had a marked effect throughout the whole intervention phase. This was also confirmed by the condition by time interval interactions that indicated that (a) the SMS condition participants exercised significantly more than the No-SMS condition participants throughout the 12 weeks, (b) exercise frequency reduced significantly over the 12 weeks in the overall sample, and (c) the reduction in exercise frequency was similar in both research conditions. This means that the SMS condition did exercise more over the whole intervention period.

These findings are difficult to interpret. However, one possibility is that the text messages slightly buffered the drop in exercise frequency at the end of the 12 weeks. Indeed, exercise frequency dropped in a similar fashion between Weeks 5 and 8 (SMS condition: -0.6 times per week, No-SMS condition: -0.6 times per week). In contrast, exercise frequency dropped more between Weeks 9 and 12 in the No-SMS condition (-0.5 times per week) compared to the SMS condition (-0.2 times per week).

The interview data provided some support for this assumption. A few SMS condition participants who experienced barriers to exercising said that the text messages were especially important at the end of the 12 weeks when the initial enthusiasm was gone. On the contrary, participants in the No-SMS condition who faced barriers to exercising indicated that as time went on the barriers increased leading to reduced exercise frequency or even cessation. It therefore seems that the text messages made the difference between continuing to exercise and giving up in participants who faced barriers to exercising.

This also implies that, for some people, those who might not have had strong enough intentions, intentions and plans that were not reinforced were more difficult to actualise, especially over time (Schwarzer, 2008). Schwarzer (2008) and Prestwich et al. (2009) support this as they write that if reinforcement is not provided plans and intentions are less powerful and the behaviour becomes less likely. For example, one participant in the No-SMS condition who discontinued exercise said that she overestimated the power of intentions indicating that her strong intentions were not enough to keep her exercising.

5.4 Exercise Self-Efficacy, Text-Messaging, and Weekly Exercise Frequency Relations

Empirical and theoretical research highlights the pivotal role of self-efficacy in PA and exercise behaviour (e.g., Bandura, 2004; McAuley, 1992, 1993; McAuley et al., 2003; Schwarzer, 2008). In my study I also measured exercise self-efficacy and its relationship to exercise frequency.

5.4.1 Exercise Self-Efficacy as the Strongest Predictor of Weekly Exercise Frequency

In my study exercise self-efficacy at baseline was the strongest predictor of how often participants exercised from Weeks 1 to 12. This means that higher levels of exercise self-efficacy right before the intervention was associated with higher exercise frequency. This is in accordance with many researchers reporting that the "belief that one is capable of successfully adopting and maintaining a regular exercise regimen" (McAuley, 1992, p. 66) is essential towards PA and exercise behaviour change in adults (e.g., Ashford et al., 2010; Kaewthummanukul & Brown, 2006; McAuley, 1992; Sallis et al., 1986) as well as older adults (Anderson-Bill et al., 2011; McAuley, 1993; McAuley et al., 2003). Further, the results of my study also lend support to the major behaviour change theories that propose a strong relationship between self-efficacy and (health) behaviour (Ajzen, 1991; Bandura, 2004; Prochaska & DiClemente, 1986; Schwarzer, 2008).

For SCT, Anderson-Bill et al. (2011) found that self-efficacy was a predictor of self-regulation and PA, and that self-regulation strongly predicted PA in older adults. Similarly, Young et al. (2014) found self-efficacy to be a consistent predictor of PA (Bandura, 2004). The results of the interview analysis in my study confirmed these findings. Participants who were exercising frequently said that they were determined and committed from the beginning. Some also mentioned that they knew that they can do the exercises. That self-efficacy was translated into self-regulation which then translated into exercise behaviour was described by some participants. For example, one participant said that she knew she can do the exercises and disciplined herself to exercise regularly. This indicates that she made a strong effort to exercise because she believed that she can do it. In this regard Bandura (1977, 1986) explained that people with high levels of self-efficacy are more persistent when trying to implement a behaviour. TPB also suggests that self-efficacy (called PBC) directly influences behaviour. This was confirmed by Sniehotta (2009) who found self-efficacy to be the only significant predictor of PA.

TTM proposes that stage progression is significantly influenced by cognitive processes (Prochaska & DiClemente, 1986). This is especially true in the earlier stages when behaviour is intended but not initiated. Self-efficacy is one of the cognitive factors that exert strong influence on stage progression, with the ultimate goal of adopting and maintaining behaviour. In my study, participants were generally interested in doing exercise and hence, had intentions to adopt exercise. The interview results showed that those with a strong belief in being able to exercise had little problems to adopt the exercises and also reported that maintaining a certain routine was not difficult.

5.4.2 The Effect of the Text Messages on Weekly Exercise Frequency Regardless of Exercise Self-Efficacy

After I established that exercise self-efficacy at baseline was the strongest predictor of exercise frequency at Week 12, I wanted to know what effect the text messages had on exercise frequency after the effect of exercise self-efficacy was adjusted for. I conducted an ANCOVA with exercise self-efficacy as the covariate. This was done to get a more accurate picture of the effect of the text messages. Conceptually, I wanted to understand how much exercise frequency was affected by the text messages when exerting more rigid experimental control by taking account of exercise self-efficacy (Field, 2013). The analysis revealed that exercise self-efficacy had the strongest influence on exercise frequency as this variable alone explained 26.5% of the exercise frequency variance. This indicates that higher exercise self-efficacy was associated with higher exercise frequency as seen in the previous section. However, when the effect of exercise self-efficacy was removed the text messages also had a strong influence on how often participants exercised. The text messages alone explained 15.9% of variance in exercise frequency. This means that participants exercised significantly more when they received the text messages compared to when they did not receive text messages regardless of their level of exercise self-efficacy at baseline. This suggests that it is likely that the majority of older adults, the target population in this study, can benefit from receiving encouraging text messages.

Other text-messaging studies have not considered controlling for the level of exercise self-efficacy and reported the unadjusted effects of the text messages (Fjeldsoe et al., 2015; Fjeldsoe et al., 2010; Gell & Wadsworth, 2014; Kim & Glanz, 2013). This is surprising considering that many researchers conclusively confirmed that the level of exercise self-efficacy before a PA and/or exercise intervention has a strong impact on PA and exercise (Darker et al., 2010; McAuley, 1992; McAuley et al., 2003; van Stralen et al., 2009).

5.4.3 Exercise Self-Efficacy as Moderator in the Relationship Between Research Condition and Weekly Exercise Frequency

As seen in the previous sections exercise self-efficacy at baseline, and the text messages were independently associated with how often older adults exercised from Weeks 1 to 12. However, I also investigated whether text messages had a different impact on exercise frequency depending on the baseline level of exercise self-efficacy. McAuley et al. (2011) reported that older adults with low exercise self-efficacy levels in an exercise intervention need to be given some extra support to help them to continue exercising. The authors recommended implementing measures that promote exercise self-efficacy. In contrast, older adults with high levels of exercise self-efficacy will be able to start and also continue exercising without support. Consequently, participants in my study who had low levels of exercise self-efficacy at baseline might have benefited more from the text messages compared to those with higher levels of exercise self-efficacy.

I conducted a moderation analysis to examine if the aforementioned assumptions were confirmed in my study. The analysis revealed that the level of exercise self-efficacy had no significant influence on how strong the effect of the text messages on exercise frequency was (p = .072). This was counterintuitive and hence, I also conducted a simple slope analysis to visualise the relationships. From the simple slopes I came to the conclusion that exercise self-efficacy was indeed a moderator of the relationship between the research condition and exercise frequency. For example, participants with low exercise self-efficacy exercised about 3.4 times per week when they received text messages and only 1.5 when they did not receive text messages. This indicates that the text messages had a strong impact on participants with lower exercise self-efficacy levels. In contrast, participants with high levels of exercise self-efficacy exercised 4.2 times per week with the text messages and 3.8 times per week without the text messages. Hence, the text messages had a small impact in participants who had higher exercise self-efficacy. With this, it seems as if the impact of the text messages decreased when exercise self-efficacy at baseline increased. This result confirms that more support is needed for people with low exercise self-efficacy compared to those with high levels (McAuley et al., 2011).

Although the research condition by exercise self-efficacy interaction was not significant I concluded that exercise self-efficacy at baseline moderated the relationship between text-messaging and exercise frequency. I made this conclusion because of the following reasons. First, the p-value of the interaction term was .072 and hence, it is very unlikely that no effect was present. Commonly, a p-value of .05 is taken as threshold for significance. However, this is a rather arbitrary threshold that can always be reached with a large enough sample size (Bland & Altman, 2015; Field, 2013). In this study, it is likely that with a larger sample size I would have reached p = .05 due to increased statistical power. Furthermore, I believe it is incorrect to conclude that when p = .05 that there is an effect, and when p = .051 (or .072) that there is no effect (Field, 2013; Hackshaw & Kirkwood, 2011). Second, rather than drawing conclusions about moderation only based on the significance level Field (2013) advised to also graph the interaction, especially when theory and the p-value indicate some interaction. From the simple slope analysis, I could clearly see that exercise self-efficacy acted as a moderator between research condition and exercise frequency. Third, my understanding of the field and the literature pointed to a significant moderation of exercise self-efficacy. With this, I have followed the recommendation by Field (2013) to not blindly accept statistical results but to rather take an active role in drawing conclusions from different sources of theoretical and empirical evidence.

The interview data also provided some evidence that the text messages were more effective in participants who indicated somewhat lower exercise self-efficacy. For example, participants in the SMS condition who described barriers to start and/or continue exercising said that the text messages had an impact on how often they exercised. On the other hand, many participants in the No-SMS condition who faced barriers to start and/or continue exercising explained that they would have benefited from some form of encouragement. Participants who did not describe barriers to start and/or keep exercising indicated that encouragement was not necessary. This is in accordance with what McAuley et al. (2011) found.

5.5 Long-Term Effect of the Text Messages on Weekly Exercise Frequency

In this study I also examined whether the effect of the text messages on exercise frequency was maintained once I removed the text messages. Examining maintenance is crucial because when research is to be translated into practice it needs to be clear if respective interventions have a long lasting impact on behaviour (Fjeldsoe et al., 2011). Further, continuing PA and exercise with the same intensity as during the time when text messages were sent ensures that positive health outcomes can be acquired and/or maintained. This is of particular importance for older adults (Floegel et al., 2015; Nelson et al., 2007). Despite the importance of investigating long-term maintenance of behavioural interventions, Fjeldsoe et al. (2011) in their systematic review reported that only 18% of controlled PA and/or diet trials conducted long-term follow-up (defined as outcome examination at least three months after intervention ended).

In my study, exercise frequency decreased significantly from Weeks 13 to 24 compared to Weeks 1 to 12 in the overall sample and within the SMS condition. With this, at Week 24, participants in the SMS condition did not exercise significantly more than No-SMS condition participants. Hence, the between-group difference at Week 12 favouring the SMS condition was not maintained once the text messages ceased. This means that the effect of the text messages in terms of exercise frequency was not maintained.

This finding adds to the current research literature on text messages as a means to promote PA and/or exercise in older adults because Kim and Glanz (2013) who conducted the only other trial that examined the effects of text-messaging on PA in older adults did not report any long-term follow-up data. Only Fjeldsoe et al., (2015) who conducted a text-messaging trial with postnatal women reported follow-up data after the text messages were removed. They also found that the effects of the text messages on PA were not maintained (Fjeldsoe et al., 2015). Thus, it seems that using text messages to promote PA and exercise is not sustainable once the text messages cease. This is an interesting finding because Fjeldsoe et al. (2011) found that the majority of PA and diet studies that reported data on behavioural maintenance were successful. In their review, 72% of the studies found a significant between-group difference for at least one behavioural outcome favouring the PA and/or diet intervention conditions after long-term follow-up without the intervention.

One reason for the reduced exercise frequency after the text messages ceased might be that the text messages were not sent long enough. This might be especially so among participants who had difficulties to start and/or continue exercising (Lally et al., 2010). This is in accordance with Fjeldsoe et al. (2011) who found longer interventions to be more successful in maintaining PA and diet behaviours. Another piece of evidence for this assumption comes from the recent text-messaging study by Fjeldsoe et al. (2015). The authors implemented a PA text messaging intervention that was 12 weeks long, and they reported that PA was not maintained beyond the intervention. Sending text messages for a longer time might thus be an option for sustainable PA and exercise effects. For older adults who have long established behavioural patterns, longer interventions that target behavioural change might be particularly important (Floegel et al., 2015).

However, Fjeldsoe et al. (2011, 2015) also suggested that it might not be necessary to intervene with the same intensity for a longer time. Instead, they recommended using follow-up prompts as a less intense alternative to a full intervention. These follow-up prompts might help participants to develop a sustainable behaviour. Prompts could be delivered via text-messaging or other channels. Similarly, Buchholz et al. (2013) in their systematic review suggested using booster text messages after intervention conclusion. In my study the interview analysis revealed that a number of participants who benefited greatly from the text messages from Weeks 1 to 12 attributed their reduced exercise frequency to not receiving the text-messaging support after 12 weeks. Some of these participants said that it was difficult to continue exercising without the text messages. On the contrary a number of participants who reduced their exercise participation said that the text messages were not needed after 12 weeks. More research is needed to gain insights into for whom, when, and how prompts can be used to maintain the effects of text messages (Fjeldsoe et al., 2011, 2015).

It might also be necessary to incorporate more face-to-face contacts between the interventionist and the research participants during the interventions. Fjeldsoe et al. (2011) found that interventions with increased face-to-face contact were associated with more behavioural maintenance beyond intervention conclusion. This might be especially important for older adults who value personal contact more than other age groups (Lattimore et al., 2011; Vroman et al., 2015). On the other hand, more face-to-face contacts will also lead to increased costs and reduced outreach. This would take away some advantages of text-messaging as an intervention delivery channel, especially at the population level (Buchholz et al., 2013; Kumar et al., 2013).

Finally, I could argue that participants in the SMS condition had very high levels of exercise frequency at Week 12 (M = 3.7 times exercise per week) and that a drop was more likely compared to No-SMS condition participants. This ceiling effect might partially explain the pronounced decrease in exercise frequency in the SMS condition.

Despite the decrease in exercise frequency from Weeks 12 to 24 in the overall sample I want to highlight that the participants still exercised about 2.5 times per week. I consider this as a meaningful result considering that the participants did not exercise at all prior to the study.

5.6 Secondary Outcomes

I will discuss the results pertaining to the secondary study outcomes, namely, weekly time spent exercising, exercise self-efficacy, PA-related energy expenditure, daily sitting time, BMI, grip strength, and lower body strength in the following sections.

5.6.1 Weekly Time Spent Exercising

Participants in the SMS condition exercised about 30 minutes more per week from Week 1 to Week 12 compared to the No-SMS condition. This difference between the conditions was not significant, probably due to the small sample size, but the effect was medium and hence, meaningful. Weekly exercise duration decreased throughout the 12 weeks in the overall sample but there were no differences between the groups on how much exercise duration decreased. With this, the results mirror the findings of the weekly exercise frequency variable. The more often participants exercised the more overall time they spent exercising. Hence, the text messages had an impact on how often participants exercised and consequently how much time they spent exercising.

In the overall sample, weekly time spent exercising decreased significantly from Week 12 to Week 24. The same is true for the SMS condition. Exercise duration reduced by 23.3 minutes in the SMS condition, from 109 minutes at Week 12 to 85.7 minutes at Week 24 and only 10.8 minutes in the No-SMS condition, from 85.6 minutes at Week 12 to 74.8 minutes at Week 24. Thus, participants in the SMS condition reduced exercise duration more than those in the No-SMS condition. As a consequence, at Week 24 there was only an 11-minute difference between the groups. This is similar to the pattern of exercise frequency where participants in the SMS condition reduced the amount of weekly exercise sessions significantly but participants in the No-SMS condition did not.

In summary, exercise frequency and exercise duration were strongly related in my study. When participants received text messages they exercised frequently and longer, but when the text messages ceased exercise frequency and duration decreased in a similar fashion. As suggested in Section 5.5 more research is needed to understand how to maintain the effects from the text messages once the text messages cease (Fjeldsoe et al., 2011, 2015).

5.6.2 Exercise Self-Efficacy

As I discussed in Chapter 2 exercise self-efficacy is essential in adopting and maintaining PA and exercise behaviour across all populations (McAuley, 1993; McAuley, Lox, & Duncan, 1993). The theories introduced in Chapter 2 also acknowledge that exercise-self efficacy is either directly or at least indirectly related to PA and exercise behaviour. It is also recommended that exercise-self efficacy should be promoted within PA and exercise interventions (McAuley, 1993; Williams & French, 2011). In my study I used the two BCTs that are supposed to affect exercise self-efficacy and exercise behaviour (Williams & French, 2011) to inform the content of the text messages sent to SMS condition participants.

From the results of my study, exercise self-efficacy decreased over the course of the study in both conditions. However, this decrease was not significant. On average the decrease was about eight points and this might be explained with the ceiling effect. At baseline participants already had very high self-efficacy scores (average of 81.7 out of 100) that made further increments less likely (McAuley et al., 2003). McAuley et al. (1992) suggested to measure exercise self-efficacy levels not before starting an exercise programme because participants might be too optimistic and cannot accurately estimate how much effort it might take them to exercise. Participants first need to be exposed to the programme to understand how challenging it might be to exercise regularly. McAuley et al. (2011) confirmed this in a study with older adults. The researchers collected EXSE data at baseline of an exercise intervention and found that the participants overestimated their exercise self-efficacy. However, after a period of three weeks, participants recalibrated their exercise self-efficacy based on their experiences with the exercise programme. From the three weeks exercise self-efficacy levels participants increased in exercise self-efficacy as they became more accustomed to the exercise intervention. As a result, McAuley et al. (2011) recommended that interventionists should consider collecting baseline exercise self-efficacy levels after a short period of about two to three weeks. The respective scores are then a more accurate representation of baseline exercise self-efficacy levels and can serve as a reference for future assessments. If I would have been able to do this, it is likely that the decrease in exercise self-efficacy would not have occurred. Unfortunately, measuring exercise self-efficacy after the intervention started was not possible because it would have meant to visit all participants again three weeks after the initial home visit (this was logistically not possible).

That there were no significant effects on exercise self-efficacy over time might also suggest that the BCTs that were supposed to promote exercise self-efficacy in the SMS condition did not have the desired effect. Although this is contradictory to other studies where researchers reported some effect on self-efficacy following a PA/exercise intervention this finding might again be related to the fact that initial levels of exercise self-efficacy were high. This then suggests that the significant difference in weekly exercise frequency between the research conditions at Week 12 was not related to exercise self-efficacy promoted through the text messages (Gell & Wadsworth, 2014). It might be that participants in the SMS condition exercised significantly more from Weeks 1 to 12 because the text messages triggered self-regulation, and that the increased levels of self-regulation lead to increased exercise frequency. This connection was also highlighted by Young et al. (2014) and Anderson-Bill et al. (2011) who found that self-regulation is directly associated with PA and exercise. Additionally, researchers using the TTM suggested that when an individual has enough cognitive resources like self-efficacy, behaviour is mostly influenced by behavioural processes like self-regulation (Nigg et al., 2011). Schwarzer (2008) in his HAPA model suggested something similar as he proposed that when people have adequate intentions and self-efficacy to behave self-regulatory skills in the form of planning are essential (Lippke et al., 2010; Luszczynska et al., 2007; Schwarzer, 2008). The results from the interview analysis provided further support for this. Low exercise self-efficacy was not an issue for most participants who faced barriers to exercising. They described barriers such as motivation, time constraints, and/or forgetfulness. Further, none of the SMS condition participants described that the text messages increased their self-efficacy. In fact, they said that they felt pushed, inspired, or reminded when they read the text messages. Some even said that the text messages made them discipline themselves to stick to the exercises. With this, the BCTs (delivered via text messages) might not have had an effect on exercise self-efficacy but they affected exercise behaviour via self-regulation (Williams & French, 2011) leading to more exercise in the SMS condition compared to the no SMS condition (see Section 5.3.2 for more explanations). It would be interesting to test the respective pathways in a later study.

At Week 24 there was no significant change in exercise self-efficacy in the overall sample compared to baseline, but weekly exercise frequency decreased at Week 24 compared to Week 12. This decrease was significant in the SMS condition. There are three potential reasons for this.

First, the participants only found their preferred level exercise frequency during Weeks 13 to 24. This means that, in the SMS condition, the text messages might have led to 'unnaturally' high exercise levels. Without the text messages participants reduced their exercise frequency to a more comfortable level. With this, their exercise self-efficacy would still be high but their exercise frequency would be lower. The interview data provided some support for this as a number of participants indicated that they stabilised their exercise routine after Week 12.

Second, as described earlier exercise-self efficacy did not play a mediating role between the text messages and exercise frequency from Weeks 1 to 12. Instead, it might be that self-regulatory processes were primarily affected by the text messages (reminder and/or push effect of text messages). Once the text messages ceased the source of self-regulation also disappeared. This might have been particularly problematic for participants who faced a number of barriers to exercising. For example, three participants indicated that they missed the push and/or reminder to exercise and that this was the reason for their reduced exercise frequency from Weeks 13 to 24 compared to the Weeks 1 to 12.

Third, Schwarzer et al. (2008) suggested that there is no generic exercise self-efficacy that is equally predictive of PA and exercise at every stage of behaviour change. In his HAPA model different modes of self-efficacy are important to (a) develop behavioural intentions, (b) initiate and maintain behaviour, and (c) maintain behaviour in the face of obstacles. In this study I used two BCTs to promote a more generic type of exercise self-efficacy throughout the initial 12 weeks (Williams & French, 2011). However, some participants were already in a very advanced stage of behaviour acquisition and might have benefited more from text messages that promoted long-term maintenance of exercise self-efficacy (McAuley et al., 2011). Such messages sent to specific participants for a certain period of time might have led to the maintenance of Week 12 exercise frequency.

In summary, due to the high exercise self-efficacy levels at baseline it is likely that the BCTs incorporated in the text messages did not affect self-efficacy but self-regulatory processes that affected exercise frequency. Researchers might explore the validity of these assumptions in later studies. The decrease in exercise frequency from Week 12 to Week 24 seems to be unrelated to exercise self-efficacy. However, it is possible that participants would have benefitted from measures that promoted a type of self-efficacy leading to the maintenance of exercise frequency (McAuley et al., 2011; Schwarzer, 2008).

5.6.3 PA-Related Energy Expenditure and Daily Sitting Time

Weekly PA-related energy expenditure did not change significantly over the 24-week study period. However, I observed a marked increase from baseline to Week 12 (about 400 MET-minutes per week) and Week 24 (about 300 MET-minutes per week) in the overall sample. These increases in MET-minutes per week are equivalent to about 100 and 80 minutes of moderate PA, respectively. Overall, the participants reported, in their exercise diaries, that they exercised on average about 100 minutes per week between baseline and

Week 12. Hence, the increase in PA-related energy expenditure seems to reflect that participants added the $_{my}$PAtHS exercises to their habitual PA. The match between diary data and the data from the IPAQ (short) also seems to suggest that the diary was a valid instrument for data collection in my study. That the increase in PA-related energy expenditure was not significant can again be explained by the small sample size. Additionally, the IPAQ (short) developers cautioned that the respective data is likely to have large standard errors especially when used in small samples (Craig et al., 2003). A larger sample will likely increase the statistical power.

Daily sitting time decreased non-significantly throughout the study (p = .054). However, the borderline significance and the large effect size indicated that there was an effect of time on daily sitting. Specifically, I observed a decrease of about 45 minutes from baseline to Week 12. This decrease is meaningful but might seem too low in light of the increased time in PA and especially exercise (see previous paragraph). However, authors of a recent review indicated that increased time in PA and/or exercise does not necessarily mean a reduction in sedentary time (Mansoubi, Pearson, Biddle, & Clemes, 2014). The researchers reported small to medium inverse relationships between MVPA and sedentary time. This relationship was stronger for light PA. This means MVPA, including exercise, and sedentary time coexist and are independent from each other as they take place at different times. To reduce sedentary time Mansoubi et al. (2014) recommended targeting the increase of light PA. This was not the goal of my study and hence, there was only a minor match between increased PA and daily time spent sitting.

5.6.4 Body Mass Index, Grip Strength, and Lower Body Strength

BMI and grip strength did not change significantly over the course of the study. This is not surprising because the exercise programme did not specifically target weight reduction or muscle hypertrophy. Further, there were no exercises that particularly targeted grip strength. However, lower body strength improved over time, non-significant but likely meaningful. This suggests that due to the participants' exercise participation there were some minor effects on leg strength (Jones et al., 1999).

5.7 Limitations and Strengths of the Study

5.7.1 Limitations of the Study

My study has some limitations that need to be highlighted. First, due to unexpectedly large standard errors in weekly exercise frequency at Week 12 and the drop-out of participants the study was not adequately powered to detect between-group differences in exercise frequency. I calculated the required sample size a priori and used the available literature as a reference for this calculation (Cohen, 1992; Fjeldsoe et al., 2010). These calculations indicated that I needed 18 participants per condition to reach adequate power. I oversampled by 15% to account for potential drop-out. Unfortunately, these measures did not prevent the loss of statistical power. However, the results of my study can now serve as a reference for future power calculations for similar studies (Fjeldsoe et al., 2010, 2015).

Second, I was not able to recruit a more representative sample of participants into my study. Malaysia has three major ethnic groups. Malays and Bumiputera make up about 65%, Chinese 21%, and Indians 6.5% of the total population (Department of Statistics Malaysia, 2012). In this study I recruited mainly Chinese Malaysians, and a few Malays. Further, the majority of study participants were female (72%) and hence, men were underrepresented. Recruiting men into PA interventions is a common problem and implies the question whether interventions have a similar impact across sexes (Waters, Galichet, Owen, & Eakin, 2011). Additionally, I have only included volunteers who were at least interested in some exercise. It is therefore questionable if the text messages would have been effective in older adults who were not inclined to do some exercise. This is a common problem in interventional research targeting health behaviours (Ziegelmann & Knoll, 2015). Representative sampling should be conducted in future studies to increase the generalisability of the results.

Third, from my study it is not entirely clear whether the text messages themselves that had an impact on exercise frequency in the SMS condition or whether the content of the text messages were responsible for the significant between-group difference at Week 12. Both conditions had the same exercise programme booklet. The difference between the conditions was that only the SMS condition received text messages. However, these text messages had an encouraging content that was based on previous research (Williams & French, 2011). Hence, I am not able to directly infer what had an impact on the SMS condition participants' exercise frequency. Kim and Glanz (2013) as well as Gell and Wadsworth (2014) were similarly unable to make accurate inferences about the exact effect of the text messages and its content in their studies. This also applies to the studies conducted by Fjeldsoe et al. (2010, 2015) where the text messages constituted the main intervention element but other components were also included (e.g., counselling, goal setting refrigerator magnet). Overall, this is a common shortcoming of RCTs and other designs that only evaluate an intervention as a whole (Collins, Murphy, & Strecher, 2007). Future studies should investigate which elements within text-messaging interventions exert the strongest impact on PA and exercise behaviour (Gell & Wadsworth, 2014).

Fourth, I designed the content of the text messages based on the research by Williams and French (2011). The authors investigated the BCTs that were successful in promoting exercise self-efficacy and exercise behaviour in adults. The participants in the current study were older adults. Hence, using the BCTs that are effective in older adults might have been more sensible (French et al., 2014). However, Williams and French (2011) in their meta-analysis included studies that targeted adults until the age of 65 (Williams & French, 2011). As the participants of my study had a mean age of about 63 years and less than one third was older than 65 years I decided to use Williams and French’s (2011) study to inform the content of the text messages.

Finally, I used a self-report instrument, exercise diary, to collect the primary outcome data, exercise frequency. Self-reports are generally less reliable compared to objective measures because people tend to over- or under-report their activities (Helmerhorst, Brage, Warren, Besson, & Ekelund, 2012). In my study the diary, however, was the most appropriate instrument to collect the outcome data. To increase the likelihood of receiving accurate data I followed the recommendations by Crosbie (2006) and explained and demonstrated how to fill up the diary. Further, during the interviews at Weeks 12 and 24 I asked the participants how often per week they normally exercised and if they faced problems filling up the diary. I did this to check if the data from the diary were reasonably reliable. The participants indicated that filling up the diary was easy. I also found a clear match between the diary records and how often the participants indicated that they exercise per week during the interview. Thus, I concluded that the diary data were a reliable representation of the exercise frequency and duration of the study participants.

5.7.2 Strengths of the Study

Despite the aforementioned limitations my study had a number of strengths. The outcome measure, exercise frequency, was measured twice, once directly after 12 weeks of text messaging and once after 12 weeks without text messaging. This allowed me to investigate whether the effects of the text messages were maintained over a longer period of time after the text messages were removed. Despite its importance, measuring behaviour maintenance beyond intervention conclusion is the exception rather than the norm (Fjeldsoe et al., 2011, 2015). Kim and Glanz (2013) in their text-messaging study with older adults did not provide maintenance data and hence, the current study filled this gap.

Furthermore, in this study I investigated the effect of the text messages on exercise frequency after controlling for exercise self-efficacy. I also examined if exercise self-efficacy moderated the relationship between receiving/not receiving text messages and exercise frequency. Although exercise self-efficacy is of primary importance to the adoption of PA and exercise across age groups (Koeneman et al., 2011; McAuley, 1993) only Gell and Wadsworth (2014) conducted some in-depth analysis to understand what role this confounder plays. They reported that PA self-efficacy did not mediate the relationship between receiving/not receiving text messages and step counts. In my study I found that the level of exercise self-efficacy plays a role in how impactful the text messages are. Participants with low self-efficacy levels at baseline benefited more from the text messages than participants with high levels of exercise self-efficacy.

The content of the text messages was informed by BCTs that are supposed to promote exercise self-efficacy and exercise behaviour (Williams & French, 2011). This is a strength of my study because these BCTs are meant to actively impact behaviour change, compared to behaviour change theories that mainly explain behaviour change (Abraham & Michie, 2008). To my knowledge this is the first study that translated BCTs into text-messaging content.

Lastly, to my knowledge this is the first study reporting on a behavioural text-messaging intervention in older adults in a non-HIC. With this, my study provides urgently needed evidence that shows that text-messaging is potentially effective in developing countries where mobile phone proliferation is highest (Bort-Roig, Gilson, Puig-Ribera, Contreras, & Trost, 2014; Gurman, Rubin, & Roess, 2012; Hall et al., 2015; Hall, Fottrell, Wilkinson, &

Byass, 2014; Vandelanotte et al., 2016). It also provides some information on text-messaging in an underserved population, older adults (Buchholz et al., 2013).

5.8 Implications for Future Research

5.8.1 Text-Messaging Interventions

My thesis provides some promising findings regarding the impact of encouraging text messages on exercise participation in older adults. However, although some important questions were answered in my study further research is warranted.

My study can serve as a reference for a larger trial with more participants and a balanced sample to gain more stable results. Enrolling about 40 older adults per condition to examine the effect of text-messaging on exercise frequency will likely yield the desired statistical power of 80% with a significance level of 5% for a between-group difference of one exercise session per week. With this, I am proposing a similar strategy that Fjeldsoe et al. (2010, 2015) applied. The authors first initiated a small study that was underpowered and had some other limitations. However, this initial study was a crucial building block for a larger, adequately powered study that the researchers carried out a few years later.

Additionally, more research is needed on text-messaging intervention characteristics (Hall et al., 2015). It is still unclear to what extend the text message content and the text messages themselves impact behaviour change (Cole-Lewis & Kershaw, 2010; Hall et al., 2015). In terms of the content it is unclear which mediating construct should be targeted. From my study, exercise self-efficacy did not seem to link the text messages and exercise frequency. However, participants had high exercise-self efficacy at baseline and it is therefore interesting to examine if the same text messages would affect self-efficacy leading to exercise in people with low levels of exercise self-efficacy. In terms of the text messages themselves several authors have highlighted that it is important to understand the optimal frequency and delivery time of text messages (Cole-Lewis & Kershaw, 2010; Gell & Wadsworth, 2014; Hall et al., 2015; Siopis et al., 2014).

In my study it has surfaced that decreasing the text-message frequency was desired by most study participants because they thought they would need less support over the course of time. To this end Head et al. (2013) also reported that decreasing text-message frequency was associated with greater intervention efficacy. However, the researchers did not include studies on older adults in their meta-analysis. Further, Fjeldsoe et al. (2010, 2015) as well as Gell and Wadsworth (2014) chose to decrease text-message frequency over time, whereas Kim and Glanz (2013) sent the same number of weekly text messages throughout the study period. Study results were similar (short-term). With this, it might be interesting to examine if text-message frequency should decrease over time, remain the same throughout the study, or if study participants should decide how many text messages they receive.

The time that text messages are sent might also impact its efficacy. In my study I chose to send the text messages in the morning to allow the participants enough time to exercise throughout the day (Gell & Wadsworth, 2014). Others might examine if it is beneficial to send text messages when participants plan to exercise, or to match the text-messaging time with the daily routines of participants.

To understand which intervention components are important and how they should be implemented a Multiple Optimisation Strategy Trial (MOST) might be best suited (Collins et al., 2007). A MOST has three phases. In Phase 1 (screening) a set of important intervention components will be identified. This can be done with fully crossed trials to isolate the effects of components. For text-messaging researchers could compare the following conditions with each other: sending text messages, not sending text messages, giving instructions to exercise, giving praise/reward for effort, sending text messages with instructions to exercise, sending text messages with praise/reward for effort, not sending text messages but giving instructions to exercise, not sending text messages but giving praise/rewards for efforts. If the text-messaging conditions were more successful than the No-text-messaging interventions in Phase 2 (refining) researchers can identify the optimal timing and dose of the text messages. This can again be done with a fully crossed design. The final intervention draft from Phase 2 can then be evaluated with a common RCT. This is Phase 3 (confirming).

Another interesting avenue of text-messaging research in older adults might be to implement an intervention that exclusively targets couples. Researchers have shown that a PA and/or exercise intervention is more effective in older couples compared to older adults who do participate without their life partner (Gellert et al., 2011). With this, sending text messages urging older couples to support each other to adopt and maintain a certain exercise routine might be valuable.

Finally, more in-depth research is needed to explore the cost-effectiveness of text-messaging interventions, especially in developing countries (Hall et al., 2015). This is crucial because if text-messaging is an effective as well as economically viable way to induce health behaviour change in people in these countries initiatives on the population level can be implemented.

5.8.2 Beyond Text-Messaging

Mobile phone text-messaging, although successful in health promotion and health behaviour change interventions (Hall et al., 2015), is only one of many tools in the mHealth toolbox (Burke et al., 2015; Danaher et al., 2015). The WHO (2011) defined mHealth broadly as a component of electronic health (eHealth) that involves health delivery and care via wireless mobile devices such as personal digital assistants (PDAs), mobile phones, smartphones, and electronic activity monitors (also called wearable activity trackers). The opportunities of mHealth are countless considering the potential reach of interventions, and the breadth of design, content, and interactivity options (Blackman et al., 2013; Bort-Roig et al., 2014; Burke et al., 2015; Kumar et al., 2013; O'Reilly & Spruijt-Metz, 2013; Okorodudu, Bosworth, & Corsino, 2015; World Health Organization, 2011).

The evidence base for mHealth is still small (Kumar et al., 2013) but an increasing number of researchers are working tirelessly on ways to impact behavioural health using mobile technology (Burke et al., 2015). For PA and exercise two research groups reported that mHealth approaches were generally successful in changing PA (Blackman et al., 2013; O'Reilly & Spruijt-Metz, 2013). Modern mHealth approaches can also be a viable way to impact PA and exercise in older adults (Chase, 2015; Müller & Khoo, 2014). This is mainly because older adults are increasingly keen to use new technologies and show growing confidence to explore their functions (Gell et al., 2015; O'Brien, Troutman-Jordan, Hathaway, Armstrong, & Moore, 2015; Zhou, Rau, & Salvendy, 2014).

A study group from Switzerland has shown that a tablet-supported home-based exercise programme is attractive for older adults (Silveira, van de Langenberg et al., 2013; Silveira, van Het Reve, Daniel, Casati, & Bruin, 2013). Participants were highly engaged with the tablet-application and reported that it helped them to exercise regularly. However, the effectiveness of the intervention in terms of exercise behaviour was not investigated. The authors called for an adequately powered efficacy trial.

Another mHealth technology that is currently being investigated for its effectiveness in PA and exercise interventions is the smartphone. This is because smartphone applications related to health and fitness are very popular, and researchers realise the inherent potential of this technology for behaviour change interventions (Conroy, Yang, & Maher, 2014; Hongu et al., 2014; Wong, Meng, Hongu, & Loprinzi, 2014). So far, researchers reported that smartphone interventions are engaging and capable of inducing PA behaviour change (Bort-Roig et al., 2014). For older adults with no smartphone experience, King et al. (2013) developed three smartphone applications to increase PA and decrease sedentary behaviour. After an intervention period of eight weeks, participants (*N* = 68) reported high satisfaction with the respective application. Further, time spent walking and MVPA levels increased significantly while sitting time reduced. I encourage more research involving larger and diverse samples of older adults from different regions of the world.

Lastly, electronic activity monitors such as the Fitbit™ that are growing in popularity have caught the attention of behavioural health researchers and practitioners (Lewis, Lyons, Jarvis, & Baillargeon, 2015; Lyons, Lewis, Mayrsohn, & Rowland, 2014). These wearable activity trackers can measure certain domains of PA accurately (Diaz et al., 2015; Ferguson, Rowlands, Olds, & Maher, 2015) and incorporate a number of potentially effective BCTs for PA and exercise behaviour change (Lyons et al., 2014). Additionally, researchers who conducted a systematic review reported significant PA changes in five out of nine studies after an intervention that employed wearable activity trackers (Lewis et al., 2015). O'Brien et al. (2015) and Cadmus-Bertram, Marcus, Patterson, Parker, and Morey (2015) found that also older adults are capable of and interested in using this technology to track PA. Researchers testing the efficacy of wearable activity trackers to increase PA and exercise in older adults reported mainly positive results (Cadmus-Bertram, Marcus, Patterson, Parker, & Morey, 2015; Fitzsimons et al., 2013; O'Brien, T. et al., 2015; Thompson, Kuhle, Koepp, McCrady-Spitzer, & Levine, 2014). However, study designs and interventions were diverse, and study sample sizes were small. A larger evidence-base informed by rigorous studies is needed to draw accurate conclusions.

5.9 Conclusion

Population ageing is a pressing issue of recent times. It can be associated with various opportunities when the older adult population is in good health. A healthy lifestyle is the cornerstone of successful ageing. PA and exercise are associated with tremendous physiological and psychological health benefits. However, due to the low levels of PA and exercise in older adults, innovative, effective, and also economically viable interventions are needed. While theory provides a general understanding of health behaviour change, specific BCTs are imperative to actively induce behaviour change. These BCTs need to be delivered effectively.

In this thesis I examined the effects of text-messaging on an exercise intervention on exercise frequency in older Malaysians. Sending text messages that provided participants with instructions to exercise and with praise for their efforts had a strong effect on exercise frequency compared to not sending text messages. These effects were stronger for participants with low levels of exercise self-efficacy at the beginning of the intervention. However, after the text messages ceased exercise frequency decreased sharply and there were no differences in participants who initially received and those who did not receive text messages. This indicates that the effect of the text messages could not be maintained and further research is needed to explore ways to increase sustainability. Further research is also crucial to establish the intervention components that effectively promote PA and exercise (e.g., text messages, content, and text-messaging frequency).

In sum, my thesis provides some important insights on the effects and mechanisms of text-messaging supported exercise promotion in older adults from a developing country, Malaysia. I encourage more research that examines how various mHealth approaches can be used for behaviour change interventions in older adults from across the globe.

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LIST OF PUBLICATIONS, PAPERS PRESENTED, AND COPYRIGHTS

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Scientific Presentations

Müller, A. M., Khoo, S., & Morris, T. (2015, June). Promoting exercise in older Malaysians using SMS reminders. Paper presented at the Annual Scientific Meeting of the International Society of Behavioral Nutrition and Physical Activity, Edinburgh, United Kingdom.

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