The Effect of Mobile Messaging-Based Health Interventions on Non-Communicable Disease Health Risks and Behaviours

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DECLARATION

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List of Abbreviations
(in alphabetical order)

AWS	Amazon web services
BBCC	Brief behaviour change counselling
BCW	Behaviour change wheel
BMI	Body mass index
C	Control group
CI	Confidence interval
COM-B	Capability, opportunity, motivation-behaviour
COVID-19	Coronavirus 19
CVD	Cardiovascular disease
GB	Gigabyte
GRADE	Grading of Recommendations Assessment, Development, and Evaluation
HBA1C	Haemoglobin A1C (glycated haemoglobin)
HBM	Health belief model
HIC	High-income country
HIV	Human Immunodeficiency Virus
IBM	International Business Machines Corporation
IG	Intervention group
Ill, USA	Illinois, United States of America
IMB	The Information-Motivation-Behavioral Skills Model
INPLASY	The International Platform of Registered Systematic Review and Meta-analysis Protocol
IQR	Interquartile range

ITT	Intention to treat
KB	Kilobyte
LMIC	Lower to middle-income country
MET	Metabolic equivalent of tasks
mHealth	Mobile health
MI	Motivational interviewing
MMAT	Mixed methods appraisal tool
MVPA	Moderate-vigorous physical activity
NCDs	Non-communicable diseases
PA	Physical activity
PEN	Package of Essential NCD protocol
PRISMA	Preferred Reporting Items for Systematic Reviews and Meta-Analyses
RCT	Randomised controlled trial
SADHS	South African Demographic and Health Survey
SMD	Standardised mean difference
SMS	Short message service
SPSS	Statistical Package for the Social Sciences
TPB	Theory of planned behaviour
TRA	Theory of reasoned action
TTM	Transtheoretical model
QoL	Quality of life
UMIC	Upper middle-income country
WoW!	Western Cape on Wellness!

Thesis Abstract

Introduction: The prevalence of non-communicable diseases (NCDs) has increased rapidly, with NCDs being a leading cause of death globally. Despite the high mortality rate, NCDs are preventable and can be managed through addressing modifiable risk factors such as obesity and physical inactivity. Many public health interventions have aimed to reduce NCD risk factors, through supporting various lifestyle modifications. These interventions include Mobile Health (mHealth) interventions, which involve the use of mobile technology to provide health care and support to patients remotely. Community-based programmes may benefit from the use of mHealth interventions, due to the potential of these interventions for scalability and cost effectiveness.

Aim: The aim of this thesis was to develop, implement and evaluate a pilot mHealth intervention that delivered automated, one-way WhatsApp messages for the promotion of healthy behaviour changes, as part of a pre-existing community health programme, *Western Cape on Wellness* (WoW!). Prior to the implementation of the pilot intervention, formative research was conducted, which included i) performing a systematic review and meta-analysis to better understand existing mHealth literature relevant to the pilot study, and ii) conducting a prospective descriptive study that aimed to determine the baseline health status, health goals, and health barriers of the population in which the intervention would be piloted.

Methods: A mixed method approach was used. First a systematic review and meta-analysis was performed by searching for relevant literature on PubMed, Scopus, and Web of Science databases. Eligibility included pre-post intervention studies using one-way mobile messaging for health behaviour change. A random effects model was used for meta-analysis and standardised mean difference for effect size. Thereafter, a prospective, descriptive study was performed by administering an online health questionnaire to recruited WoW! members. Lastly, a quasi-experimental two-arm intervention was piloted on the participants recruited in the descriptive study. The intervention involved a WhatsApp bot that was programmed to send biweekly messages that were tailored to the intervention participants' pre-selected health goals and health barriers, using the COM-B model (Capability, Opportunity, Motivation-Behaviour). The control condition included regular, non-tailored WhatsApp messages. After 12 weeks of messages, participants were prompted to complete a follow-up health assessment.

Results: The systematic review and meta-analysis (n=43) found that unidirectional mobile messaging had minimal but significant effects on physical activity (d+: 0.14, 95% CI: 0.05 to 0.23,

p=0.003, I^2=65%), and no effect on weight loss (d+: 0.04, 95% CI: −0.02 to 0.10, p=0.21, $I^{2=}$29%). The descriptive study (n=95) observed a high prevalence of obesity (52%) and insufficient physical activity (70%) in the target population. The most frequently selected health goal by participants was to achieve a healthy weight (55%) which correlated to the high levels of obesity and physical inactivity. Upon the completion of the pilot intervention, only 26% of the 95 participants completed the follow-up post intervention. Although no significant changes were observed post intervention, most participants in the intervention group who completed the evaluation found the intervention acceptable.

Discussion: The results of our systematic review and meta-analysis are similar to our findings in the feasibility pilot. In both, we showed that unidirectional, tailored mobile messaging had little to no effect on NCD risk factors, including physical activity and weight-related outcomes. These results suggest that messaging alone is not sufficient to elicit lifestyle changes to reduce the burden of NCDs and the associated risk factors. However, due to the small sample size, the study may have been underpowered to detect any significant changes. Future studies should consider using other intervention components, in addition to mobile messages, such as interactive texting, phone calls or in-person group sessions to potentially improve intervention effectiveness.

Conclusion: Although mobile health has shown some potential in managing NCD risk factors, using unidirectional messaging alone may not be sufficient as a standalone intervention. More research using messaging in conjunction with other intervention components may be needed to realise the scalable potential of mHealth for NCD management in South Africa.

CHAPTER 1: Background and Thesis Topic

Non-communicable diseases (NCDs) contribute to a significant proportion of morbidity and mortality globally. Fortunately, many NCDs can be prevented and managed through healthy lifestyle changes.[1–3] Thus, there is a need for the development and evaluation of innovative, cost-effective, scalable behaviour change interventions that target NCDs and its associated risk factors.

This thesis aimed to develop, implement and evaluate a pilot, community, mobile messaging health intervention targeting NCD risk factors and barriers preventing healthy lifestyle change. This was achieved through first performing formative research to aid in the development of the intervention. This research included a brief review of the literature, followed by a comprehensive systematic review and meta-analysis on mobile messaging-based interventions targeting NCD lifestyle risk factors. Thereafter, a descriptive study was performed analysing the health characteristics, health goals and barriers of community members on which the intervention would be piloted. See figure 1.1 below for the study flow diagram.

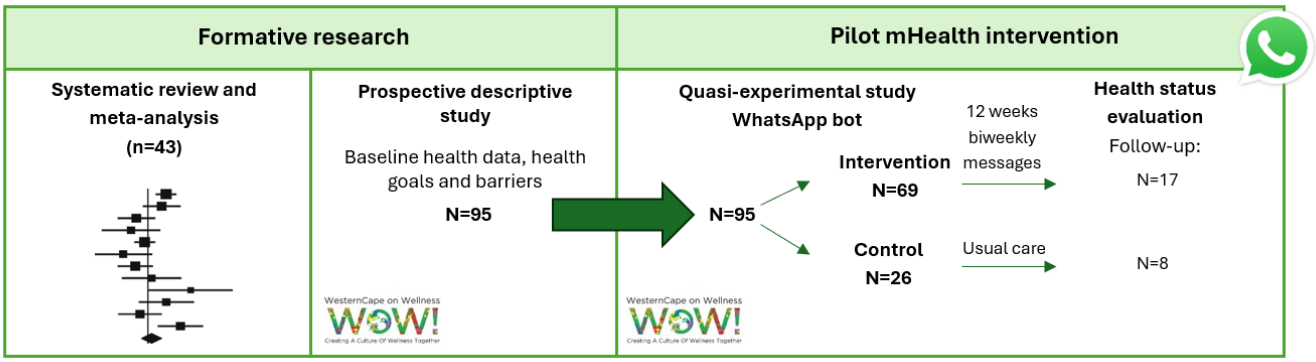

Figure 1.1 showing a flow diagram of the overall thesis study structure

The current chapter serves as an introduction to the literature, and outlines the epidemiology of NCDs, socio-economic barriers to lifestyle change, current interventions aimed at reducing NCD burden, the use of technology as a behaviour change intervention (mHealth), and behaviour change theories.

Non-Communicable Disease Prevalence

The prevalence of non-communicable diseases (NCDs) has increased rapidly in recent years, with NCDs becoming a leading cause of death globally. Approximately 70% of deaths worldwide have been accounted for by NCDs.[1,2] Furthermore, it has been estimated that deaths due to NCDs will more than double from 2005 to 2060, and will outnumber communicable disease deaths by more than five to one by 2060.[3]

NCDs are chronic, non-infectious conditions that develop over time, and are caused by a combination of modifiable and non-modifiable risk factors. Non-modifiable risk factors are factors that cannot be improved or changed, and include sex, age, and genetics.[2] Modifiable risk factors are factors that may be altered and improved and include i) behavioural factors such as smoking, unhealthy diet, physical inactivity, alcohol use; ii) biological factors such as hyperlipidaemia, insulin resistance, high blood pressure, and obesity; and iii) ecological and environmental factors, such as socioeconomic status and education levels.[2] The four main NCDs that contribute to global annual mortality are cardiovascular disease (17.9 million deaths), cancer (9 million), chronic respiratory disease (3.9 million), and diabetes (1.6 million).[2,4]

Although the effects of NCDs are experienced worldwide, 85% of the health burden is found in lower to middle-income countries.[4] Communities in low-resource settings are more vulnerable to chronic disease due to poorer access to healthcare, higher levels of unemployment, lower levels of health education and limited affordable healthy food options, limiting their ability to make healthy lifestyle choices.[5–7]

In Sub-Saharan Africa alone, deaths due to NCDs are estimated to increase from 40% to 79% in 2030.[8] Furthermore, in South Africa, 51% of deaths have been attributed to NCDs.[9] Additionally, NCD risk factors comprise five out of the ten factors that contribute to Disability Adjusted Life Years in South Africa, including: high body mass index (BMI), high fasting blood glucose, high blood pressure, alcohol use and smoking.[10]

There is also a high prevalence of NCDs in the Western Cape, with NCDs accounting for up to 25% of mortality between 2009 and 2013 in the region.[10] This burden places a large strain on public health care facilities and resources. For example, hypertension was the most common cause of public healthcare service attendance in 2011 in four provinces, including the Western Cape.[9,11] Furthermore, many individuals with NCDs are left undiagnosed or with poorly controlled disease. A cross-sectional study by Folb et al., found that 59% of patients with hypertension attending primary care clinics across the Western Cape, had a blood pressure of greater than 140/90 mmHg, which is above desired therapeutic values.[12]

Lifestyle Risk Factors of NCDs

There are several modifiable risk factors of NCDs that can be mitigated through lifestyle changes. These include unhealthy diet, physical inactivity, overweight/obesity, smoking and alcohol misuse, stress and insufficient sleep.[2,13,14]

Physical inactivity

The global burden of physical inactivity is high, with one third of the world's population being physically inactive and not meeting recommended guidelines.[15,16]

There is a wealth of evidence showing that regular physical activity is vital for one's health, as it reduces the risk of chronic diseases such as obesity, type 2 diabetes and cardiovascular disease (CVD), strengthens immunity, and increases life expectancy.[17] According to a review by Lee et al., almost 10% of the prevalence of coronary heart disease, diabetes, colon and breast cancer, and premature mortality can be attributed to physical inactivity. Furthermore, it is estimated that with a decrease in physical inactivity of 10-25%, more than a million deaths worldwide can be prevented.[17]

Potential mechanisms for the protective effect of physical activity include the release of 'exerkines', a broad range of signalling molecules produced by multiple organ systems that are released after a bout of exercise. However, knowledge on these mechanisms is still limited and thus research is ongoing.[18]

Unhealthy diets

Various dietary factors have been implicated in the development of NCDs,[19] with an estimated eight million deaths being attributable to diet-related risks in 2019. Of these diet-related deaths, more than two thirds were attributable to CVD. Dietary risks include food products high in sodium, high consumption of red meat and sweetened beverages, and low intake of wholegrains, fruits, vegetables and legumes.[20]

Consuming an unhealthy diet increases one's risk of obesity and chronic diseases such as breast cancer, cardiovascular disease and type 2 diabetes.[21,22] Conversely, the intake of healthy foods is protective against chronic disease, with some individuals even 'reversing' their diabetes after improving their eating habits. [20]

Potential mechanisms for the increased risk of obesity and subsequent chronic disease due to unhealthy eating, include excess adiposity leading to an increase in pro-inflammatory cytokines, and visceral adipose tissue deposition around internal organs.[23]

Smoking and alcohol use

Smoking is a major public health crisis worldwide, with over one billion tobacco smokers and seven trillion cigarette-equivalents of tobacco used in 2019.[24] Tobacco smoking is the leading preventable cause of NCD deaths, contributing to 15% of deaths globally in 2019, most notably through the development of CVD and cancer.[25] Furthermore, smoking was the leading risk factor for male deaths in 2019, according to a systematic analysis from the Global Burden of Disease Study.[24]

Possible mechanisms for the negative health effects of smoking tobacco include an increase in oxidative stress, development of insulin resistance, dysregulation of the autonomic nervous system, and inflammation.[26]

Another substance that may increase the risk of chronic diseases is alcohol.[27] Research suggests that excessive alcohol use may increase the risk of CVDs including ischaemic heart disease, hypertension and stroke. Studies have observed an increase in oxidative stress, cell damage, and inflammation after repeated exposure of large amounts of alcohol, which may contribute to the development of diseases such as diabetes, cancer, and CVDs.[28]

Chronic stress and lack of sleep

Risk factors of NCDs that are often overlooked include stress and insufficient sleep.[13,29] Existing studies have reported an association between chronic stress and NCDs such as CVD.[13] Similarly, a lack of sleep has been linked to obesity, diabetes, hypertension, all-cause mortality and CVD events.[14] It has been postulated that chronic stress and lack of sleep increase inflammation and impair blood glucose control.[13,29] However, despite the multiple benefits of adopting healthy lifestyle practices, unhealthy behaviours persist globally.[2]

Barriers Preventing Lifestyle Change

There are many potential barriers that prevent individuals from adopting healthier lifestyles, including financial constraints. The cost of gym memberships, exercise equipment, and transport costs to areas suitable for physical activity may prevent individuals from being physically active.[30,31] Furthermore, many individuals feel that their outside environments are not safe enough to perform physical activity.[32] Additionally, the lack of affordable healthy food options make it difficult for some to maintain healthy diets.[30,33]

An additional barrier that prevents individuals from engaging in a healthy lifestyle is a lack of time.[31] Many people report not having enough time to exercise or make healthy meals, due to it competing with other daily activities such as work or household tasks.[32,33] Social factors may also prevent people from making healthy changes, with social gatherings often involving the consumption of unhealthy foods and alcohol.[32] Social pressures and lack of support from family and friends may also make it difficult for individuals to change their lifestyle habits, with some families resisting healthy dietary changes.[32,33]

Another barrier to adopting a healthy lifestyle is stress and poor mental health.[30] Poor physical health has also be cited as a reason for not engaging in lifestyle changes such as physical activity.[31] Therefore, it is important to develop behaviour change intervention that target unhealthy lifestyle risk factors while also accounting for the possible barriers preventing the adoption of healthy lifestyle changes.

Interventions to Address NCDs

The World Health Organisation (WHO) and several other organisations have suggested several interventions to reduce the risk and prevalence of NCDs, both on a population and individual level.[20]

Population level interventions

Population level interventions suggested by the WHO as 'best buys' to increase healthy diets and reduce obesity include: reducing salt intake by reformulation of products to contain less salt, taxation on sugar-sweetened beverages, subsidies to increase fruit and vegetable intake, nutritional labelling of food products, behaviour change communication and mass media campaigns on healthy diets.[20]

Population level interventions recommended to target smoking and alcohol misuse include: increased taxes on tobacco and alcohol products, standardised health warnings on products, banning or restriction of tobacco and alcohol advertisements, restrictions on the availability of tobacco and alcohol products, and mass media educational campaigns on the dangers of smoking.[25,27]

Furthermore, governments can improve budget allocation towards primary health care, develop policies towards chronic disease management and collaborate with non-governmental organisations, research centres and the private sector to develop and implement action plans targeting NCDs.[21]

In 2022, the South African National Strategic Plan for the Prevention and Control of Non-Communicable Diseases was launched. This plan aims to develop and improve health systems to facilitate the prevention and management of chronic diseases. Strategies include increasing stakeholder engagements, supporting research on NCDs, and decreasing modifiable risk factors of NCDs such as sedentary activity, through health promotion and behaviour change.[34]

Individual Level Interventions

On an individual level, counselling on healthy diets and physical activity is recommended to be included in routine primary health care services.[22] The WHO package of essential NCD (PEN) interventions report highlights the importance of healthy lifestyle counselling as a non-pharmacological component of prevention and management, that is feasible in both high and low resourced settings.[35] Similarly, the American Association of Clinical Endocrinologists and the United States Preventative Services Task Force recommend behaviour modification counselling as the first line treatment for overweight and obesity.[36,37]

Healthy lifestyle counselling involves guiding and supporting patients in adopting healthy behaviours to reduce the risk and severity of NCDs. For patients with cardiovascular disease and diabetes, counselling on healthy diets, physical activity to achieve a healthy weight, smoking cessation and alcohol misuse is vital in addition to pharmacological treatment, especially in the early stages of the disease.[35] Healthy lifestyle counselling, in conjunction with other intervention methods have been implemented in several community behaviour change interventions.[38,39]

In a longitudinal cohort study aimed at improving physical activity and diet, motivational lifestyle counselling using the WHO PEN protocol was implemented in public primary health care centres, in addition to community-based education sessions and screening events to raise awareness on hypertension and diabetes risk factors. The study observed higher motivational stages of physical activity and diet, and a non-significant decrease in BMI.[38]

The Isfahan healthy heart programme was a six-year community-based intervention in a low-income country that implemented both population level and individual level interventions to improve hypertension control.[40] A key principle in the study was developing and maintaining close contact with community representatives throughout the study. The intervention involved educating the broader population on cardiovascular disease management and importance of healthy lifestyles, through educational media campaigns, and events held in various worksites and schools. On a more individual level, patients and relatives were educated on hypertension risk factors and management strategies. The intervention reduced the prevalence of hypertension in the study population, while an increase was observed in the control population that did not receive the study interventions.[39]

The PRORIVA programme was another behaviour change intervention targeting cardiovascular disease and was conducted in low-income communities. Similar to the Isfahan study, the intervention emphasized a 'bottom-up' approach through regular engagement with community members during intervention development and deployment. Through community-organised events such as weekly exercise groups and Sunday morning walks, participants were motivated to engage in healthier behaviours.[41]

Another 'bottom-up', community-based intervention that is currently being implemented in South Africa and is aimed at targeting NCD risk factors, is the Western Cape on Wellness programme.[42]

Western Cape on Wellness (WoW!)

WoW! is a provincial, government-led, community-based, partnership programme launched in 2015, that aims to train and support volunteer wellness champions, as they assist community members in making sustainable lifestyle changes to improve their health and wellbeing.[42,43]

WoW! champions are community volunteers that are recruited and trained using evidence-based training materials, to educate and lead their respective members and communities towards healthier lifestyles. They operate by establishing separate WoW! groups in their local settings.[42]

Groups vary in size, ranging from 10 to over 100 members per group. Groups also meet at different intervals, with some groups meeting weekly, and other groups meeting less frequently. Furthermore, some groups primarily meet for group-based physical activity, whereas other groups engage in a variety of healthy lifestyle activities and various forms of community upliftment. There are approximately 750 active WoW! wellness champions, with an overall retention rate of 67% in the programme.[42]

The community-based approach of WoW! enables initiatives to be tailored to a community's needs and context, by accounting for the "lived experience" of its members. The WoW! programme has facilitated numerous health initiatives, with the help and support of over 70 partnerships. These initiatives include but are not limited to: [42,43]

- Establishing over 200 community food gardens that promote food security and healthy eating.
- Hosting healthy eating workshops that provided education on behaviour change for improved management of NCDs.
- Plant-based cooking course with over 1000 participants.
- Wellness Champion exercise sessions held twice monthly.
- WoW! 'Active Public' that promotes regular physical activity through hosting free exercise sessions in public open spaces.
- WoW! senior wellness events that promote healthy eating and physical activity in the elderly.
- WoW! wellness monitors (brief health risk assessments) and wellness passports (feedback assessment) that enable members to "know their numbers" and track personal health indications such as weight, blood pressure, physical activity levels and alcohol consumption.
- Multi-Channel Wellness Campaigns which involve healthy lifestyle promoting channels sharing health education and advice via printed material, Facebook, SMS, and WhatsApp group broadcasts.

The use of mobile messaging and social media enables WoW! to connect with wellness champions and members all over the Western Cape and may help to extend limited resources. Mobile technology has been used in many other public health interventions worldwide, and forms part of a larger scope of interventions called "Mobile Health" or mHealth.[42]

Mobile Health

MHealth is an innovative technological development consisting of the use of mobile devices and other technologies to promote and provide healthcare.[6] mHealth can be used for rapid communication of important health information, including sharing health promotional material, appointment and medication reminders via mobile messaging, and health applications for tracking physical activity levels, water and caloric intake.[6,44,45]

With rapid digitalisation globally and more recently in Africa, mHealth holds potential to improve healthcare services and the management of chronic diseases.[46] Up to 95% of the global population is covered by a mobile broadband network.[47] In Africa, active mobilebroadband subscriptions increased from under 2% in 2010 to 48% in 2023, while 3G network coverage increased from 22% to 83%.[48] While in 2021, 71% of the South Africa's population used the internet.[49] Furthermore, the use of digital technology substantially increased during the COVID-19 pandemic, with individuals using communication technology such as mobile messaging and social media as an alternative to in-person communication and services. Additionally, there was an increase in the deployment of mHealth services as an innovative alternative for healthcare delivery and health education.[44]

Although there are many different potential mHealth mediums, the most frequently reported mHealth modality used in existing literature is text messaging. A systematic review on mHealth use in low-income countries found that 93% of studies used text messaging as part of the intervention, while 62% used text messaging exclusively, and only 12% used smart phone applications.[45]

Potential reasons for the popularity of SMS use for mHealth interventions, includes the relatively low cost compared to other modalities such as mobile applications, its reliability and accessibility. SMS can be used on any mobile device and is not limited to smartphone devices, which are more costly.[45] Additionally, one does not require internet connectivity for text messaging. However, SMS use has substantially declined with the development of smartphone instant messaging platforms such as WhatsApp, and the reduction of mobile data costs.[45]

Instant messaging surpasses SMS in functionality, enabling rapid, real-time communication along with several other additional functionalities including sharing locations, images, videos, and audio messages.[50] Instant messaging is one of the most popular mobile applications used, with 40% of individuals spending over four hours on messaging applications per day in South Africa. However, instant messaging comes with additional costs and accessibility barriers, with both parties requiring internet access as well as mobile data.[50]

Mobile data costs have declined across Africa, with the average cost of 1 gigabyte (GB) of data decreasing from 8.8% to 5.8% of monthly income from 2019 to 2020. However, this is still greater than the United Nation's target of 2% per monthly income for 1 GB. Additionally, with high levels of inequality in the region, many are still unable to afford data and internet access.[51,52] Fortunately, the cost of instant messaging applications such as WhatsApp, are relatively cost-effective, with one text message without media costing 1 kilobyte to 5 kilobytes (KB) ($1x10^3$ KB in 1 GB).[53]

WhatsApp is a free, instant messaging, social media platform available on smartphones, that allows for easy sharing of text messages, images, videos, and documents. In 2021, the amount of active WhatsApp users was estimated at two billion users globally. While in 2022 in South Africa, WhatsApp had 9.9 million users and was the most popular messaging application used,[51,54] with 94% of internet users engaging with the instant messaging platform.[55] This makes it a suitable and promising mHealth medium for NCD interventions.

Effectiveness of mHealth interventions

Various mHealth interventions have been conducted in high income countries (HICs) and lower to middle income countries (LMICs), targeting a broad range of health issues including infectious diseases, maternal health, sexual and reproductive health, and NCDs and the associated risk factors.[56]

A systematic review of 15 reviews found that SMS-based mHealth interventions were effective in changing behaviours such as smoking, physical activity, and weight loss.[57] While a systematic review of mHealth interventions in LMICs found that seven out of eight studies observed a positive effect on management of diseases such as diabetes, cardiovascular disease, and hypertension.[45] In another systematic review focusing on the effect of mHealth interventions to promote physical activity and healthy diets in developing countries, 13 out of 15 studies observed favourable outcomes.[58] However, results are inconsistent, with not all studies demonstrating a positive effect.[59–61]

For example, a study by Nanditha et al. showed no improvements in clinical outcomes of diabetic patients in India after receiving motivational and educational text messages.[59] In the South African context, Owolabi et al. and Farmer et al. both conducted randomised controlled trials investigating the effect of text messages on lifestyle changes in people living with diabetes.[60,61] The only statistically significant improvement found was in systolic blood pressure,[61] with no changes in blood glucose, BMI, and weight being evident.[60] Therefore, although studies generally show a positive effect of mHealth interventions on health behaviours and outcomes, results are equivocal.

In terms of interventions using instant messaging, several WhatsApp-based mHealth studies targeting NCDs have been published, including those promoting management of diabetes,[62–64] smoking cessation,[65] healthy eating [66,67] and physical activity.[68] Durmaz and colleagues conducted a study using educational WhatsApp messages and observed an increase in smoking cessation in the intervention group (OR 3.50, 95% CI=1.30–9.44,$p<0.05$) compared to the control group receiving usual care.[65] An improvement in the diet of participants receiving educational material via WhatsApp was observed by Ng et al., with an increase in mean number of days of fruit and

vegetable consumption in the intervention group being observed (p=0.002).[67] However, the increase in fruit consumption was also observed in the control group receiving printed materials (p=0.033). Al Omar and colleagues observed a greater reduction in glycated haemoglobin (HBA1C) levels in participants receiving educational WhatsApp messages (p=0.001) compared to receiving usual care. However, control participants also experienced a reduction in their HBA1C levels (p=0.032).[63]

The above results show potential for the use of WhatsApp to improve risk factors for NCDs. However, evidence is limited due to the few existing studies, and some studies failing to show a statistically significant difference between intervention and control group outcomes. Thus, more research is required to strengthen the evidence for the use of WhatsApp-based mHealth interventions to improve risk factors for NCDs.

There are several other limitations of existing mHealth studies. Many of the existing mHealth interventions have not been based on theoretical frameworks,[58] which have been suggested to improve the effectiveness of behaviour change interventions.[69] Additionally, most literature on mHealth has been conducted in HICs,[56] with most studies in LMICs being conducted on infectious disease (such as HIV), and outcomes other than NCDs (such as maternal and sexual health).[70] In a systematic review on mHealth studies performed in developing countries, 30% of included studies had maternal health as primary outcome, followed by infectious disease management.[45] Furthermore, LMICs may face additional barriers challenging the implementation of mHealth interventions.

mHealth Barriers in LMICs

Despite the potential benefits of mHealth in LMICs, lower income regions face multiple challenges of implementing mHealth interventions, with the lack of affordability of mobile devices and lack of digital literacy being two major barriers.[47] A systematic review on mHealth interventions performed in developing countries identified over 20 potential barriers to mHealth implementation, including insufficient infrastructure, resource limitations, lack of public policy, literacy issues, language barriers, psychosocial issues and privacy and confidentiality concerns.[45]

Additionally, varying cultural beliefs and practices may also impact the uptake and effectiveness of mHealth interventions in particular regions.[71] During the development of a text message based intervention aimed at reducing unintended pregnancies, participants highlighted several potential cultural barriers that may reduce the uptake and effectiveness of the intervention. These included the presence of cultural stigma, shame and general negative attitudes around the topic of conception and contraception in their communities.[71]

In a study using text messages to encourage blood pressure control in hypertensive patients in South Africa, many participants cited psychosocial stressors such as poverty and emotional stress as barriers to treatment adherence and personal health.[72] Furthermore, several participants highlighted difficulties with using technology and their mobile phones, as well as issues with mobile phone reception.[72] Similarly, during the development of an mHealth study using text messages and phone calls for prehypertension, low-income participants mentioned a lack of cellular signal as a potential barrier.[73]

Thus, although the use of mHealth may be beneficial in LMICs, barriers still exist that may diminish its effects on lifestyle health improvements. These barriers as well as cost to benefit analyses should be considered when developing an mHealth intervention for behaviour change in low-resourced settings.[45,47] A method that may assist in overcoming some of the barriers faced by LMICs, include intervention tailoring and use of behaviour change theories.

Tailoring and Behaviour Change Theories

Tailored communication involves using individual assessment to develop messaging that is based on unique, personal characteristics that relate to the outcome of interest.[74] Interventions can be tailored to characteristics such as participant preferences, socio-economic factors and physical health.[75] Tailoring acknowledges that a ‘one size fits all’ approach may not be effective, and thus health messaging should be individualised to one or more pre-existing characteristics to increase personal relevance. [76]

Many behaviour change studies have utilized tailoring in their intervention methods. A community-based weight management programme by Bouhaidar et al. used tailored text messages

to promote healthy lifestyle changes.[77] The messages were tailored to address participants' pre-selected health barriers against weight loss, such as lack of time, unhealthy eating behaviours, and inconsistent exercise. The intervention group lost significantly more weight than the control group, who did not received the tailored intervention.[77] Similarly, another study used contextually tailored mobile application push messages to encourage physical activity. Messages were tailored to time of day, day of the week, weather and location of participants.[78]

Reviews report mostly positive outcomes of message tailoring, with small effect sizes. In a systematic review and meta-analysis of 57 tailored print health interventions, there was a marginal improvement in effectiveness of tailored interventions compared to controls (r=0.074; CI = 0.066–0.082).[74] A slightly larger effect size (Hedges g=0.170) was observed in a meta-analysis on a combination of print, telephone and computer-tailored interventions (n=88) for health behaviours including smoking cessation, physical activity and diet.[79] Similarly, Lustria et al. reported an effect size of 0.139 (95% CI = 0.111–0.166) for 40 web-based interventions on behaviours including smoking, physical activity and diet.[80] Many of the studies included in these reviews used behaviour change theories to tailor their interventions.[74,80]

Frequent behaviour change theories that have been used for intervention tailoring include: the transtheoretical model (TTM) and stages of change, the health belief model (HBM), theory of reasoned action (TRA), theory of planned behaviour (TPB), and the social cognitive theory (SCT).[74,76]

The TTM postulates that behaviour change occurs in five non-linear stages, with individuals displaying different attitudes and skills within each stage. Stages include pre-contemplation (absence of the desire to change), contemplation (thinking of changing in the future), commitment (preparing to change), action (performing the change) and maintenance (sustaining the change). An individual can start at any stage and at any time 'relapse' to a lower stage.[81]

The HBM theorises that behaviour change is influenced by the perception of the severity/seriousness of the outcome or disease, susceptibility to the outcome, and the benefits and barriers of changing the behaviour. Thus, an individual is more likely to intend to change if they believe that they are at risk of a serious health outcome, and perceive potential benefits that outweigh the costs of making the change.[82]

The TRA and TPB suggest that an important predictor of health behaviour is the intention or perceived likelihood of performing a change.[83,84] Furthermore, the TRA posits that behaviour change is also influenced by one's attitude to the behaviour as well as the subjective norms in the surrounding environment.[83] In addition, one's perceived control of the behaviour is also an important factor to consider, according to the TPB.[84] Thus, an individual is more likely to commit to change if they have a positive attitude towards the change, feel that they are in control of the behaviour, and if there are normative pressures towards the behaviour.[83]

Lastly, the SCT postulates that behaviour change is influenced by the interaction between the behaviour itself, environmental and individual characteristics, with a key characteristic being one's self-efficacy in performing the change. Self-efficacy reflects one's confidence in successfully performing the change and obtaining desirable outcomes.[85]

Although each theory has unique characteristics, they share the core concept that personal characteristics drive behavioural intentions and influence individuals' decisions to engage in certain behaviours.[76] Systematic reviews on the effect of tailored interventions suggest an increase in intervention effectiveness when tailored to behaviour change theories.[74]

A behaviour change study targeting the diet of hypertensive participants, used monthly phone call counselling sessions that were tailored to participants stage of change, according to the TTM. For example, participants who were in the pre-contemplation stage received messages that were best suited to individuals in that particular stage of change, such as consciousness raising and self-evaluation-based messages. While participants in the planning stage of change received a different set of messages. The study observed an improvement in diet score, while the non-tailored intervention arm had no improvements.[86]

Similarly, a study by Rubinstein et al. used tailored phone call counselling sessions and educational text messages to promote lifestyle changes in prehypertensive patients. The calls and messages were tailored to participants' pre-selected health goal as well as participants' stage of change.[87] Although the study did not find statistically significant changes in blood pressure, improvements in diet and bodyweight were observed.

Although behaviour change theories such as the TTM have been effective in predicting behaviour, the practical application of theories and models to change behaviour is limited. Furthermore, due to the large number of existing theories, it may be a challenge to determine which theory or model is most suited to use for a particular behaviour change intervention.[88] Thus, more recently, efforts have been made to combine existing, overlapping theories to form one integrated theory for behaviour change. This was done by highlighting the most important determinants of behaviour change within one theoretical framework. The Behaviour Change Wheel (BCW) and COM-B model is a theoretical framework which combines 19 behaviour change models into one construct and can be used to guide behaviour change intervention development.[89]

The BCW consists of a 'behaviour system' including three domains-Capability, Opportunity, and Motivation (i.e. the COM-B model), as seen in Figure 1.2 below. These domains are theorised to interact with one another to influence and drive behaviour change. 'Capability' refers to both physical and mental ability to engage in a certain behaviour.[88,89] This includes physical skill and knowledge. 'Opportunity' refers to physical and social external factors that create an environment that encourages behaviour change. Examples of physical factors include time and resources, while social factors include social norms and interpersonal relationships. Lastly, 'Motivation' is defined as cognitive processes that direct behaviour, both reflectively through evaluation and thought, and automatically via impulse and emotion[88,89]

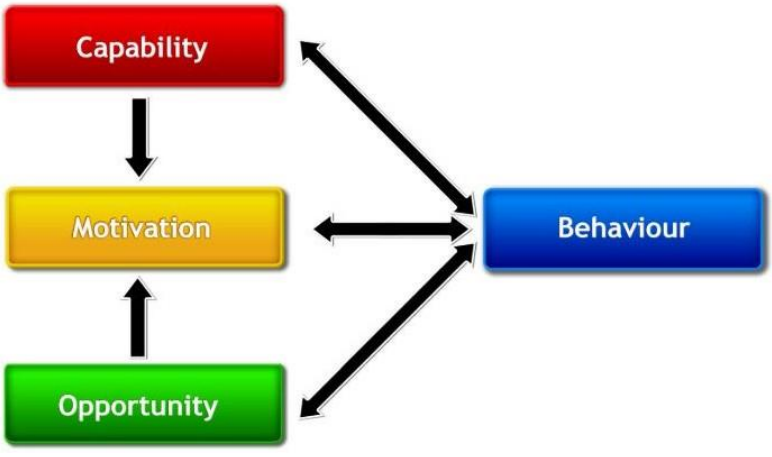

Figure 1.2 showing the COM-B model.[89]

The model can be utilised to address various barriers to behaviour change.[90,91] For example, common barriers to lifestyle changes experienced particularly in low-resourced settings are limited financial resources, lack of time, and lack of social support.[31] These barriers can be categorized into the 'opportunity' component of the model.[89] The BCW and COM-B model have been used in several mHealth interventions and have showed positive effects on behaviour change.[61,91–93]

A study by Bhandari et al. used the COM-B model to design text messages that would help participants overcome certain barriers to lifestyle change.[91] For example, a lack of knowledge on hypertension and its treatment was identified and linked to the "Capability" ("C" in COM-B) component of the model. In response to this barrier, messages educating participants on the importance of blood pressure medication were included. The study observed a statistically significant improvement in systolic and diastolic blood pressure in the intervention group after three months of three weekly text messages, compared to the control group.[91]

Similarly, Farmer et al. observed a statistically significant improvement in the blood pressure of participants receiving 6 months of text messages, where message development was guided by the COM-B model. However, the study found no differences in HBA1C levels and BMI.[61] Likewise, another study that used the BCW to design tailored text messages to target patients' health behaviours, found no effects on outcomes such as weight, physical activity, and smoking after 12 weeks of weekly messages. However, there was a statistically significant improvement in dietary behaviours compared to the control group.[49]

The Current Study

Due to the high burden of NCDs on morbidity and mortality, particularly in low resourced settings,[5,10] it is critically important that countries implement and evaluate interventions that have the potential to be sustained, are cost-effective and scalable, to prevent and manage NCDs and associated risk factors.[2]

mHealth is an innovative intervention type that has the potential to be cost effective and scalable and may benefit both HICs and LMICs, as demonstrated in previous studies.[6,45,94] WhatsApp is a promising medium of mHealth delivery, due to its various functionalities, frequent use, and

relatively low data costs globally and in South Africa.[51,52,54]

mHealth also allows for easier tailoring of interventions to the target population's context. Interventions can be tailored to the health needs and barriers of the community through the use of behaviour change theories such as the COM-B model.[91] It is also important that these interventions utilise a bottom-up approach and involve the community in the intervention development and implementation process.[39]

Thus, our study aimed to develop, implement, and evaluate a pilot, tailored, WhatsApp message-based mHealth intervention to reduce and manage risk factors of NCDs. The study was integrated into a pre-existing community-based intervention in the Western Cape, the *Western Cape on Wellness!* programme.

For the aim of the study to be achieved, formative research was conducted by performing a systematic review and meta-analysis on existing one-way mobile messaging interventions on risk factors for NCDs. Thereafter, a descriptive study was conducted to determine the health status of the target population, their health goals and barriers, and whether the chosen health goals were appropriate for their respective health statuses.

Messages were then developed using the COM-B model to tailor messages to participants health goals and health barriers. The messages were piloted as part of the WoW! programme to assist in reducing the risk of lifestyle risk factors of chronic disease in the community.

The next chapter consists of a systematic review and meta-analysis of unidirectional mobile messaging interventions targeting physical activity and weight loss.

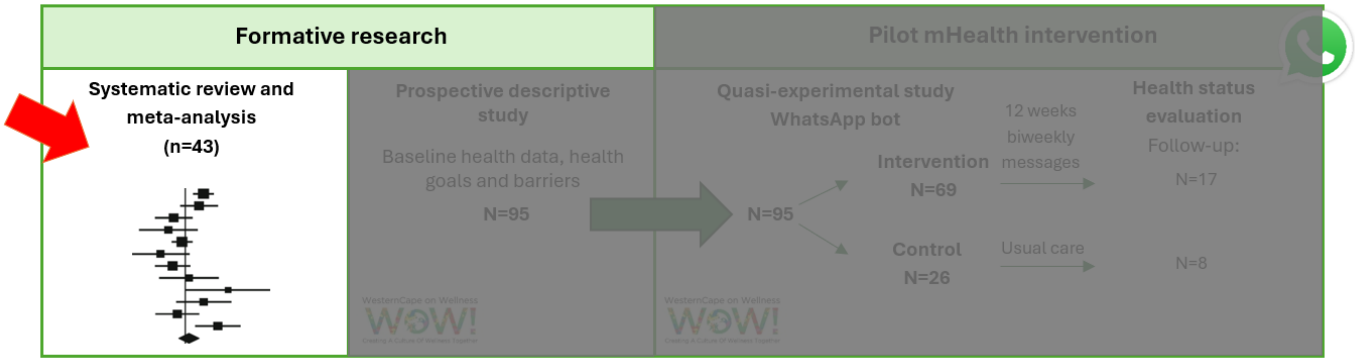

Figure 1.4 showing a flow diagram of the overall thesis study structure. Red arrow indicates next chapter.

CHAPTER 2: Systematic Review and Meta-analysis

The Effect of Text Message and Instant Message-Based mHealth Interventions on Physical Activity and Weight Loss: A Systematic Review and Meta-analysis.

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The systematic review and meta-analysis have been published in The American Journal of Lifestyle Medicine for review. Permission has been obtained by all authors to include the review in this thesis.

Abstract

Introduction: Physical inactivity and obesity remain significant public health concerns globally, with a prevalence of approximately 30% worldwide. Physical inactivity and obesity are detrimental to one's overall health, as they may increase the risk of developing non-communicable diseases (NCDs) such as diabetes and cardiovascular disease. Fortunately, physical inactivity and obesity can be improved by supporting individuals in modifying certain lifestyle behaviours. This support may be provided remotely by Mobile Health (mHealth) messaging interventions, which involve using mobile messages, such as text messages and instant messages, for health improvement and support.

Aim: This study aimed to determine the effect of mHealth interventions using unidirectional text messaging and/or instant messaging on physical activity and weight-related outcomes in adult populations.

Methods: An electronic literature search was conducted using PubMed, Scopus, and Web of Science, for pre-post intervention studies using unidirectional messaging, for physical activity and weight-related outcomes. Studies that used other interventions in addition to mobile messaging, and with no control group were excluded. The MMAT tool was used for quality appraisal. JASP software (University of Amsterdam) was used for meta-analysis using a random effects model.

Standardised mean differences were used as a measure of effect size and the I^2 statistic for heterogeneity.

Results: Out of 99 articles filtered for full text screening, a total of 43 articles were included for review. Most articles were excluded due to having the incorrect intervention type. Most studies used non-tailored text messages, while only four studies used instant messaging. Majority of the studies were randomised controlled trials and were performed on clinical populations in high income countries. While most participants had positive attitudes towards the interventions, meta-analyses showed that messages had minimal effects on physical activity (d+: 0.14, 95% CI: 0.05 to 0.23, p=0.003, I^2=65%), and no effect on weight loss (d+: 0.04, 95% CI: −0.02 to 0.10, p=0.21, $I^{2=}$29%).

Conclusion: Results suggest that unidirectional mobile messaging alone is not sufficient to promote physical activity and weight loss. Future studies should consider using other interventions in conjunction with messages, such as mobile applications, websites, in-person counselling, or bidirectional messaging, to potentially improve intervention effectiveness.

Introduction

Physical inactivity and obesity remain significant public health concerns globally. Approximately 28% of the global population do not meet minimum physical activity requirements,[95,96] while 38% of people worldwide are overweight or obese.[97] Physical inactivity and obesity are detrimental to one's overall health, as they may increase the risk of non-communicable diseases (NCDs) such as diabetes and cardiovascular disease.[8,16] NCDs place a substantial burden on global mortality, with more than 74% of deaths worldwide being accounted for by NCDs.[8]

Fortunately, physical inactivity and obesity are modifiable risk factors of NCDs, and thus can be improved through public health interventions promoting healthy lifestyle changes.[8] An example of a promising NCD intervention medium, which use has increased substantially within the past few years, is mobile health or mHealth interventions.[95] mHealth refers to the use of mobile technologies such as mobile applications and text messaging, to promote or provide healthcare at a distance.[94] It is appealing to many due to its potentially low cost, accessibility, and scalability.[58]

Several systematic reviews and meta-analyses have reported positive effects of mHealth interventions on NCD risk factors, including physical activity and weight management.[58,98–100] A systematic review by Dale et al. found an overall positive effect of mHealth interventions on increasing physical activity behavior.[101] While a systematic review and meta-analysis by Buss and colleagues observed weight loss and decreased BMI as their most successfully reported results.[100]

Despite some positive findings, many reviews highlight that the evidence of mHealth use for health behaviour change is limited. This is due to small effect sizes and low-quality studies.[98,100] Additionally, heterogeneity of studies is high due to a wide range of possible mHealth mediums and health outcome measurements used.[101–103]

Although there is a wide range of possible mHealth modalities, text messaging is one of the most frequently used mHealth mediums.[94] Systematic reviews on text message-based mHealth interventions report mostly positive, small effect sizes on health outcomes, including physical activity.[94,104] However, with the increased use of instant messaging services such as WhatsApp and

WeChat, SMS use has declined.[50] Instant messaging differs from text messaging, as it relies on internet connection as opposed to mobile network connectivity. Furthermore, instant messaging has a broader range of functionalities, including the ability to share much larger messages and files, and enabling the exchange of various media formats, such as images, videos, documents, and voice messages. However, both instant messaging and text messaging enable two-way communication between users.[105]

Although both instant messaging and text messaging allow for bidirectional communication, one-way messaging is potentially a simpler and more cost-effective method to implement messaging into mHealth interventions, as it does not require participants to respond to intervention messages.[93,106,107] Unidirectional messaging has also shown effectiveness in promoting weight loss and has been used in several previous mHealth studies.[93,106,108]

Other characteristics that may differ between mobile message interventions include differences in message content, message tailoring, and use of theory to develop messages. These factors are important to consider, as they may impact the effectiveness of messaging interventions.[104]

Considering the high prevalence of physical inactivity and obesity, the potential benefits of unidirectional messaging interventions, and the increased use of instant messaging, we conducted a systematic review and meta-analysis to determine the effectiveness of unidirectional text messaging and instant messaging interventions on physical activity and weight management. Secondly, we aimed to explore factors that may influence the effectiveness of the interventions, such as the type of messages (e.g. theory based, tailored), frequency of messages and study duration.

As far as we are aware, no systematic review and meta-analysis have been conducted on studies using unidirectional SMS and/or instant messaging and measuring physical activity and weight loss as health outcomes. Thus, this review and meta-analysis will add to the existing body of evidence on the effectiveness of mHealth interventions on physical activity and weight loss.

Methods

Overview

This systematic review was conducted following the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines.

The review protocol was registered in The International Platform of Registered Systematic Review and Meta-analysis Protocols (registration number INPLASY202370072). The review protocol can be accessed via the INPLASY website.

Search Strategy

An electronic literature search was conducted between November 2022 and November 2023 searching the databases PubMed, Scopus, and Web of Science. We searched for literature on mHealth text messaging and/or instant messaging interventions targeting physical activity and/or weight loss. Search terms included: mHealth, eHealth, physical activity, exercise, weight loss, interventions, and programs. The full search strategy with Boolean operators can be viewed in Appendix A-Table 2.1.

Studies were included if they were published between the years 2010 and 2023. This date range was used as we believed that the most relevant articles for our review would be during this period, due to the rapid growth of mHealth and mobile technology development in recent years.[103,109] Only articles available in English and involving adult populations were included. Both non-clinical and clinical populations with NCDs were included.

Eligibility Criteria

Eligible study designs were pre-post intervention studies (randomised controlled trials (RCTs), non-RCTs, quasi-experimental and mixed method studies) with a comparator group that received either no intervention, or 'standard of care' treatment. Control groups that received neutral, generic messages were also included as this was considered 'standard of care.'

Eligible interventions included mHealth interventions that sent one-way, motivational, educational, or advice-based text messages or instant messages to participants to improve physical activity levels and/or body weight. Message content was classified according to the respective authors classification, as well as additional criteria. Motivational content included messages with encouraging, positively reinforcing language. Educational content included informative content on a particular health topic, while advice messages had suggested tips to improve lifestyle behaviours. Interventions of any duration were included. Studies that used multimodal interventions (i.e. other interventions in addition to text messaging such as mobile applications, websites or in-person sessions) were excluded. Studies using "group chats" were also excluded. Furthermore, studies using messages solely as reminders or cues to engage in physical activity after a period of inactivity, were excluded. The above criteria were chosen to reduce the heterogeneity of the included studies.

Outcomes

Outcomes were grouped into (a) physical activity-related outcomes and (b) weight loss-related outcomes. Because the studies had a range of measures for physical activity and weight loss, specific measures were included in the following order of hierarchy, based on frequency of use:

a) physical activity: i) metabolic equivalent of tasks (METs), ii) moderate/vigorous physical activity (MVPA), iii) step count, iv) minutes of exercise per week. When studies only had one measure for physical activity, that measure was used. These included sedentary time, number of exercise sessions per week, adherence to guidelines, and physical activity score.

b) weight loss-related outcomes: i) body mass index (BMI), ii) change in body weight in kg, iii) percentage weight change. In one study, adherence to weight guidelines was used as this was the only measure of weight performed.[68]

Outcomes were eligible if they were self-reported or objectively measured, and if they were primary or secondary outcomes. Studies were included if they had only one or a combination of the above outcomes.

Data Collection Process

Article titles and abstracts of all papers found during the literature search were downloaded and exported into *Rayyan Intelligent Systematic Review* website (https://www.rayyan.ai/)[110] for screening. One reviewer screened the titles for eligibility (AE). Thereafter, at least two reviewers independently screened the abstracts for eligibility (AE, EVL, MRB, JL). In some cases, the abstract did not provide enough information to make an inclusion decision, and reviewers would screen the full text for eligibility. Once all reviewers had completed the screening, conflicting decisions were assessed and discussed, and a group decision was made whether to include or exclude the study. After abstract screening, two reviewers screened the articles for full text eligibility (AE, JL).

Data Extraction and Management

Data was extracted independently by two investigators (AE, RB) according to a study specific excel spreadsheet. Conflicts were initially reviewed and resolved between the two investigators. Where a resolution was not reached, a third reviewer was asked to provide input (EVL). The following information were included in the data extraction table: i) primary author, ii) study characteristics such as study design and duration, iii) population characteristics such as age, sex, country type (high income versus lower to middle income), iv) intervention characteristics such as outcomes measured, comparator, mode of message, message content, whether the messages were tailored or non-tailored, message frequency, whether messages were linked to theory, and iv) effect sizes (standardised mean differences) of each outcome. Tailoring was defined as *"*any combination of strategies and information intended to reach one specific person, based on characteristics that are unique to that person, related to the outcome of interest, and derived from an individual assessment*"*.[74] The economic status of countries was determined using The World Bank data.[111]

When studies had both self-reported and objective outcome data, the objective data were extracted. Additionally, when studies had more than one intervention group, only one intervention group was included. For example, one study had two intervention groups receiving either promotion or prevention-based messages. In this case, the first intervention group mentioned in the study (promotion messages) was included in the review.[112] Another study had two intervention groups

with different study durations. The group with the longer duration (20 weeks) was chosen.[113] Only one group was included from each study to avoid 'double counting' of participants in the control group, as both intervention groups were being compared to the same control group.[114]

Statistical Analysis

IBM SPSS (SPSS Inc., Chicago, Ill., USA) version 28.0.1.1 was used to summarize study descriptive statistics and for analysis of potential effect moderators. Statistical tests used in SPSS included the Pearson Chi squared test, independent t-test, and Pearson correlation coefficient test. Meta-Analysis was conducted using JASP Version 0.17.21, a free and open-source program for statistical analysis supported by the University of Amsterdam. A Random effects model was used to calculate weighted averages and pooled estimates due to likely variance in included studies.

Standardised mean difference (SMD, as Hedges g) was used as a measure of effect size. SMD was calculated for continuous data by extracting each study's intervention and control group sample sizes, and pre-post intervention mean changes and standard deviations (SD) into an excel spreadsheet. When studies used standard error or 95% confidence intervals instead of SD, these values were converted into SD. If the study only used median values, the study was omitted from meta-analysis. Negative values for weight change were adjusted into positive values to ensure improvement of outcomes were in the same direction. When studies had multiple time points for the outcome measurement, the final time point at the end of the intervention was used for SMD calculation.

Once effect sizes for each study were calculated, these were uploaded into JASP software for meta-analysis. A 95% Confidence Interval was used as an estimate of effect size with statistical significance set at a p value of <0.05. Heterogeneity was measured using the I^2 statistic. A Funnel plot analysis was used to measure publication and reporting bias.

Two sensitivity analyses were conducted to determine the robustness of the primary results, by removing outlier studies and non-RCT studies. The overall meta-analysis results were evaluated

and scored using the Grading of Recommendations Assessment, Development, and Evaluation (GRADE) framework.[115]

Studies Critical Appraisal

The Mixed Method Appraisal Tool (MMAT) version 2018 was used to assess the methodological quality of selected studies.[116] This tool was selected as it allows for the critical appraisal of a combination of different study designs including qualitative randomised controlled trials, quantitative non-randomised trials, mixed method studies, and qualitative studies. MMAT includes two general screening questions before further appraisal can be performed, and five questions specific to each study design, which must be answered with "Yes," "No" or "Can't tell" if not enough information is present. The tool discourages generating an overall quality score for each study, but rather provides a detailed analysis of each criterion. MMAT was applied to each study by two independent authors (AE, RB) for quality appraisal. When conflicts were present, they were highlighted and resolved between authors.

Results

A total of 8 221 records were identified across the three journals in the database search, following removal of 4 285 duplicates. After screening of titles, 991 publications were identified for abstract screening. Most of the excluded articles were unrelated to mHealth and behaviour change. Abstract screening identified 99 articles, with most articles being excluded due having the incorrect intervention type. After reviewing full texts for eligibility, 40 records were chosen for inclusion. Several studies that initially appeared to meet all the inclusion criteria, were excluding after full text review, due to having bidirectional messaging. Three additional articles were identified during full text reference screening, leaving 43 articles meeting all the inclusion criteria for systematic review. Study screening and selection are summarised in the PRISMA flow diagram (Figure 2.1).

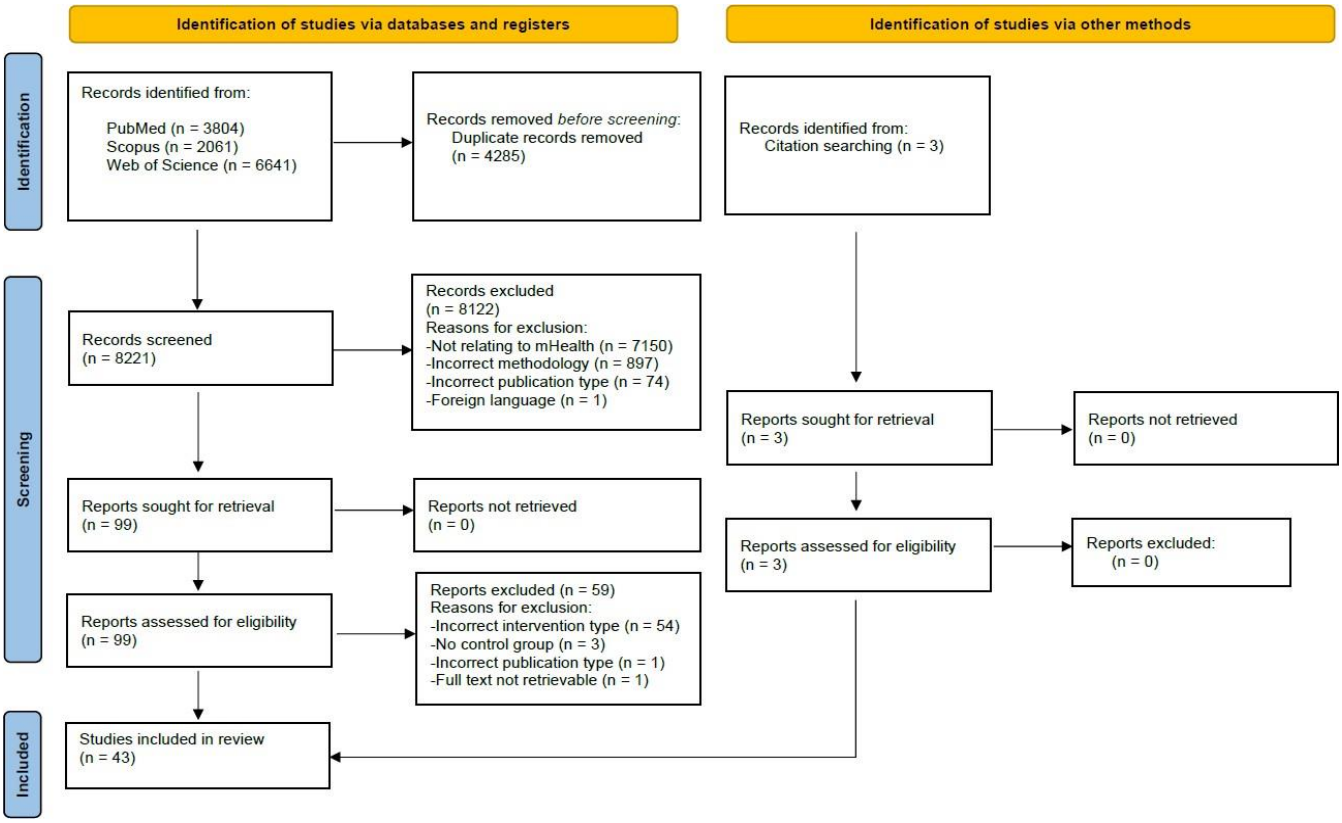

Figure 2.1: Flow diagram of study selection

Characteristics of Included Studies

Study characteristics are summarized in Table 2.2. Studies were published between the years 2013 to 2023. Most studies were conducted in high income countries (n=31) and were performed on a clinical population (n=31), with the most common population condition being persons living with diabetes and obesity.

Mean age of participants was 47 years, with 37% of participants being male. Most studies were RCTs (n=36), with the remaining being non-randomised (n=2), quasi-experimental (n=4), and mixed method studies (n=1). Study durations ranged between 2 weeks and 24 months, with the most frequent length being 6 months (n=10). Sample sizes ranged from 10 participants to 1031 participants, with a median of 55 participants for the intervention group and 50 for the control group.

Physical activity was measured in 26 studies, was self-reported in 20 studies, and was most frequently reported in METS min/week (n=10). The remaining studies used steps per day (n=5), moderate to vigorous activity (n=3), minutes of exercise per day (n=2), sedentary time (n=2), adherence to guidelines (n=2), physical activity sessions per week (n=1), and physical activity score (n=1).

A total of 29 studies measured weight-related outcomes, with outcomes being objectively measured in 24 of the included studies. Outcomes were reported as BMI in 23 studies, weight change in four studies, percent weight loss in one study, and adherence to weight guidelines in one study.

Four of the included studies were performed specifically in low-income/low resource populations.[60,117–119] Reasons cited for the necessity of mHealth interventions in low income populations included a lack of knowledge on health topics such as nutrition, an increased risk of NCD risk factors such as unhealthy weight, and transportation and medical costs.[117–119]All four studies used educational text messaging to promote healthy lifestyle changes, including weight loss. However, none of the studies found any significant weight changes in participants.[60,117–119]

Most studies used text messages/SMS as the mode of message delivery. The remaining used different forms of instant messaging to deliver messages, including smart phone application push messages (n=1), messenger-based applications (n=2), and web-based applications (n=1). Most of the studies used messages that were non-tailored (n=31) and were not based on theory (n=23). Messages were sent most frequently two to four times per week (n=20), with the lowest number of messages being one per month, and the most messages being more than seven per week. Message content most frequently included a combination of educational, advice-based, and motivational content on physical activity and healthy eating, followed by general disease information (e.g., diabetes and cardiovascular risk factors) (Appendix B-Table 2.3).

A total of 23 out of 43 studies included participant evaluations. Participants expressed an overall positive response to the text messages received. Most participants found the message content understandable and helpful. In the study by Huo et al., 97% of participants found the messages easy to understand and 94% found the messages useful.[120] In contrast, Chan et al. found that 11 out of 15 participants that completed the evaluation survey did not find the messages helpful.[121] Message acceptability and satisfaction ranged from 44% to 100%, and participants perceived effect of the messages on their lifestyle ranged from 17% to 80%. Many participants reported reading majority of the messages, and were open to continue receiving messages, should the interventions continue (Appendix B).

Effect of Interventions on Physical Activity and Weight-related Outcomes

Only 8 of the 26 studies observed statistically significant improvements in physical activity in the intervention group compared to the control group, with a mean effect size of 0.23 (SD ± 0.38). Two of these studies showed improvements in objectively measured steps per day,[122,123] three in self-reported METS min/week,[124–126] and one in self-reported minutes of exercise per day.[127] Several studies had statistically significant increases in physical activity of the intervention group, without a between-group effect.[128–131]

For weight-related outcomes, 5 out of 29 studies showed statistically significant improvements in BMI between groups, with a mean effect size of 0.07 (SD ± 0.14).[106,124,132–134] Three studies had improvements in weight-related outcomes in intervention groups, with no statistically significant difference between groups.[113,117,131]

Analyses were conducted on potential effect moderators including message tailoring, primary versus secondary outcomes, theory-based messages, objective versus self-reported outcomes, message frequency and study duration.

The mean effect sizes of physical activity were slightly higher when messages were tailored (tailored: 0.29 vs non-tailored: 0.16), when outcomes were primary (primary: 0.32 vs secondary 0.09), when messages were based on theory (theory: 0.28 vs no theory: 0.18), and when outcomes were objectively measured versus self-reported (0.41 vs 0.14). However, these differences were not statistically significant.

There were no statistically significant differences between effect size and message frequencies, and no correlation between effect size and study duration. No differences in effect moderators for weight-related outcomes were found.

TABLE 2.2: CHARACTERISTICS OF INCLUDED STUDIES (N=43)

First Author	Study Design	Sample size	Study duration (months)	Participant characteristics	Outcomes of interest	Tailored /non-tailored messages	Intervention linked to theory	Frequency of messages	Results
Kim et al.[123]	RCT	IG: 26 C:10 Per protocol	1.5	*Age:*70 *Percent male*:20 *Population condition*: diabetes and hypertension *Country type*: HIC	Steps per day	Non-tailored	None	>7 per week	Improvement in steps per day in intervention compared to control. (IG: +679 steps vs C: +398 steps, p<0.05)
Tamban et al. [127]	RCT	IG:46 C:36 ITT	6	*Age*:50 *Percent male:*27 *Population condition*: diabetes *Country type:* LMIC	Adherence to PA guidelines and BMI	Non-tailored	None	2–4 per week	Improvement in adherence to exercise in minutes (IG: 37.40 +14.87, C: 31.44 + 10.82) (p=0.02)
Shaw et al.[112]	RCT	IG: 41 C: 39 ITT	3	*Age:*53 *Percent male:* 74 *Population condition:* overweight/obesity *Country type:* HIC	Weight change	Non-tailored	Regulatory focus theory	Daily	No improvement in weight (p=0.22)
Munoz et al. [135]	RCT	IG:59 C: 55 Per protocol	4	*Age:* 21 *Percent male:* 36 *Population condition:* non-clinical *Country type:* HIC	Steps per day and BMI	Non-tailored	None	2–4 per week	The intervention and control groups did not differ significantly in BMI, and physical activity (p=0.47).
Ahn et al.[106]	RCT	IG: 25 C: 29 Per protocol	3	*Age:* 49 *Percent male:*50 *Population condition:* overweight/obesity *Country type:* HIC	BMI	Non-tailored	None	2–4 per week	Improvement in BMI (IG: 27.9 vs C: 28.3, p=0.02)
Chow et al.[125]	RCT	IG:352 C:358	6	*Age:*58	METS and BMI	Tailored	None	2–4 per week	Decrease in BMI and

		ITT		*Percent male*:82 *Population condition:* CVD Country type: HIC					increase in METS in intervention group compared to the control group (p<0.001)
Kim et al.[131]	RCT	IG:101 C:95	6	*Age:*41 *Percent male*:100 *Population condition*: overweight/obesity *Country type:* HIC	METS and weight change	Tailored	None	2–4 per week	Decrease in weight in intervention (−1.71kg) and control group (−1.56kg). However, no difference between groups (p=0.78). Increase in METS in intervention group (p<0.008). However, no between group difference (p=0.14)
Gell et al.[136]	RCT	IG: 37 C:37 ITT	6	*Age:*47 *Percent male:*0 *Population condition*: non-clinical *Country type:* HIC	Steps per day	Non-Tailored	None	2–4 per week	Difference in steps between groups at12 weeks (6540.0 vs. 5685.0, p=0.01). No statistically significant difference in steps per day between groups at 24 weeks (6867.7 vs. 6189.0, p= 0.06).

Martin et al.[122]	RCT	IG:16 C:16 ITT	0.5	*Age:* 58 *Percent male*:54 *Population condition:* CVD *Country type:* HIC	Steps per day	Tailored	Behaviour change theory	2–4 per week	Statistically significant improvement in steps per day between groups. Mean difference between groups: 2534 (1318–3750), P<0.001
Cotton et al.[128]	RCT	IG: 41 C: 41 ITT	1.5	*Age:* 21 *Percent male:* 26 *Population condition:* non-clinical *Country type:* HIC	Moderate Physical Activity	Non-tailored	None	>7 per week	Increase in moderate PA in intervention group (p=0.02) However, no difference in PA between groups. (p=0.16)
Kinnafick et al.[137]	RCT	IG: 34 C: 31 ITT	2.5	*Age:* 25 *Population* *Percent male:*6 *Population condition:* non-clinical *Country type:* HIC	Moderate Physical Activity	Tailored	Self-determination theory	2–4 per week	No improvement in MPA (p=0.06)
Peimani et al.[132]	RCT	IG:50 C:50 Per protocol	3	*Age:*53 *Percent male:*54 *Population condition*: diabetes *Country type*: LMIC	BMI	Tailored	Social cognitive theory	Daily	Statistically significant decrease in BMI in the intervention group compared to control group (p<0.001)
Abaza et al.[117]	RCT	IG:34 C:39 Per protocol	3	*Age*:52 *Percent male:*44 *Population condition*: diabetes *Country type*: LMIC	Weight change	Non-tailored	None	Daily	Intervention group had a decrease in weight of 1.3kg and control group decreased by 0.5 kg. However, no statistically

									significant difference in weight between groups (p=0.22)
McCoy et al.[130]	Quasi-experimental	IG:50 C:27 Per protocol	2.5	*Age*:53 *Percent male*:13 *Population condition*: overweight/obesity *Country type:* HIC	Minutes of exercise per day	Non-tailored	Health belief and IMB model	2–4 per week	Intervention participants increased exercise time by 8% (p = 0.03), while the control group's exercise time remained constant. However, no statistically significant difference between groups.
Fang et al.[138]	RCT	IG:58 C:51 Per protocol	12	*Age*:57 *Percent male*:86 *Population condition*: diabetes *Country type*: UMIC	BMI	Non-tailored	None	1 per month	No statistically significant difference in BMI between groups (p= 0.80)
Silina et al.[133]	RCT	IG: 63 C: 60 Per protocol	12	*Age:* 37 *Percent male:*29 *Population condition:* overweight/obesity *Country type:* HIC	BMI	Non-tailored	Ideas of planned behaviour and social cognitive theory	1 every 2 weeks	Statistically significant improvement in BMI (mean difference −1.14 (95% CI –1.9,–0.41), p=0.002)
Lemanu et al.[129]	RCT	IG:44 C:44 Per protocol	1.5	*Age:*44 *Percent male*:69 *Population condition*: overweight/obesity *Country type*: HIC	METS	Non-tailored	None	Daily	Intervention had increase in METS. However, no difference between groups (p=0.27).
Abbaspoor et al. [124]	RCT	IG: 44 C: 44	3	*Age:* 29 *Percent male:* 0	METS	Non-tailored	None	2–4 per week	Improvement in METS (IG: 852.42

		Per protocol		*Population condition:* pregnancy and prediabetes *Country type:* LMIC					± 350 vs C: 637.12 ± 210, p<0.001)
Boels et al.[139]	RCT	IG:114 C:115 ITT	6	*Age:*59 *Percent male:*60 *Population condition:* diabetes *Country type:* HIC	METS and BMI	Tailored	Fogg Behaviour Model	Varied	No improvements in BMI (p=0.95) or METS (p=0.65)
Owolabi et al.[60]	RCT	IG:108 C:108 ITT	6	*Age:*60 *Percent male:*17 *Population condition:* diabetes *Country type:* UMIC	BMI	Non-tailored	Behaviour change theory	Daily	No statistically significant difference in BMI between groups (p=0.44)
Nepper et al.[126]	Quasi-experimental	IG:35 C:35 Per protocol	3	*Age:*57 *Percent male:*34 *Population condition*: diabetes *Country type*: HIC	METS	Non-tailored	None	2–4 per week	Statistically significant increase in METS for intervention group compared to control group (p=0.02).
Gore et al.[118]	Quasi-experimental	IG: 204 C:208 Per protocol	12	*Age:*50 *Percent male:*40 *Population condition:* non-clinical *Country type:* HIC	BMI	Non-tailored	None	Daily	No improvement in BMI (p=0.92)
Vinitha et al.[140]	RCT	IG:126 C:122 ITT	24	*Age:*43 *Percent male:*68 *Population condition:* diabetes *Country type*: LMIC	BMI	Non-tailored	None	2–4 per week	No improvement in BMI (p=0.58)
Chan et al.[121]	RCT	IG: 18 C: 15 Per protocol	2	*Age:* 38 *Percent male:*16 *Population condition:* non-clinical *Country type:* HIC	BMI	Non-tailored	None	2–4 per week	No improvements in BMI (p=0.22)
Keating et al.[141]	Mixed methods	IG: 50 C: 45 Per protocol	2	*Age:* 21 *Percent male:*21 *Population condition:* overweight/obesity	BMI	Non-tailored	Transtheoretical model	Daily	No improvement in BMI (p=0.83)

				Country type: HIC					
Huo et al. [120]	RCT	IG:251 C:251 ITT	6	*Age:*60 *Percent male*:83 *Population condition:* CVD and diabetes *Country type:* UMIC	METS and BMI	Non-tailored	Behaviour change theory	5–6 per week	No statistically significant difference in METS (p=0.78) and BMI (p=0.21) between groups
Nanditha et al.[59]	RCT	IG:1031 C:1031 ITT	24	*Age:*52 *Percent male*: 64 *Population condition:* prediabetes *Country type*: HIC and LMIC	MVPA and BMI	Tailored	Transtheoretical and health belief model	2–4 per week	No statistically significant difference in physical activity and BMI between groups.
Bolmsjö et al.[142]	RCT	IG:29 C:28 Per protocol	6	*Age:*67 *Percent male:*44 *Population condition*: hypertension *Country type:* HIC	BMI	Non-tailored	None	2–4 per week	No improvement in BMI (p=0.13)
Holmes et al.[119]	RCT	IG:38 C: 34 Per protocol	4.5	*Age:* 27 *Percent male:* 0 *Population condition:* pregnancy *Country type:* HIC	Gestational weight guidelines	Non-tailored	Social Cognitive Theory	1 per week	No improvement in weight (p=0.37)
Sadanshiv et al.[134]	RCT	IG:161 C:159 ITT	3	*Age:*48 *Percent male:*55 *Population condition:* diabetes *Country type:* LMIC	BMI	Non-tailored	Transtheoretical model	2–4 per week	Decrease in BMI in IG compared to control. (mean difference:−0.6, p<0.001)
Ritchie et al. [143]	Non RCT	IG:236 C:252 ITT	12	*Age:*50 *Percent male:*26 *Population condition:* prediabetes *Country type:* HIC	Percent weight loss	Non-tailored	None	5–6 per week	No improvement in weight (p=0.37)
Farmer et al.[61]	RCT	IG:510 C:511 Per protocol	12	*Age*:57 *Percent male*:30 *Population condition:* diabetes *Country type*: UMIC	BMI	Non-tailored	Behaviour change wheel	2−4 per week	No improvement in BMI (p=0.67)

Waller et al.[93]	RCT	IG:186 C:189 Per protocol	6	*Age:*62 *Percent male*:51 *Population condition*: diabetes *Country type:* HIC	PA sessions per week and BMI	Non-tailored	Behaviour change wheel	Varied	No improvement in PA (p=0.19) or BMI (p=0.51)
Saldivar et al.[113]	Non RCT	IG:94 C186 Per protocol	5	*Age:*54 *Percent male:*17 *Population condition*: overweight/obesity *Country type:* HIC	Weight change	Tailored	None	2−4 per week	Both groups had reduction in weight (C: 114±27 kg vs. 112±26 kg, p<0.001; IG:111± 28 kg vs. 109±28 kg, p<0.01) No difference between groups (p=0.25)
Bootwong et al.[144]	RCT	IG:160 C:162 Per protocol	3	*Age:* 40 to over 50 *Percent male*:44 *Population condition*: prediabetes *Country type*: UMIC	METS and BMI	Non-tailored	None	5−6 per week	Improvement in MET at 6 weeks (p=0.02), but not at 12 weeks (p=0.51) No difference in BMI (P=0.36)
Singleton et al.[145]	RCT	IG:78 C:78 ITT	6	*Age:*56 *Percent male:*0 *Population condition*: cancer *Country type*: HIC	METS and BMI	Non-tailored	None	2−4 per week	No statistically significant difference in METS (p=0.79) and BMI between groups.
Franco et al.[146]	RCT	IG:96 C:91 Per protocol	3	*Age:*43 *Percent male:*11 *Population condition*: non-clinical *Country type:* HIC	PA Score and BMI	Tailored	None	2−4 per week	No statistically significant difference in PA (p=0.70) and BMI (p=0.79) between groups
Zamanillo Campos et al.[147]	RCT	IG:89 C:90 ITT	3	*Age:*62 *Percent male:*65 *Population condition:* diabetes *Country type:* HIC	PA adherence	Tailored	Yes, type not specified	5−6 per week	No difference in physical activity levels (p=0.10)

Kellner et al.[148]	RCT	IG:16 C:18 Per protocol	0.5	*Age:*22 *Percent male:*15 *Population condition:* non-clinical *Country type:* HIC	Sedentary time	Non-tailored	Theory of action- and coping planning	Daily	Reduction in sedentary time in intervention group (p=0.03), with no group effect (p=0.12)
Kellner et al.[149]	RCT	IG:41 C:31 Per protocol	1.5	*Age:*21-24 *Percent male:*11 *Population condition:* non-clinical *Country type:* HIC	Sedentary time	Non-tailored	Theory of action- and coping planning	Daily	Statistically significant decrease in sedentary time in intervention group compared to control (p=0.43)
Golbus et al.[150]	RCT	IG:97 C:97 ITT	6	*Age:*60 *Percent male*:69 *Population condition:* CVD *Country type:* HIC	Steps per day	Tailored	None	Daily	No difference in steps in intervention compared to control group at 6 months (p=0.32).
Acevedo et al.[108]	RCT	IG:278 C:242 ITT	9	*Age:*52 *Percent male:*0 *Population Condition:* CVD *County type:* HIC	Adherence to ideal cardiovascular BMI and PA guidelines	Non-tailored	Social Cognitive Theory	1 per week	No difference between intervention and control groups in BMI (p=0.38) and PA (p=1.00).
Huang et al.[151]	Quasi-experimental	IG:89 C:105	2	*Age:*39 *Percent male:50* *Population condition:* non-clinical *Country type:* HIC	METS	Tailored	Theory of Planned Behaviour	1 per week	Statistically significant increase in METS in the intervention group compared to the control group (p=0.02)

RCT: Randomised controlled Trial; IG= intervention group; C=Control; LMIC: lower middle-income country; UMIC: upper middle-income country; HIC: High income country; ITT=intention to treat; BMI=body mass index; PA=physical activity; METS=Metabolic equivalent of tasks; MVPA=moderate to vigorous physical activity; CVD=cardiovascular disease; IMB model=The Information-Motivation-Behavioural Skills Model.

Age presented as mean or median; results considered improved if statistically significant change in outcome values between groups was present.

Quality Appraisal

Table 2.4 shows a summary of the MMAT appraisal results of each study.

As depicted in Table 2.4, most studies were assessed using the quantitative randomised controlled trial criteria. The lowest quality criterion observed for the RCTs included in the review was for randomisation. For randomisation to be appropriate, random allocation and allocation concealment need to be performed. More than half the studies (61%) did not provide enough information to determine whether allocation concealment was completed. Another criterion that was not met by more than half of the included studies was the blinding of outcome assessors, with 33% of studies not stating whether blinding occurred, and 28% having no blinding. Almost all studies had intervention and control groups that were comparable at baseline (97%). Most studies also met the criteria of having complete outcome data (participation retention rate of 80%), and participation adherence to assigned intervention (72%).

For non-randomised studies, half of the studies did not give enough information to determine whether the analysis accounted for possible confounders. Most studies had samples that were representative of the population (83%) and had interventions that were administered as intended (83%).

Only one study used a mixed methods approach and met two of the five specific criteria. Not enough information was provided to ascertain whether the other criteria were met.

Table 2.4 MMAT Appraisal tool

Study	Randomised Quantitative (n=36)							MMAT scoring
	S1	S2	Q1	Q2	Q3	Q4	Q5	
Kim et al.[123]	Y	Y	N	Y	N	N	N	3/7
Tamban et al.[127]	Y	Y	Y	Y	Y	Y	Y	7/7
Shaw et al.[112]	Y	Y	C	Y	Y	C	Y	5/7
Munoz et al.[135]	Y	Y	C	Y	N	C	N	3/7
Ahn et al.[106]	Y	Y	Y	Y	N	C	N	4/7
Chow et al.[125]	Y	Y	Y	Y	Y	Y	Y	7/7
Kim et al.[131]	Y	Y	C	Y	N	N	N	3/7
Gell et al.[136]	Y	Y	C	Y	Y	C	Y	5/7
Martin et al.[122]	Y	Y	C	Y	Y	C	Y	5/7
Cotten et al.[128]	Y	Y	C	Y	N	C	N	3/7
Kinnafick et al.[137]	Y	Y	C	Y	Y	Y	Y	6/7
Peimani et al.[132]	Y	Y	C	Y	Y	N	Y	5/7
Abaza et al.[117]	Y	Y	C	Y	Y	Y	Y	6/7
Fang et al.[138]	Y	Y	C	Y	Y	C	Y	5/7
Silina et al.[133]	Y	Y	C	Y	Y	C	Y	5/7
Lemanu et al.[129]	Y	Y	Y	Y	Y	Y	Y	7/7
Abbaspoor et al.[124]	Y	Y	C	Y	Y	C	Y	5/7
Boels et al.[139]	Y	Y	C	Y	Y	N	Y	5/7
Owolabi et al.[60]	Y	Y	C	Y	N	Y	N	4/7
Vinitha et al.[140]	Y	Y	C	Y	Y	Y	Y	6/7
Chan et al.[121]	Y	Y	N	N	N	N	N	2/7
Huo et al.[120]	Y	Y	Y	Y	Y	Y	Y	7/7
Nanditha et al.[59]	Y	Y	C	Y	Y	Y	Y	6/7
Bolmsjö et al.[142]	Y	Y	Y	Y	Y	Y	Y	7/7
Holmes et al.[119]	Y	Y	Y	Y	Y	N	Y	6/7
Sadanshiv et al.[134]	Y	Y	Y	Y	Y	C	Y	6/7

Farmer et al.[61]	Y	Y	Y	Y	Y	N	Y	6/7
Waller et al.[93]	Y	Y	Y	Y	Y	N	Y	6/7
Bootwong et al.[144]	Y	Y	C	Y	Y	Y	Y	6/7
Singleton et al.[145]	Y	Y	Y	Y	Y	Y	Y	7/7
Franco et al.[146]	Y	Y	Y	Y	N	N	N	4/7
Campos et al.[147]	Y	Y	C	Y	Y	Y	Y	6/7
Kellner et al.[149]	Y	Y	C	Y	N	C	N	3/7
Kellner et al.[148]	Y	Y	C	Y	N	C	N	3/7
Golbus etal.[150]	Y	Y	C	Y	Y	N	Y	5/7
Acevedo et al.[108]	Y	Y	C	Y	Y	Y	Y	6/7
Non-randomised Quantitative (n=6)								
McCoy et al.[130]	Y	Y	N	N	Y	C	Y	4/7
Nepper et al.[126]	Y	Y	Y	Y	Y	Y	Y	7/7
Gore et al.[118]	Y	Y	Y	C	C	C	Y	4/7
Ritchie et al.[143]	Y	Y	Y	Y	Y	Y	Y	7/7
Saldivar etal.[113]	Y	Y	Y	Y	N	C	C	4/7
Huang et al.[151]	Y	Y	Y	Y	Y	Y	Y	7/7
Mixed methods (n=1)								
Keating et al.[141]	Y	Y	C	Y	Y	C	C	4/7
Criteria met (%)	100	100	33	97	72	38	72	

Y: Yes-criteria met; **N:** No-criteria not met; **C**: Cannot tell if criteria was met

Screening questions (all studies) S1. Are there clear research questions? S2. Do the collected data allow to address the research questions?

Quantitative randomised controlled trials: 2.1. Is randomisation appropriately performed? 2.2. Are the groups comparable at baseline? 2.3. Are there complete outcome data? 2.4. Are outcome assessors blinded to the intervention provided? 2.5 Did the participants adhere to the assigned intervention?

Quantitative non-randomised: 3.1. Are the participants representative of the target population? 3.2. Are measurements appropriate regarding both the outcome and intervention (or exposure)? 3.3. Are there complete outcome data? 3.4. Are the confounders accounted for in the design and analysis? 3.5. During the study period, is the intervention administered (or exposure occurred) as intended?

Mixed methods: 5.1. Is there an adequate rationale for using a mixed methods design to address the research question?
5.2. Are the different components of the study effectively integrated to answer the research question?
5.3. Are the outputs of the integration of qualitative and quantitative components adequately interpreted?
5.4. Are divergences and inconsistencies between quantitative and qualitative results adequately addressed?
5.5. Do the different components of the study adhere to the quality criteria of each tradition of the methods involved?

Publication Bias

Funnel plot analysis suggested no publication bias for studies measuring weight-related outcomes (Rank correlation test: p=0.12, Egger's test p=0.19). Similarly, the rank correlation test suggested no publication bias for studies measuring physical activity (p=0.53). However, potential bias was suggested by the Egger's test (p=0.004). (Figure 2.2 and 2.3)

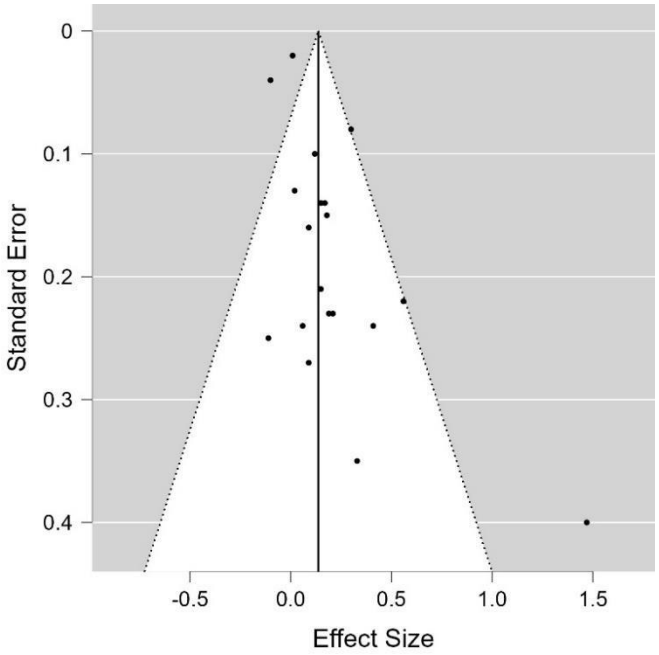

Figure 2.2: Funnel plot for publication bias of studies measuring physical activity outcomes.

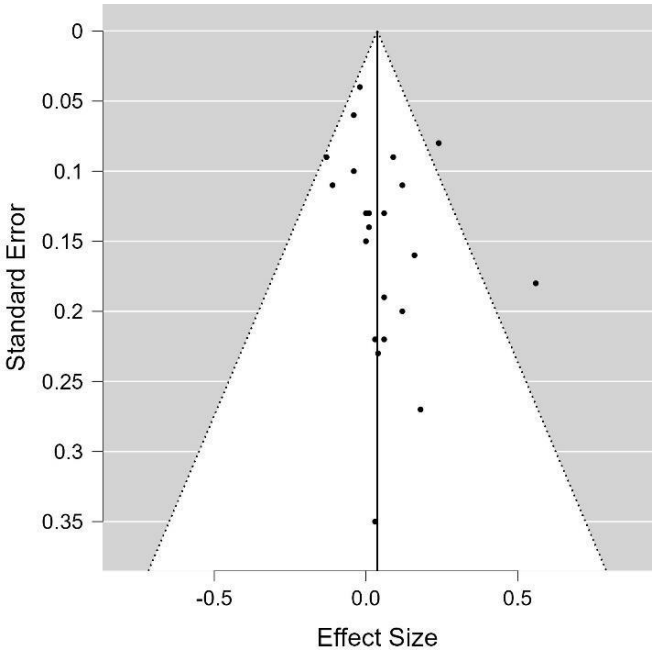

Figure 2.3: Funnel plot for publication bias of studies measuring weight-related outcomes.

Meta-Analysis

A summary of the meta-analysis's findings can be seen in Figure 2.4 and 2.5. A total of 19 studies were included for the physical activity meta-analysis and 22 studies for the weight-related outcome meta-analysis. Ten studies were excluded from meta-analysis due to insufficient data being available.

The pooled effect size for the meta-analysis concerning physical activity-related outcomes was 0.14 (95% CI: 0.05 to 0.23, p=0.003) and for weight-related outcomes was 0.04 (95% CI: −0.02 to 0.10, p=0.21). Heterogeneity was high for physical activity (I^2=65%), and moderate for weight-related outcomes ($I^{2=}$29%). This demonstrates that mHealth studies using unidirectional messaging had small but significant effects on physical activity and no effects on weight-related outcomes.

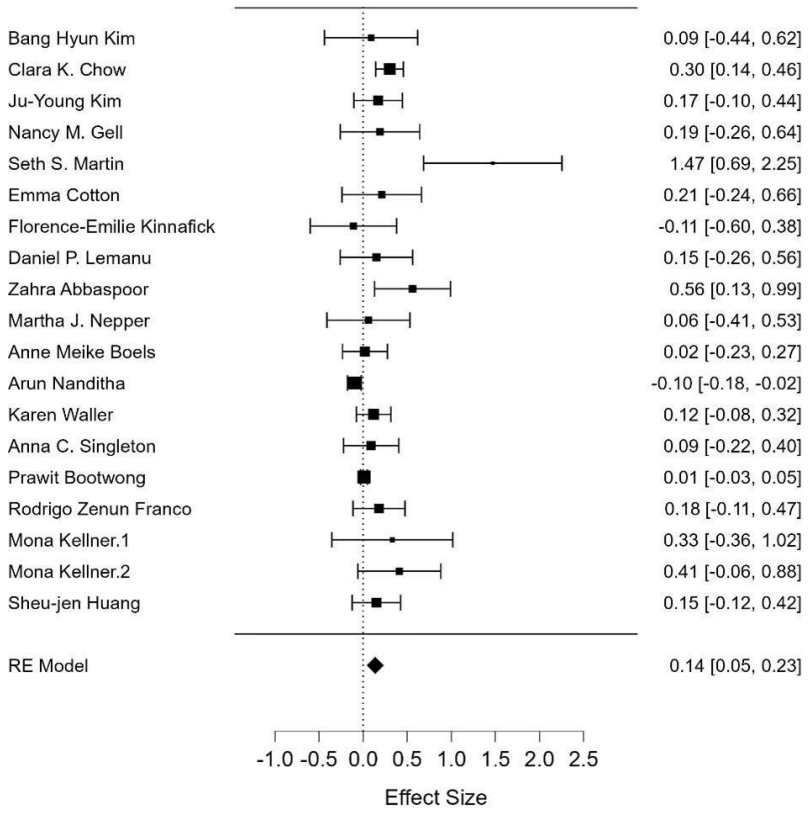

Figure 2.4: Forest plot showing meta-analysis of messaging-based mobile health interventions on change in physical activity-related outcomes.

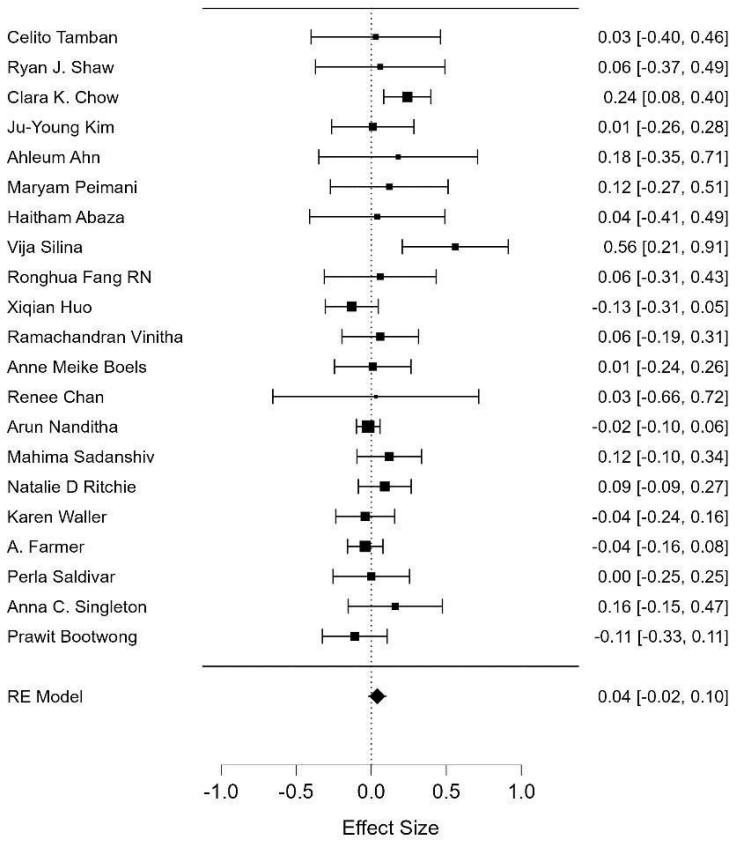

Figure 2.5: Forest plot showing meta-analysis of messaging-based mobile health interventions on weight-related outcomes.

For subgroup meta-analysis, statistically significant pooled effect sizes were observed for physical activity for studies using non-tailored messages [d+: 0.13 (−0.02 to 0.22), p=0.02], for studies with physical activity as a primary outcome [d+: 0.21 (0.10 to 0.37), p<0.001], non-theory based messages [d+: 0.17 (0.03 to 0.31) p=0.01], and self-reported physical activity [d+: 0.14 (0.05 to 0.23) p=0.002]. However, the subgroup analyses yielded no statistically significant differences between the effect moderators, such as tailored versus non-tailored messages (Table 2.5).

Table 2.5 showing subgroup analysis of outcomes and potential effect moderators

Subgroup	k	d+ (95% CI)	I^2	P value	Test for subgroup differences
Physical activity					
Tailoring	8	0.14 (−0.02 to 0.30)	74	0.08	0.92
Non-tailoring	11	0.13 (−0.02 to 0.22)	31	0.02*	
Theory-based	8	0.15 (−0.05 to 0.35)	74	0.14	0.87
No theory	10	0.17 (0.03 to 0.31)	66	0.01*	
Self-reported	14	0.14 (0.05 to 0.23)	41	0.002*	0.29
Objective	5	0.31 (−0.16 to 0.79)	83	0.19	
Primary	11	0.21 (0.10 to 0.37)	0	<0.001*	0.28
Secondary	6	0.09 (−0.05 to 0.23)	70	0.20	
Weight					
Tailoring	7	0.05 (−0.05 to 0.15)	39	0.31	0.77
Non-tailoring	15	0.03 (−0.05 to 0.10)	22	0.45	
Theory-based	9	−0.01 (−0.06 to 0.05)	0.005	0.75	0.16
No theory	13	0.07 (−0.01 to 0.15)	14	0.09	
Self-reported	3	0.02 (−0.21 to 0.25)	0	0.86	0.82
Objective	19	0.04 (−0.02 to 0.10)	35	0.21	
Primary	5	0.17 (−0.05 to 0.38)	50	0.13	0.11
Secondary	14	0.03 (−0.04 to 0.09)	32	0.44	

k: number of articles included in meta-analysis, d+: pooled effect size, * indicates statistical significance of $p<0.05$.

The overall quality of evidence is presented in Table 2.6 The quality of evidence for studies included in the meta-analysis was scored low, due to lack of allocation concealment and blinding in the RCTs (as presented in MMAT appraisal). Additionally, most studies had small sample sizes which may lead to imprecision of intervention effects.

Table 2.6: Quality of evidence

Outcome	Number of participants (number of studies)[a]	Study type number	Standardised mean differences (95% CI)	Quality of evidence (GRADE[b])
Physical activity-related outcomes	8512 (19)	RCT: 17 Non-RCT:2	0.14 (0.05 to 0.23)	Low[c,d]
Weight-related outcomes	8326 (22)	RCT: 20 Non-RCT:2	0.04 (0.02 to 0.10)	Low[c,d]

a: Studies used in meta-analysis
b: GRADE: Grading of Recommendations Assessment, Development, and Evaluation
c: Downgraded due to risk of biases (selection, detection, performance bias and blinding)
d: Downgraded due to imprecision (small sample sizes)

Sensitivity Analysis

Sensitivity analysis was conducted by removing effect outlier studies that were identified during funnel plot analysis. Pooled effects decreased slightly for both physical activity [d+ 0.11 (0.04 to 0.18), p=0.007], and weight [d+ −0.01 (−0.05 to 0.04), p=0.80]. However, heterogeneity substantially decreased for both outcomes (physical activity I^2=20%; Weight I^2=0%).

A second sensitivity analysis was conducted by excluding the non-RCT studies, which are at higher risk of bias. When non-RCT studies were removed, effect sizes remained similar for both outcomes, while heterogeneity slightly increased [physical activity 0.14 (0.04 to 0.25), p=0.005, I^2=70%; Weight 0.04 (−0.02 to 0.10), p=0.27, I^2=35%].

Discussion

The primary aim of this systematic review and meta-analysis was to determine the effect of unidirectional text message/instant message-based mHealth interventions on physical activity and weight-related outcomes.

The meta-analysis showed that mobile message-based mHealth interventions had very small, pooled effects on physical activity outcomes [d+: 0.14 (95% CI: 0.05 to 0.23, p=0.003)], and little to no effect on weight-related outcomes [d+: 0.04 (95% CI: −0.02 to 0.10, p=0.21)]. These findings are similar to another meta-analysis on mHealth interventions promoting physical activity and weight loss, which had a pooled effect size for physical activity of 0.22 (95% CI 0.03 to 0.41; p<0.001) and 0.02 (95% CI –0.07 to 0.10; p=0.48) for weight loss. However, only 38% of the included studies used text messaging, while the remaining studies used other forms of mobile technology, such as wearable activity monitors.[99]

In contrast, a meta-analysis on 19 text message-based mHealth interventions observed effect sizes for physical activity of 0.51 (95% CI: 0.24 to 0.78; p<0.001) and for weight loss 0.25 (95% CI: 0.06 to 0.46; p<0.01).[62] However, only nine of the included studies used text-only interventions, while the remaining studies were multimodal and used other intervention components in addition to text messaging, such as face to face counselling.[104] Thus, these findings are not completely comparable to the current review and meta-analysis.

Therefore, it is evident that existing systematic reviews and meta-analyses have mixed findings, which mostly consist of results with small effects on physical activity and weight changes. It is also evident that text message-based studies are often heterogenous and vary in several intervention characteristics, thus limiting the potential to make and interpret study comparisons.

The differences in intervention characteristics are important, as they may influence meta-analysis results. Other potential differences in intervention characteristics include message direction and the type of intervention modalities used. Our review included unidirectional, instant/text message-only interventions, and found limited effects on physical activity and weight loss outcomes. This suggests that despite unidirectional messaging potentially being more straightforward and cost-effective for participants, it may not be as effective as bidirectional messaging.[107] Limitations in

unidirectional messaging include its lack of interactivity, which may make participation engagement more challenging, especially when the intervention is performed remotely.[102,107]

Nonetheless, a study by Sahin et al.[152] showed that unidirectional messaging had greater effects than bidirectional messaging interventions in participants with diabetes [unidirectional: d+=0.79 (0.13 to 1.46); bidirectional: d+=0.27 (0.10 to 0.63). p=0.02]. Furthermore, the review observed greater effects in multimodal interventions compared to text message-only interventions [Multimodal: d+=0.79 (CI:0.19 to 1.39) p=0.013; text message only: d+=0.18 (CI: −0.02 to 0.38)]. In contrast, Head et al. showed no differences in intervention effects of unidirectional and bidirectional messaging, and text-only versus text plus other interventions.[104]

Other potentially important effect moderators included tailoring messages, theory-based messages and primary versus secondary outcomes. For subgroup analysis, physical activity measured as a primary outcome had a statistically significant pooled effect size [d+: 0.21 (0.10 to 0.37), p<0.001]. This may be due to intervention messages generally being more targeted to primary outcomes compared to secondary outcomes. Self-reported physical activity also had a statistically significant pooled effect [d+: 0.14 (0.05 to 0.23) p=0.002]. This may be explained by the possibility of participants overreporting their physical activity post intervention.[153]

Surprisingly, non-tailored and non-theory-based messages had statistically significant subgroup effect sizes for physical activity. This may partly be due to a larger sample size of studies using non-tailored messages (72%) being included in the review. Additionally, the type of theory used in included studies may have influenced the significance of the subgroup effect. In a review that showed a statistically significant difference in the effect of theory-based messaging, most studies used the transtheoretical model and social cognitive theory.[104] While only six of the 20 studies in our review used these aforementioned theories. Furthermore, there were no statistically significant differences between pooled estimates of tailored versus non-tailored, and theory versus non-theory-based interventions.

In contrast, previous reviews have demonstrated the benefits of using tailoring and theory-based messages. Head et al. observed greater effect sizes for tailored and targeted messages when compared to non-tailored messages (d+=0.42 versus d+=0.27), and for theory-based interventions

compared to non-theory-based interventions (d+=0.37 versus d+ =0.27).[104] However, not all studies have demonstrated this relationship. A study by Peimani et al. failed to show that text messages tailored to individuals' health barriers were more effective than general, non-tailored messages.[132] Thus, knowledge gaps are still present as to whether certain intervention characteristics such as message tailoring have significant effects on study results. Other intervention characteristics that may affect study findings include differences in the nature and frequency of messages, as well as differences in study populations. However, the current review found no statistically significant correlations between intervention effects, message frequency and population age.

Additional knowledge gaps identified by this review include the limited number of studies being conducted in lower to middle income countries. Only 12 of the 43 studies included in the review were conducted in LMICs. Existing systematic reviews have also reported a disparity between mHealth studies conducted in LMICs versus HICs.[98,99] In a review on the effect of mHealth interventions on physical activity and weight-loss, all eight studies were conducted in HICs.[99] While another systematic review exploring the effectiveness of mHealth interventions on physical activity, found that 106 out of 117 studies were conducted in HICs.[98]

Nevertheless, previous research has demonstrated the potential of mHealth interventions in LMICs, observing improvements in several NCD risk factors, including physical inactivity.[58] Furthermore, according to the World Health Organization's Global Status Report on Physical Activity, the use of mHealth programs in LMICs had increased from 10% in 2019, to 40% in 2021.[95]

Another potential gap in literature identified in this review, is the limited number of studies found using instant messaging for promotion of physical activity and weight loss. Only four studies included in this review used instant messaging as an mHealth medium. With the replacement of text messaging with instant messaging, as well as the rapid development of machine learning technologies, more studies using advanced communication mediums should be explored.[154]

Strengths and Limitations

This systematic review and meta-analysis included instant message applications, which are more widely used in current times. Additionally, this review had more stringent inclusion criteria compared to existing systematic reviews on mHealth and lifestyle changes.[58,155]

However, despite the stricter inclusion criteria, study heterogeneity was moderate to high during primary meta-analysis. This may be due to several factors, such as population type, sample size variations, study duration, number of messages participants received, and the heterogeneity of text message content. However, when outlier studies were removed in sensitivity analysis, heterogeneity substantially decreased.

Another limitation in the review process was not including grey literature or unpublished studies in the search strategy, as this may influence meta-analysis results.[156] Additionally, the literature search was only performed using three electronic databases, which may not have included all articles that met the inclusion criteria.

Further limitations in the methodology was including only articles published in English, as this may have excluded important studies from the review, particular those conducted in LMICs.[157] Furthermore, the systematic review did not explore socioeconomic factors such as employment and education levels, which may have contributed to the success or failure of the included studies.[5]

Most included studies used self-reported physical activity data, which may be less accurate than objectively measured outcomes. This may also explain why a statistically significant pooled effect was observed for physical activity, but not for weight, as most weight-related outcomes were objectively measured.

Additionally, more than half of the included studies had physical activity as the primary outcome, while most included studies had weight as secondary outcomes. Because not all studies had weight and physical activity as their primary outcomes, text message content did not always directly relate to these outcomes. For example, the review by Farmer et al. included 70% of messages relating to medication adherence, and only 30% of messages relating to lifestyle change (such as diet and physical activity).[61]

Additionally, Waller et al. had 35% of messages on nutrition, 35% on physical activity, 10% on weight management, and 20% on diabetic care.[93] Furthermore, studies are not usually statistically powered to detect differences in secondary outcomes. [158] However, when performing subgroup meta-analyses on primary and secondary outcomes for both physical activity and weight-related outcomes, no statistically significant differences were observed.

Lastly, the overall quality of the studies included in this review was scored low, due to many studies having small sample sizes, being unblinded, lacking allocation concealment and not accounting for potential confounding. These factors are important as they may result in a high risk of selection, performance, and detection bias and may distort the interpretation of results.[119,120] The results of this review and meta-analysis should thus be understood with these limitations in mind, while still acknowledging its utility for guidance of future research.

Conclusion

Based on the studies identified in this review, the use of unidirectional, message-only based mHealth interventions have small, albeit statistically significant effects on physical activity, and no effects on weight loss. These small effects may be due to unidirectional text messages alone not being sufficient to elicit sustained behaviour change. Studies using bidirectional messaging in addition to other interventions may have a greater effect on physical activity and weight-related outcomes. Additionally, although findings are equivocal, the use of theory and tailoring may also potentially improve effectiveness of such interventions. Lastly, this systematic review and meta-analysis have highlighted important gaps in mHealth literature. Few studies were identified that used instant messaging and that were conducted in LMICs. Thus, more research is required to address these limitations, and to ultimately determine whether mobile message-based interventions are an effective alternative to in-person interventions promoting physical activity and weight changes.

The next chapter discusses our descriptive study (see diagram below), which aimed to determine the baseline demographic and health status of members of the *Western Cape on Wellness!* initiative. Furthermore, the study aimed to explore participants self-selected health goals and barriers, and whether their health status correlated with their chosen health goals.

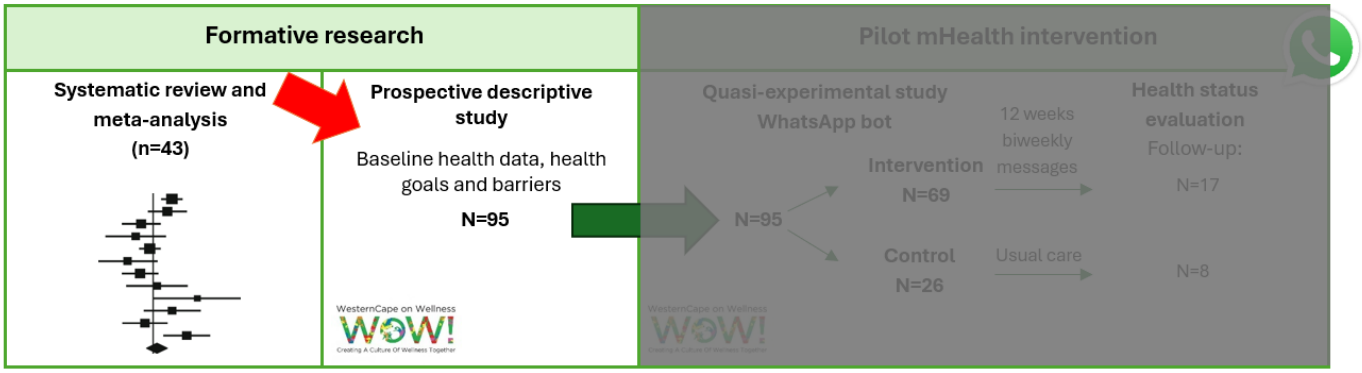

Figure 2.6 showing a flow diagram of the overall thesis study structure. Red arrow indicates next chapter.

CHAPTER 3

Health Characteristics, Health Goals and Health Barriers of Members of *Western Cape on Wellness*! - a Community-Based Lifestyle Intervention.

Abstract

Introduction: There is a high prevalence of non-communicable diseases (NCDs) in the Western Cape, with over 130 000 deaths being attributed to NCDs such as diabetes and cardiovascular disease. As a result, many public health interventions have been implemented to manage this chronic disease burden, including the Western Cape on Wellness (WoW!) programme. WoW! is a governmental, community-based programme aimed at making sustainable improvements in the health and wellbeing of its community members.

Aims: This study aimed to determine the baseline health status, health goals and health barriers of WoW! members, and to determine whether their health goals aligned with their health status.

Methods: A prospective descriptive study was performed through recruiting participants from four preexisting WoW! WhatsApp groups consisting of both community-based, trained volunteers (i.e. WoW! champions) and general WoW! members. Baseline data were collected via an online health assessment questionnaire consisting of questions related to demographics, lifestyle behaviours, health indicators, and a selection of one of six personal health goals, and two of six barriers to achieving these goals. The health barriers included in the questionnaire were chosen and categorised based on the COM-B model of behaviour change (COM-B: Capability, Opportunity, Motivation-Behaviour).

Results: A total of 95 participants enrolled in the study and completed the baseline questionnaire. Many participants were overweight or obese (52%) and had low self-reported physical activity levels (70% not meeting recommended guidelines). The most frequently selected health goal was achieving a healthy weight (55%). The most frequently selected barriers were "difficulty prioritising lifestyle change" (75%) and "lack of time" (55%), which belong to the "motivation" and "opportunity" categories of the COM-B model.

Discussion: The prevalence of NCD risk factors were high, with most participants being overweight and inactive. Participants health status and goals appeared to be aligned, with most participants selecting healthy weight as their goal. This suggests that participants were aware of

their unhealthy weight status. However, according to the health barriers selected, they struggled with finding the motivation and time to implement the necessary lifestyle changes to achieve their goals. Future WoW! interventions may benefit from motivation-based health promotional resources focusing on time management and weight loss.

Conclusion: There is a high prevalence of NCD risk factors in this cohort of WoW! wellness champions and members, with most members finding a lack of motivation and lack of opportunity as a barrier to improving their lifestyles.

Introduction

There is a high prevalence of non-communicable diseases (NCDs) in the Western Cape, with over 130 000 deaths being due to diabetes and cardiovascular disease between the years 2008 to 2018.[34] NCDs are chronic, non-infectious diseases that develop over time, and are caused by a combination of modifiable and non-modifiable risk factors.[2] Non-modifiable risk factors are factors that cannot be altered, and include sex, age, and genetics. Modifiable risk factors are factors that in principle, can be changed and improved through lifestyle modifications and include factors such as healthy eating, reduced alcohol consumption and physical activity.[2]

Due to the high prevalence of NCDs, many public health interventions have been implemented to address these modifiable risk factors.[34] Examples of interventions that have been implemented in South Africa include sugar sweetened beverage taxes, reducing salt content in certain sold foods, the Western Cape Education Smoking Policy, chronic disease support clubs within community-oriented primary care facilities, the South African National Strategic Plan for the Prevention and Control of Non-Communicable Diseases (2022–2027),[34] and the Western Cape on Wellness programme (WoW!).[10,43]

WoW! is a provincial government-led, community-based, partnership programme launched in 2015, that aims to train and support volunteer wellness champions, as they assist community members in making sustainable lifestyle changes to improve their health and wellbeing.[10] Wellness champions work with community members to co-create supportive environments, provide brief behaviour change counselling and peer-leadership for self-management in the reduction and control of chronic NCDs and associated modifiable risk factors.[42]

WoW! champions are community volunteers that are recruited and trained using evidence-based training materials, to educate and lead their respective members and communities towards healthier lifestyles.[43] They operate by establishing separate WoW! groups in their local settings. Groups vary in size, ranging from 10 to over 100 members.[42] Groups also meet at different intervals, some meeting weekly, and others meeting less frequently. Some groups primarily meet for group-based physical activity, whereas other groups engage in a variety of healthy lifestyle activations and various forms of community upliftment. There are approximately 750 active

WoW! wellness champions, with an overall retention rate of 67% in the programme.[42]

The community-based approach of WoW! enables initiatives to be tailored to the community's needs and context, by accounting for the "lived experience" of its members. The WoW! programme has facilitated numerous health initiatives, with the help and support of over 70 partnerships.[43] These initiatives include but are not limited to: i) Establishing over 200 community food gardens that promote food security and healthy eating, ii) hosting healthy eating workshops that provided education on behaviour change for improved management of NCDs, iii) WoW! health assessments ("wellness monitors") and health feedback ("health passports"), that enable members to "know their numbers" and track personal health indications such as weight and blood pressure, and iv) healthy lifestyle promoting channels sharing health education and advice via printed material, Facebook, SMS, and WhatsApp group broadcasts.[42,43]

This descriptive study aimed to determine the baseline demographic and health status of members and champions of WoW! Furthermore, the study aimed to explore participants self-selected health goals and barriers, and whether their health status correlated with their chosen health goals.

Methods

Participants and Setting

The study included Western Cape on Wellness (WoW!) champions and members. WoW! champions are trained WoW! members who promote sustainable healthy lifestyles, by recruiting and inviting members in multiple settings including worksites, communities, healthcare facilities, schools, and public spaces to join the programme.[43]

The WoW! programme aims to support widespread adoption of healthy lifestyle behaviours and the development of health promoting structures and supportive environments, to combat the high prevalence of NCDs in South Africa.[43] WoW! communicates with members and partners through a wellness print magazine, monthly newsletter, and weekly health messaging via text messages and WhatsApp groups.[42]

Participant Recruitment and Data Collection

Due to WoW! already making use of WhatsApp-based communication channels to inform and motivate its members, the popular instant messaging platform was suitable and convenient to recruit members and administer the study questionnaire. Participants were recruited from four pre-existing WoW! WhatsApp groups hosted by the WesternCape Department of Health and Wellness. One group was made up of 212 wellness champions, while the remaining three groups included 515 WoW! members, forming a total of 727 potential participants. A staggered recruitment method was used over a period of two months (September to November 2023).

A study advertisement with a brief description of the study and instructions on how to enrol was shared with the WoW! WhatsApp groups by a Western Cape Department of Health staff member. The study advertisement included a PDF and accompanying WhatsApp message, asking participants to complete the WoW! wellness monitor questionnaire by clicking on a website link provided in the advertisement. The website was hosted on Amazon Web Services (AWS).

The study received ethics approval by the Faculty of Health Sciences Human Research Ethics Committee at the University of Cape Town (Ref. No. 799/2022) (Appendix C). Informed consent was given by participants at the beginning of the wellness monitor questionnaire. The wellness monitor consisted of 28 questions about participant demographics, alcohol and smoking use, physical activity levels, diet, sleep, and anthropometric and clinical measures such as body mass index and blood pressure (Figure 3.1 and Appendix D).

At the end of the questionnaire, participants were asked to choose one main health behaviour goal out of a selection of six, namely: i) achieve or maintain a healthy weight, ii) eat a healthy diet iii) increase fitness, iv) manage stress v) improve sleep health and vi) stop or reduce smoking. Thereafter they were prompted to choose two out of six perceived barriers preventing them from achieving their chosen goal: i) lack of knowledge, ii) lack of time, iii) lack of support from family and friends iv) lack of resources, v) lack of confidence in their ability to achieve their goal, and vi) difficulty in prioritising the goal.

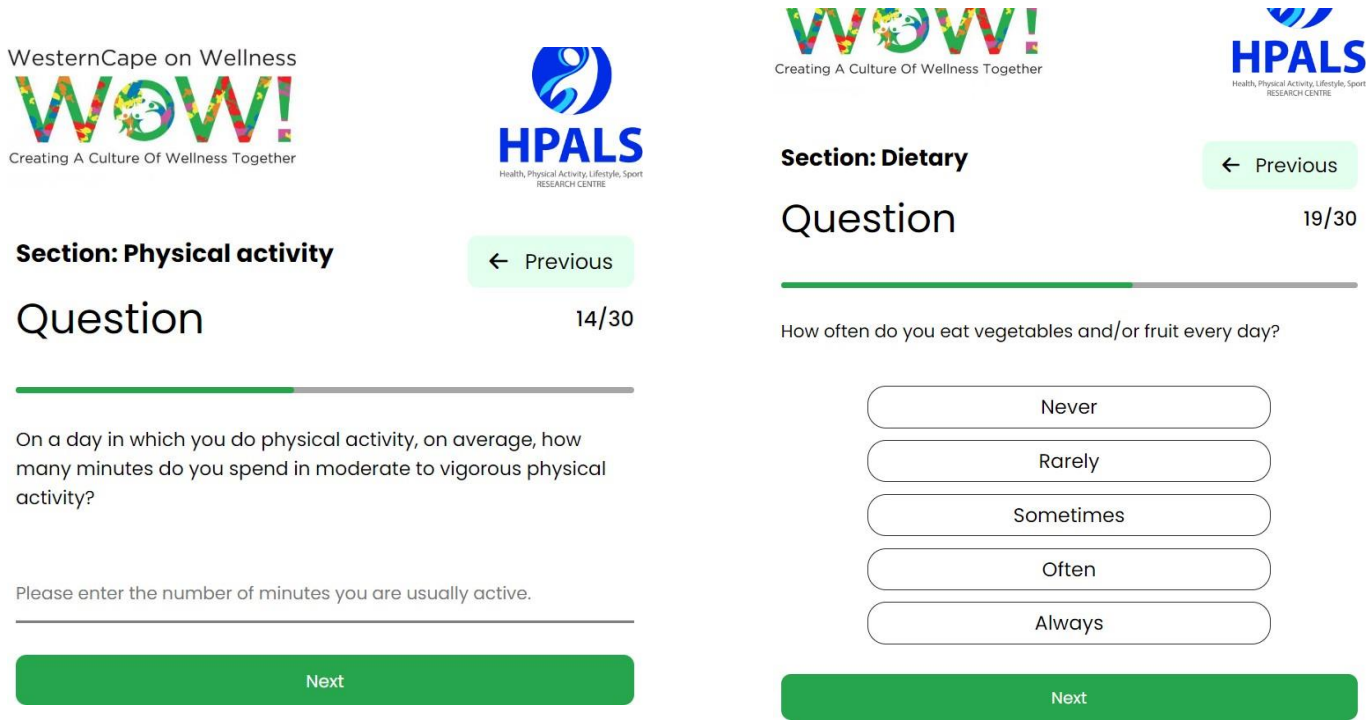

Figure 3.1 showing examples of questions from the online WoW! wellness monitor questionnaire

Our study used the COM-B model to select and categorise health barriers. The COM-B model forms part of the Behaviour Change Wheel (BCW), which is a theoretical framework that aids in the development of behaviour change interventions. The BCW consists of a 'behaviour system' including 3 domains-Capability, Opportunity, and Motivation-Behaviour (i.e., the COM-B model).[88] These domains are theorised to interact with one another to influence and drive behaviour change. 'Capability' refers to both physical and mental ability to engage in a certain behaviour. This includes physical skill and knowledge. 'Opportunity' refers to physical and social external factors that create an environment that encourages behaviour change. Examples of physical factors include time and resources, while social factors include social norms and interpersonal relationships. Lastly, 'Motivation' is defined as cognitive processes that direct behaviour, both reflectively through evaluation and thought, and automatically via impulse and emotion.[89] Each barrier chosen fit into one of the three domains . The health barriers and respective COM-B classifications are presented below.

Barrier	**Source of Behaviour**
1. Lack of knowledge about what to do and how to do it	Capability
2. Not enough time	Opportunity
3. Lack of support from family, friends, co-workers	Opportunity
4. Lack of resources (e.g. funds, facilities, access to transport)	Opportunity
5. Lack of confidence in my ability to achieve the goal	Capability
6. Difficulty with prioritising lifestyle change	Motivation

After completing the questionnaire, participants were sent an electronic "WoW! wellness passport" containing a summary of their results, classifying their health outcomes into a "high risk," "moderate risk" or "low risk" health category (Figure 3.2). The passport was automatically generated via AWS and sent to the WhatsApp number which participants provided in the questionnaire.

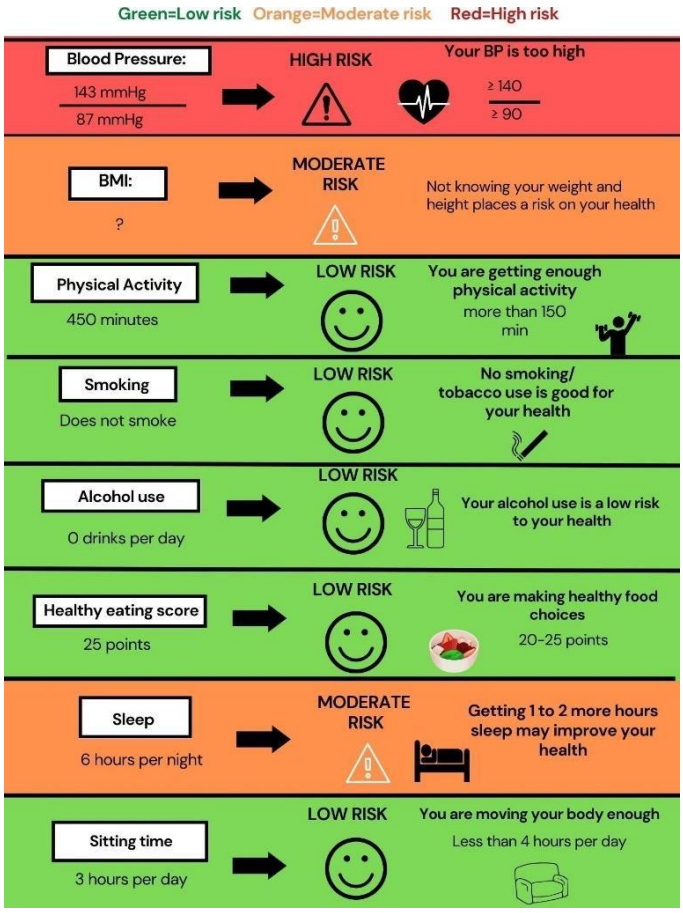

Figure 3.2 Showing an example of the WoW! Wellness passport

Baseline Characteristics

Participants' self-reported demographic and health characteristics were recorded. These included i) overall health quality of life, ii) smoking use, iii) alcohol use, iv) physical activity levels (minutes per week), v) hours of sleep per night, vi) hours of sitting time per day, vii) healthy eating (fruit and vegetable intake, wholegrain intake, protein intake, sugary drinks intake, fast foods/takeout food intake), viii) blood pressure, and ix) body mass index. Participants self-selected health goal and barriers were also recorded. Subgroup analyses were conducted between participants' baseline health characteristics, health goals and health barriers.

Statistical Analysis

The programme IBM SPSS (SPSS Inc., Chicago, Ill., USA) version 28.0.1.1 was used to conduct statistical analyses. Non-parametric tests were used due to data not being normally distributed. Descriptive statistics were calculated for participants' demographics, health characteristics and chosen goal and barriers, and were presented as median and interquartile ranges for continuous variables. Categorical variables were expressed as number and percentages.

Participants' health goals were compared against participants' health characteristics, and differences were calculated using the Kruskal-Wallis test and the Pearson Chi squared test. Correlations between self-reported health characteristics were determined using Spearman's rank correlation tests. Statistical significance was set at an alpha level of 0.05.

Results

Table 3.1 shows the overall baseline characteristics of participants. A total of 95 participants enrolled in the study at baseline.

Demographic and Health Characteristics

The median age of participants was 44 years with 79% of participants being women. Participants most frequently reported having a "good" quality of life (43%), followed by a quality of life that was "neither bad nor good" (37%).

Participants were based in various geographical regions in the Western Cape, with the majority of participants residing outside of Cape Town (38%), followed by in the Cape Flats/South-East Suburbs (24%), most commonly in the Mitchell's Plain sub-area.

Majority of participants did not smoke (70%), and more than half of participants reported not consuming any alcohol. Only 11% of participants reported having diabetes, while 27% reported having high blood pressure.

The median self-reported physical activity per week was 90 minutes. Approximately 70% of participants did not meet the WHO guidelines for physical activity of 150 minutes per week.[16] Mean self-reported sitting time was 5 hours per weekday and weekend day, and the average sleeping time was 6 hours per weeknight and 7 hours per weekend night.

The median BMI of participants was 29 kg/m^2, which is classified as being overweight. About 50% of participants were considered either overweight or obese. The healthy eating score included in the wellness monitor was calculated by adding Likert type scores of out 5 for questions on i) fruit and vegetable intake, ii) wholewheat and wholegrain carbohydrate intake, iii) protein intake, iv) fizzy drinks restrictions, and iv) takeout food restrictions. Most participants reported eating fruit and vegetables and restricting fizzy drinks and takeout foods "often". In contrast, participants reported eating wholegrain foods and healthy proteins only "some of the time".

The median systolic blood pressure was 124 mmHg, which is categorised within healthy blood pressure values. However, 6% of participants had a measured systolic blood pressure over 140 mmHg and would be considered hypertensive.

There was a statistically significant negative correlation between BMI and the healthy eating score. (r=−0.27 95% CI −0.45 to −0.06; p=0.04). A positive correlation was observed between age and having a systolic blood pressure of 130 or more (r=0.38 95% CI 0.18 to 0.55; p<0.001). Additionally, age was correlated to the healthy eating score (r=0.23 95% CI 0.02 to 0.42; p=0.04).

Table 3.1 showing participant baseline characteristics

Baseline characteristics	**Participants (n=95)**
Age (years) [Median (IQR)]	44 (19)
Sex [n (%)]	
Female	74 (78)
Male	15 (16)
Other	2 (2)
Unreported	4 (4)
Geographical region [n (%)]	
Outside Cape Town	33 (35)
Cape Flats	21 (22)
Northern suburb	12 (13)
Southern suburb	12 (13)
Eastern suburb	7 (7)
City Bowl	1 (1)
Unreported	9 (9)
Quality of life [n (%)]	
The best it has been	5 (5)
Good	41 (43)
Neither bad nor good	35 (37)
Bad	10 (11)
The worst it has been	2 (2)
Unreported	2 (2)
Smoking [n (%)]	
Never smoked	66 (70)
Ex-smoker	14 (15)
Current smoker	13 (14)
Unreported	2 (1)
Alcohol [n (%)]	
Does not drink	53 (56)
Less than 14 drinks per week	40 (42)

More than 14 drinks per week	1 (1)
Unreported	1 (1)
Sleep (hours) [Median (IQR)]	
Weeknight	6 (1)
Weekend night	7 (2)
Sitting time (hours) [Median (IQR)]	
Weekday	5 (5)
Weekend day	5 (3)
Physical activity	
Minutes per week [Median (IQR)]	90 (130)
Meeting WHO guidelines [n (%)]	30 (32)
Healthy eating scores (out of 5) [Median (IQR)]	
Fruit and vegetable intake	4 (1)
Wholegrain food intake	3 (2)
Protein intake	3 (1)
Fizzy drink restriction	4 (1)
Takeout food restriction	3 (1)
Total score (out of 25)	17 (4)
Blood pressure[a] (mmHg) [Median (IQR)]	
Systolic	124 (11)
Diastolic	80 (10)
BMI[b] (kg/m^2) [Median (IQR)]	29 (11)
BMI Category [n (%)]	
Underweight	1 (1)
Normal weight	12 (13)
Overweight	20 (21)
Obese	32 (31)
Unreported	30 (39)
Diabetes [n (%)]	11 (12)
High blood pressure [n (%)]	26 (27)
Health goal [n (%)]	
Healthy weight	52 (55)
Healthy diet	11 (12)
Increase fitness	16 (17)
Reduce stress	9 (9)
Improve sleep	3 (3)
Reduce smoking	3 (3)
Unreported	1 (1)
Health barriers [n (%)]	
Lack of knowledge	21 (22)

Lack of time	52 (55)
Lack of support	9 (9)
Lack of resources	13 (14)
Lack of confidence	24 (25)
Difficulty prioritising change	71 (75)

Data is presented as median (interquartile range) for continuous variables, and number (percentage) for categorical variables. Values are rounded to nearest whole number, thus percentages may not equal 100. For health barriers: percentages add up to 200 due to participants choosing 2 barriers each. Health eating score: Likert scale from 1 to 5: 1-Never, 2-Rarely, 3-Sometimes, 4-Often, 5-Always

a: Blood pressure n=46

b: BMI n=66

Health Goals and Barriers

The most frequently chosen health goal was achieving or maintaining a healthy weight (55%), followed by increasing fitness (17%) and improving healthy eating (12%). Only 3% of participants chose improving sleep or reducing smoking as their goal. When comparing participant characteristics across the different health goals chosen, the BMI of participants who chose weight loss as a goal was statistically significantly higher than the BMIs of participants who chose other goals (p=0.02) (Table 3.2).

Furthermore, most participants that were obese chose the goal of achieving a healthy weight (69%), followed by 14% choosing increase fitness. Of those that were overweight, more than half chose achieving a healthy weight as their goal (59%), followed by 24% choosing increase fitness. For the 11 participants that were normal weight, 27% chose the healthy weight goal.

Of the three participants that chose improving sleep as a health goal, two of them were not meeting the sleep guidelines. For participants that currently smoked, only 25% chose the goal to stop or reduce smoking.

Most participants chose the health barriers “difficulty prioritising lifestyle change”, and “lack of time”. These were the most frequently chosen barriers across all six health goals. The least frequently chosen barriers were “lack of support” and “lack of resources”.

Table 3.2 showing baseline characteristics of participants by health goal

Health characteristics [Median (IQR)]	**Healthy weight** (n=52)	**Healthy diet** (n=11)	**Increase fitness** (n=16)	**Reduce stress** (n=9)	**Improve sleep** (n=3)	**Reduce smoking** (n=3)	**P value**
BMI (kg/m^2)	32 (12)[a]	23 (9)[b]	27 (7)[b]	24 (9)[b]	27 (9)	*No data*	0.02*
Physical activity (Minutes per week)	90 (143)	20 (225)	128 (186)	150 (195)	90	90	0.81
Healthy eating score (out of 25)	17 (6)	16 (5)	18 (5)	18 (4)	20	17	0.09
Weekday Sitting time (hours)	5 (5)	5 (4)	7 (3)	5 (3)	5	4	0.63
Weekend Sitting time (hours)	5(4)	5(3)	5(4)	4 (6)	2	4	0.91
Weeknight Sleep (hours)	7 (2)	7 (1)	6 (2)	6 (1)	6	6	0.06
Weekend Sleep (hours)	7 (2)	8(2)	6 (4)	7 (2)	*No data*	*No data*	0.55
Systolic blood pressure (mmHg)	120 (14)	120 (90)	125 (24)	123 (5)	*No data*	*No data*	0.83
Diastolic blood pressure (mmHg)	80 (7)	84 (50)	87 (17)	80 (4)	*No data*	*No data*	0.45

*Data is presented as median (interquartile range). Values are rounded to nearest whole number. P values from Kruskal Wallis test, *p<0.05. ab: statistically significant differences between the BMI of participants who chose the healthy weight goal, and those that chose healthy diet, fitness, and reduce stress as goals. Some values omitted for sleep and smoking goal, as participants with this goal did not complete all survey questions. There are some values without an IQR due to small sample sizes.*

Discussion

The baseline data show that many participants had risk factors for NCDs, with more than half of the participants being overweight and obese and reporting insufficient physical activity levels. Healthy eating scores suggest that participants were consistent with reducing intake of unhealthy foods such as fizzy drinks and takeout food. However, they did not regularly eat healthy foods such as wholegrain foods and healthy proteins. The high level of participants with an unhealthy weight may potentially be explained in part, by the inadequate levels of physical activity and unbalanced diet observed.

The high rate of obesity in this cohort correlates with South African statistics, with South Africa having one of the highest rates of obesity in sub-Saharan Africa.[159] In 2016, 68% of women and 31% of men were classified as overweight or obese.[160] Additionally, South Africa has high levels of physical inactivity, with 30% of males and 45% of females being characterised as unfit.[161]

Another metabolic risk factor present in some participants was high blood pressure and smoking. About 27% of participants reported being diagnosed with hypertension. However, only 6% of participants reported blood pressures greater than 140 mmHg at the time of completing the questionnaire. This suggests that some participants with hypertension were controlling their condition successfully. The Western Cape has one of the highest levels of hypertension in South Africa (45%) according to the South African Demographic and Health Survey (SADHS), with less than 20% of the population controlling their hypertension, despite the availability of affordable and effective blood pressure medication.[160]

Only 15% of participants were current smokers, and another 15% were ex-smokers. This is lower than the prevalence recorded by the SADHS, where 25% of women and 43% of men were cigarette smokers in the Western Cape.[34]

The high BMI levels, low physical activity levels, high blood pressure, and smoking make participants more susceptible to develop NCDs. Furthermore, for those that already have NCDs, the presence of these risk factors may exacerbate their chronic conditions. This highlights the importance of behaviour change interventions in this community, such as the Western Cape on Wellness programme.

In terms of health goals, achieving a healthy weight was the most frequently chosen goal. This aligns with participants health status, as more than half of the participants in both groups were overweight or obese. Similar results were observed in a systematic review and meta-analysis on the prevalence of weight loss attempts globally. In total, 42% of the general adult population had annual attempts to lose weight,with the highest rates of weight loss attempts being observed in overweight or obese populations.[162] Furthermore, a study exploring the prevalence of health goals and barriers amongst American adults showed that more than half of the goals chosen by participants were weight-related, with participants who had health goals having a higher BMI compared to those who did not have any goals (mean BMI: 26 kg/m^2 versus 24 kg/m^2, $p<0.05$).[162]

The most frequently chosen health barriers across all health goals, including weight loss, were "difficulty prioritising lifestyle change" and "not enough time", which belong to the "Motivation" and "Opportunity" categories of the COM-B model, respectively. This suggests that most participants believed that they had the capability (i.e. knowledge and resources) to achieve their health goals, but lacked the motivation and opportunity to do so. Similar findings were observed in a systematic review on adult participants with obesity, where the most frequent barriers to weight loss were poor motivation (6 of 7 studies), followed by lack of time (5 of 7 studies), while only 2 of the 7 included studies had lack of knowledge as a barrier.[163] Furthermore, a meta-analysis of qualitative studies in prediabetic participants found "the individual's evaluation of the importance of initiating lifestyle change" as a key theme for barriers to lifestyle changes.[164]

A possible reason why few participants in the study chose capability-based barriers such as "lack of knowledge" and "lack of resources", may be due to WoW! members already having access to free health educational resources from WoW! prior to the start of the intervention. Thus, WoW! members may benefit from receiving messages and resources with motivation and time management-based tips, in addition to the general knowledge-based health messages.

Several correlations were found between different participant characteristics. Small to moderate correlations were observed between the variables BMI and healthy eating score, age and high blood pressure, and age and healthy eating score. BMI and healthy eating score had an r value of −0.28, which suggests that the higher the participants' BMI was, the lower the healthy eating score

(i.e., the less healthy the diet). This association is understandable, considering that diet intake has a significant influence on body weight, with an unhealthy diet being a major cause of obesity.[161,165]

Age and systolic blood pressure had a positive correlation of 0.38. The relationship of increased blood pressure with age has been established in existing literature and may be due to structural changes in the cardiovascular system that occur with an increased age.[166] The positive correlation between age and healthy eating (r=0.23) is interesting, as it suggests that the older participants had healthier diets than younger participants. However, the study did not account for other possible confounding factors that may have influenced food intake, such as socio-economic status and education level.

Several other limitations exist in the study methodology. The study used self-reported data as opposed to objectively measures health data. Thus, participants may have underreported certain health characteristics such as blood pressure and diabetes. This is particularly probable in this cohort of participants, due to the high prevalence of overweight and obesity, and the well-established link between obesity, hypertension and diabetes.[167,168] In a longitudinal study by Ahmad et al., the strongest risk factor for developing hypertension was BMI, with obese females having almost five times greater incidence of hypertension than females with a healthy BMI.[167] Furthermore, in the South African Demographic and Health Survey of 2016, the proportion of people who self-reported having hypertension and diabetes were much less that the prevalence objectively measured in the survey.[160]

Another key limitation of the study is the sample size being underpowered to detect significant differences between outcomes. The non-randomised method of recruitment also exposes the study to selection bias. It may be that those with worst health conditions and more lifestyle risk factors were more likely to take part in the study, as opposed to those who had less health risks.

Further limitations include not collecting data on the socio-economic variables of participants such as education, employment and income levels, as these factors may have influenced the health and lifestyle characteristics of participants.[5]

Lastly, some participants did not complete all health questions in the questionnaire, with 30% of participants not providing their BMI values. Thus, the prevalence of NCD risk factors in this cohort of WoW! members may be even higher than reported.

Conclusion

The results of the study highlight a high prevalence of risk factors of NCDs in this cohort of WoW! members, with the most notable risk factors being high BMI values and low physical activity levels. Results also show that the most selected health goal was weight loss, with most participants struggling to improve their weight due to difficulty prioritising the lifestyle change, and a lack of time. These barriers fall under the COM-B behaviour change category of "Opportunity" and "Motivation", suggesting that participants had the capability and knowledge to make lifestyle changes, but lacked the motivation and opportunities to apply their knowledge effectively. Future WoW! programmes my benefit from incorporating motivation and time management focused health promotional resources into their future health initiatives. The results of this study reiterate the importance of community behaviour change interventions such as Western Cape on Wellness!, to reduce the risk and severity of non-communicable diseases in the Western Cape and South Africa.

The penultimate chapter of the thesis discusses the pilot intervention study, which consisted of assessing the effectiveness of a WhatsApp message-based mHealth intervention, targeting leaders and members of Western Cape on Wellness! to promote healthy behaviour changes.

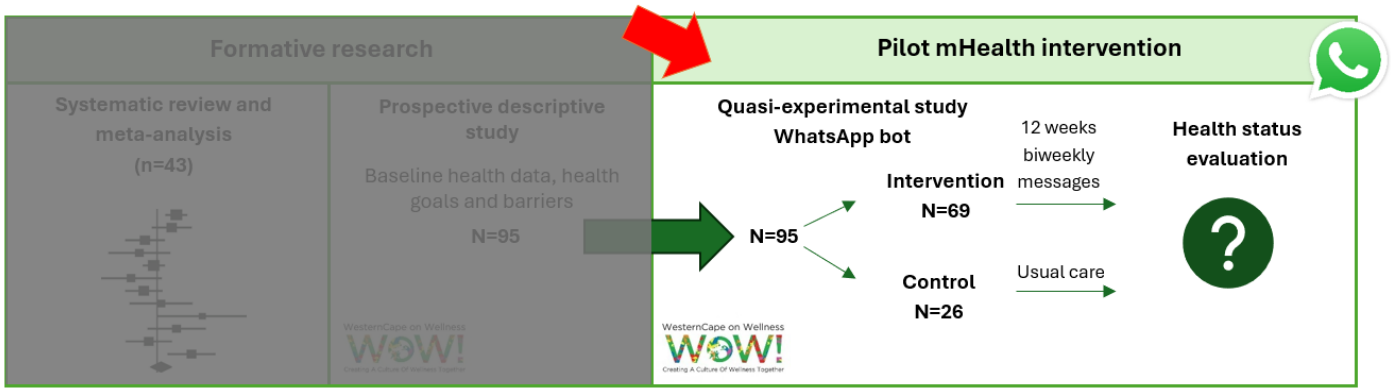

Figure 3.3 showing a flow diagram of the overall thesis study structure. Red arrow indicates next chapter.

CHAPTER 4

The Effectiveness, Acceptability, and Feasibility of a Tailored WhatsApp Message mHealth Intervention to Improve Health Risks and Behaviours: A Pilot Study for the Western Cape on Wellness (WoW!) Programme

Abstract

Introduction: The prevalence of non-communicable diseases (NCDs) is a global health concern, accounting for substantial morbidity and mortality. Many public health interventions have been implemented to reduce the burden of NCDs through lifestyle modifications such as healthy eating and physical activity. One such intervention, mHealth, refers to the use of mobile devices to provide health support, and has been shown to be cost effective and scalable in targeting these risk factors.

Aim: Our study aimed to evaluative the effectiveness, acceptability, and feasibility of a tailored WhatsApp message mHealth intervention on leaders and members of the Western Cape on Wellness! (WoW!) programme.

Methods: Participants were recruited from four preexisting WoW! WhatsApp groups, with two groups being recruiting for the intervention arm and two groups for the control arm. A WhatsApp bot was programmed to send biweekly messages that were tailored to the intervention groups pre-selected health goals and health barriers for 12 weeks. Both the control and intervention groups received usual care, which included three times weekly generic wellness messages.

Results: A total of 95 participants enrolled in the study, with 69 participants in the intervention group and 26 in the control group. A total of 83% of all messages were read by participants. The participant follow-up rate post intervention was low (26%). Most participants that completed the follow-up questionnaire found the intervention messages acceptable and consistently read all the messages. However, no self-reported health changes were observed post intervention.

Discussion: The tailored WhatsApp messages did not result in any self-reported changes in participants' health risk behaviours. This may be due to the unidirectional messages alone not being effective enough to elicit lifestyle changes, over and above the generic weekly messages. However, these results only represent a small proportion of the study cohort due to a low follow-up rate and thus may not be representative of the entire sample.

Conclusion: The WhatsApp message intervention was feasible and acceptable for a pilot study. However, it was ineffective at eliciting any health changes and requires further technical modifications for improved performance. Future interventions may benefit by having additional intervention components, such as phone calls or in-person sessions to increase intervention effectiveness. Moreover, there is a need to explore strategies to increase uptake of and engagement with the WhatsApp intervention and other mHealth interventions performed in the future.

Introduction

There has been a significant global shift in burden of disease from infectious agents to chronic non-communicable diseases (NCDs) over the past decade,[169] with the increase in globalisation and urbanisation leading to unhealthy, sedentary lifestyles.[6,170] Two-thirds of global deaths have been attributed to NCDs, while 39% of deaths in South Africa are associated with NCDs.[8] Furthermore, it has been estimated that deaths due to NCDs will more than double from 2005 to 2060, and will outnumber communicable disease deaths by more than five to one by 2060.[3]

Although this shift has been observed in both high- and low-income countries, the burden disproportionately affects low-income populations. Lower to middle income countries (LMICs) have a greater prevalence of NCD risk factors and a higher risk of mortality due to NCDs.[5] Additionally, communities in low-resource settings generally have poorer access to healthcare, higher levels of unemployment, lower levels of health education and limited affordable healthy food options, limiting their ability to make healthy lifestyle choices.[5–7]

An innovative intervention method that has been shown to be cost effective and scalable in targeting NCD risk factors such as physical inactivity and obesity, is mHealth or mobile health. mHealth refers to the use of mobile devices and other technologies to promote and provide health support.[57] Due to the ubiquity of mobile devices and mobile broadband coverage globally,[47] mHealth has the potential to reduce the risk and prevalence of NCDs in both high- and low-income countries. It has even been reported that some low-income countries have greater accessibility to mobile phones than basic services such as electricity and clean water.[171]

Furthermore, the cost of mobile data has continually declined across Africa, with the average cost of 1 gigabyte (GB) of data decreasing from 8.8% to 5.8% of monthly income from 2019 to 2020. However, this is still greater than the United Nation's target of 2% per monthly income for 1GB. Additionally, with high levels of inequality in the region, many are still unable to afford data and internet access.[51,52] In South Africa, a third of the population is unable to afford mobile data regularly, and will only buy data when they have the money available to do so.[51]

Despite the potential affordability barriers, numerous studies in LMICs have shown mHealth as being effective in the management of NCDs such as diabetes and cardiovascular disease.[45,58] In a systematic review of mHealth interventions for NCDs, seven out of eight studies observed a positive effect on management of diseases such as diabetes, cardiovascular disease, and hypertension.[45] In another systematic review focusing on the effect of mHealth interventions on physical activity and diet in developing countries, 13 out of 15 studies observed favourable outcomes.[58]

However, not all studies have shown positive effects. For example, a study by Nanditha et al.[59] showed no improvements in clinical outcomes of diabetic patients in India after receiving motivational and educational text messages. Additionally, in a study by Shetty et al.,[172] there were no statistically significant changes in physical activity, diet, or BMI in participants with diabetes. Thus, although studies generally show a positive effect of mHealth interventions on health behaviours and outcomes, results are equivocal.

There are several other limitations of existing mHealth studies. Many mHealth study interventions have not been based on theoretical frameworks,[58] which have been suggested to improve the effectiveness of behaviour change interventions.[69] This is evident in a systematic review by Webb et al.,[109] which observed that mHealth studies based on theory had higher effect sizes than those without any theoretical basis.

Another limitation in the literature is that most mHealth studies have used short message service (SMS) or text messages as a form of intervention. Although text messages have proven to be effective in some studies,[45] the use of this form of messaging has declined with the development of more sophisticated mobile messaging technologies such as WhatsApp.[57] WhatsApp is a free, instant messaging, social media platform available on smartphones, that allows for easy sharing of text messages, images, videos, and documents. In 2017, the amount of active WhatsApp users was estimated at 1.2 billion users globally.[173] Furthermore, it is the most popular messaging application in several LMICs.[174] This makes it a suitable and promising mHealth medium.

Several WhatsApp-based mHealth studies targeting NCDs have been published, including those promoting management of diabetes,[62–64] smoking cessation[65], healthy eating[66,67] and physical

activity.[68] Durmaz and colleagues conducted a study using educational WhatsApp messages and observed an increase in smoking cessation in the intervention group (OR 3.50, 95% CI = 1.30–9.44, $p<0.05$) compared to the control group receiving usual care.[65] While Al Omar and colleagues observed a greater reduction in HBA1C levels in participants receiving educational WhatsApp messages ($p=0.001$) compared to receiving usual care. However, control participants also experienced a reduction in their HBA1C levels ($p=0.032$).[63]

The above results show potential for the use of WhatsApp to improve risk factors for NCDs. However, evidence is limited due to the few existing studies, and some studies failing to show a statistically significant difference between intervention and control group outcomes. Thus, more research is required to strengthen the evidence for the use of WhatsApp-based mHealth interventions to improve risk factors for NCDs.

Our study aimed assess the effectiveness, feasibility, and acceptability of a WhatsApp-based mHealth intervention. The intervention involved sending educational and motivational messages biweekly to participants, with messages being tailored to participants pre-selected health goal and health barriers.

Message development was guided by theory and involved using the COM-B model of behaviour change (Capability, Opportunity, Motivation-Behaviour),[89] motivational interviewing principles,[175] and the 5 A's of Brief Behaviour Change Counselling.[176] The study was conducted on a cohort of individuals belonging to the Western Cape on Wellness Programme (WoW!), a government-supported, community-based health promotion initiative in the Western Cape.[43] mHealth was a suitable intervention medium to integrate into WoW!'s existing health programme, due to its convenience, scalability and reach, helping overcome any resource constraints that the programme may experience. Moreover, WoW! already has established WhatsApp-based communication channels to inform and motivate its members, thus there was a familiarity associated with its use.

Methods

Participant Recruitment

Participants were recruited from an existing behaviour change initiative, called Western Cape on Wellness! (WoW!). WoW! is a provincial, government-led, community-based, partnership programme launched in 2015, that aims to train and support volunteer wellness champions, as they assist community members in making sustainable lifestyle changes to improve their health and wellbeing.[42] Both wellness champions (volunteer WoW! leaders) and general members were included in the study. A staggered recruitment method was used over a period of 2 months (September to November 2023).

Participants were recruited via sharing a study advertisement with four pre-existing WoW! WhatsApp groups. One group was made up of 212 wellness champions, while the remaining three groups included 515 WoW! members, forming a total of 727 potential participants. The study advertisement included a PDF and accompanying WhatsApp message with a brief description of the study and instructions on how to enrol.

For participants to enrol in the intervention study, they had to activate the WhatsApp bot by sending the word "register" to the bot number provided in the study advertisement. Thereafter, participants were required to click on a link in the advertisement which led to an online WoW! wellness monitor questionnaire for the collection of demographic and baseline health data. At the end of the questionnaire participants were required to select a health goal and two health barriers preventing them from achieving their goal. Participants also received a health summary, categorising their health behaviours into high risk, moderate risk, and low risk categories. The questionnaire and health summaries were generated via Amazon Web Services (AWS).

The study received ethics approval by the Faculty of Health Sciences Human Research Ethics Committee at the University of Cape Town (Ref. No. 799/2022) (Appendix C). Informed consent was given by participants at the beginning of the study via the online questionnaire.

Study Design and Intervention

The intervention was a 12-week pilot, quasi-experimental study consisting of an intervention and control group. Participants were recruited from four preexisting WoW! WhatsApp groups, with two groups being recruited for the intervention arm and two groups for the control arm.

The intervention group received biweekly, tailored, motivational and educational WhatsApp messages, on Tuesday and Thursday at 10 am for 12 weeks (Figure 4.1, and Appendix E). The messages were tailored to the health goal and barriers selected by the participants. Participants were able to stop receiving weekly messages, by sending "STOP" to the WhatsApp bot.

Both the control and intervention groups continued to receive "usual care". Usual care included generic, non-tailored group messages that all WoW! members received on Monday's, Tuesdays, and Fridays, containing general health content on healthy eating, mental well-being, and physical activity. However, the control group received no tailored messages, and only had access to pre-existing WoW! resources, such as the WoW! website and weekly generic group messages.

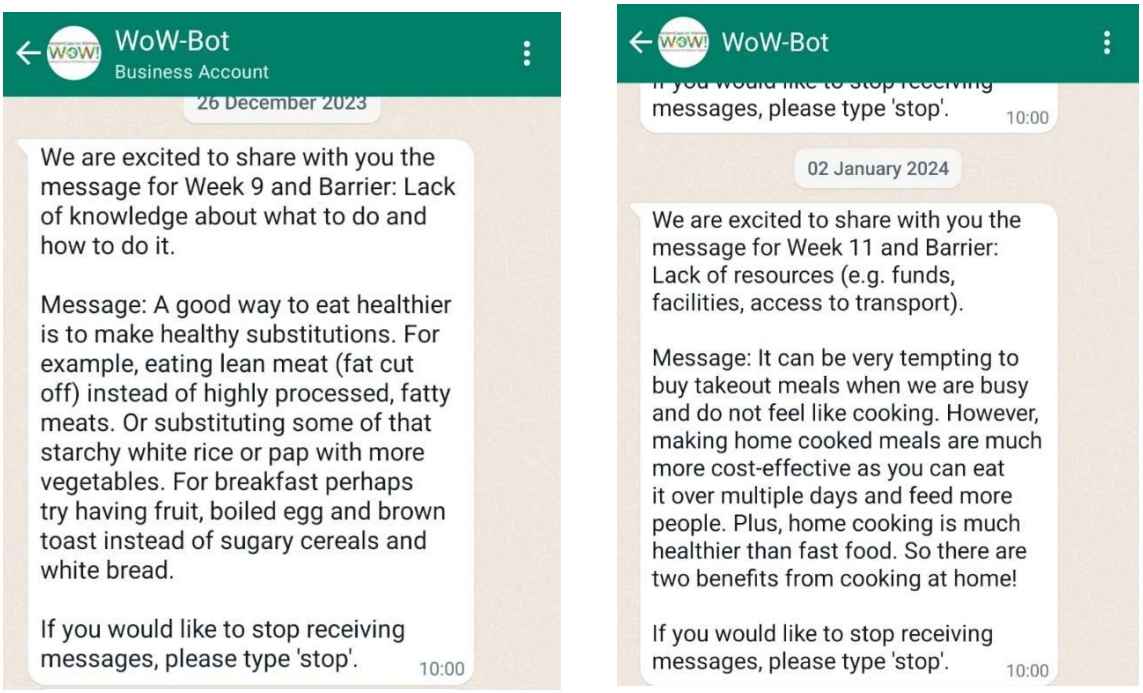

Figure 4.1 Showing examples of the biweekly tailored WhatsApp bot messages.

After the 12 weeks study duration, all participants were sent a message inviting them to complete the WoW! wellness monitor for the second time. Additionally, participants in the intervention group were invited to complete a survey in which they rated their perception of the acceptability of the WhatsApp messages on a Likert scale of 1–5 (1=strongly disagree, 5=strongly agree). The survey included rating message attributes such as message suitability, frequency, length and understanding.

Once participants submitted their questionnaire responses, their answers were automatically stored on a database hosted by AWS. Participants taking the questionnaire for the first time were instructed to choose the "new participant" option at the beginning of the questionnaire, and "returning participant", when taking the questionnaire after the 12 weeks.

Tailored WhatsApp Messages

The WhatsApp 'bot' was developed using the application *Twilio* (https://www.twilio.com/en-us). The *Twilio* website provided a centralised platform where the WhatsApp messages could be programmed and sent to participants. The bot was programmed to send unidirectional messages only, due to the simplicity and lower cost of developing and hosting a one-way messaging platform, compared to bidirectional messaging.[93,107] Additionally, participants would not have to respond to messages, and thus did not have any additional data costs.

A total of 432 messages were written by research staff and post-graduate students in the Division of Physiological Sciences in the Faculty of Health Sciences at the University of Cape Town, to match each potential goal and barrier combination for 12 weeks of messages. These were edited and approved by the Western Cape Department of Health and Wellness. All messages were written with the average readability not exceeding the Flesch-Kincaid Grade 8 reading level. Content of the messages include educational advice, health tips and motivational reminders. Additionally, three evidence-based behaviour change theories and methods were used for message development. These included principles of motivational interviewing, the 5 A's of brief behaviour change counselling and the COM-B model.

Motivational interviewing is an evidence-based, patient centred method of counselling. It involves giving the patient the responsibility and autonomy to make health changes, while the practitioner guides the process in an empathetic, non-judgmental manner.[175] Using the first principle of motivational interviewing of expressing empathy, the WhatsApp messages were written in a non-judgemental, empathetic tone. The first message included an empathetic statement to help build trust between the participant and the researcher at the beginning of the study. For example: *"It may seem overwhelming to increase your fitness and become more active, but making the decision to start is the biggest hurdle to overcome. Well done! It doesn't have to be so complicated. Remember every extra step you take counts toward improving your fitness and well-being!"*

Furthermore, all the messages supported self-efficiency (principle two) by being written in an autonomy supportive manner. The messages suggested health behaviour changes and tips rather than instructing the participant to perform certain actions. Many messages were also written as questions which enabled the participant to think for themselves instead of the researcher providing direct instructions. This encouraged the participant to take charge of their own health and develop discrepancy, which is another principle of motivational interviewing.[177] For example: "*How about reflecting on small changes you can make daily to increase your fitness? Perhaps walking part or all the way to work; climbing the stairs instead of using escalators and lifts and putting in a big effort with household cleaning. Every step and every move counts."*

The second evidence-based approach used in message development was the Five A's of Brief Behaviour Change Counselling (BBCC). The Five A's of Brief Behaviour counselling represent the following: Ask, Advise, Assess, Assist and Arrange.[178,179]

"Ask" involves the counsellor seeking permission to discuss and identify patient behavioural risk factors.[179] This enables the patient to take charge of the conversation and address risk factors that they are comfortable discussing. Our study incorporated this by asking the participant what health goal they would like to address at the beginning of the intervention.

The second component, "Advise", entails providing information on risks and benefits of health behaviours relevant to the patient, and the provision of tailored and clear advice.[179] Our study included this component of BBCC, by sending tailored messages containing advice and

educational information to help the participant achieve their selected health goal and overcome their chosen health barriers. For example: *"Did you know that a healthy goal is to accumulate 30 minutes of moderate exercise on most days of the week? But, this does not have to take place all at once. Ten minutes here and 5 minutes there can all add up to 30 minutes."*

"Assess" involves evaluating the patient's health status.[178] This was achieved in our study by the health questionnaire completed by the participants at the beginning of the study.

"Assist" comprises of providing motivation to the patient, encouraging seeking social support, developing confidence to change, and providing additional educational resources and motivation.[178] Our study demonstrated this component by proving motivational, supportive messages to the participant as well as supplementary resources such as websites or helpful videos.

"Arrange" involves scheduling follow-up appointments or arranging future assistance for the patient.[179] The final WhatsApp message was written with suggestions to assist the participant in their future health journeys, with some messages containing resources if further help was needed in the future. For example: *"We hope that we have been able to reassure you that getting fit does not take a lot of knowledge or skill. Activity can fit into your everyday life. We thank you for making this commitment and we hope you are looking forward to your ongoing fitness journey. This is one hurdle that you have overcome! Well done! If you still feel a bit lost, make sure to contact your WoW! team to assist you further at 066-390-6646.".* Additionally, participants were contacted after 12 weeks to retake the wellness monitor questionnaire, to determine whether they made any health changes.

Lastly, the Behaviour Change Wheel and the COM-B model were used to develop tailored messages for participants in the study. The Behaviour Change Wheel (BCW) is a theoretical framework developed by Michie et al. which combines 19 behaviour change models into one construct, that can be used to guide the development of behaviour change interventions.[89]

The BCW consists of a 'behaviour system' including 3 domains- Capability, Opportunity, and Motivation for behaviours (i.e., the COM-B model).[88] These domains are theorised to interact with one another to influence and drive behaviour change. 'Capability' refers to both physical and

mental ability to engage in a certain behaviour. This includes physical skill and knowledge. 'Opportunity' refers to physical and social external factors that create an environment that encourages behaviour change. Examples of physical factors include time and resources, while social factors include social norms and interpersonal relationships. Lastly, 'Motivation' is defined as cognitive processes that direct behaviour, both reflectively through evaluation and thought, and automatically via impulse and emotion.[89]

Our study used the COM-B system to categorise barriers to selected health goals, and to develop appropriate short, sequential text messages in response to the selected goals and barriers. Each barrier fit into one of the three domains (Capability, Opportunity, and Motivation). Twelve messages were then constructed for each barrier and goal combination.

Barrier	Source of Behaviour
1. Lack of knowledge about what to do and how to do it	Capability
2. Not enough time	Opportunity
3. Lack of support from family, friends, co-workers	Opportunity
4. Lack of resources (e.g. funds, facilities, access to transport)	Opportunity
5. Lack of confidence in my ability to achieve the goal	Capability
6. Difficulty with prioritising lifestyle change	Motivation

Study Outcomes

Participants' self-reported demographic, health and lifestyle characteristics were collected and compared between the intervention and control groups, and pre and post intervention. These included: i) overall health quality, ii) smoking use, iii) alcohol use, iv) physical activity levels (minutes per week), v) hours of sleep per night, vi) hours of sitting time per day, vii) healthy eating (fruit and vegetable intake, wholegrain carbohydrate intake, lean protein intake, sugary drinks intake, fast foods/takeout foods intake), viii) blood pressure, and ix) body mass index.

Several subgroup analyses were conducted on the participants' baseline health goals and characteristics, including, i) between participants that read all messages and participants who failed

to read some messages and ii) between participants that completed follow-up and those that did not. This was performed to determine whether there were differences in the health characteristics and goals of participants that read their messages and completed the follow-up questionnaire, compared to those that did not read all their messages and were lost to follow-up.

Participants' attitudes towards the messages were evaluated using a Likert scale survey, and included questions on message frequency, timing, length, and acceptability. Additionally, the number of messages read were also calculated as well as the technical performance of the WhatsApp Bot (i.e. how many messages failed to send).

Sample Size Calculation

Using G power 3.1.9.4, a sample size of 64 participants was calculated using an effect size of 0.2, power of 0.85 and correlation among repeated measures of 0.2 The effect size was based on a study by Gell et al.,[136] that detected a statistically significant change in physical activity of participants receiving text messages. The correlation coefficient was derived from an mHealth study protocol on diabetes management.[180]

Statistical Analysis

The programme IBM SPSS (SPSS Inc., Chicago, Ill., USA) version 28.0.1.1 was used to conduct statistical analyses. Non-parametric tests were mostly used due to data not being normally distributed. Descriptive statistics were calculated for participants' demographics, health characteristics and chosen goal and barriers, and were presented as median and interquartile ranges for continuous variables. Categorical variables were expressed as number and percentages. The Mann Whitney U test was performed to determine between group differences in continuous variables, while the Pearson Chi squared test was used for categorical variables. To determine within group differences between health data pre and post intervention, the Wilcoxon signed rank test was used. Repeated measures ANOVA was used to determine changes in the number of unread messages and failed messages from week 1 to week 12 of the intervention. Statistical significance was set at a p value of <0.05.

Results

Demographic and Health Characteristics

Table 4.1 shows the baseline characteristics of participants in the intervention versus the control group. A total of 95 participants enrolled in the study (intervention group: 69 participants; control group: 26 participants).

There was a statistically significant difference in quality of life between the intervention and control groups (p=0.04). Participants in the intervention group most frequently reported having a "good" quality of life (54%), while 58% of participants in the control group reported a quality of life that was "neither bad nor good".

For diet, the intervention group had a statistically significantly higher healthy eating score than the control group at baseline (p=0.02).

Table 4.1 showing participant baseline characteristics in the intervention and control groups

	Intervention group (n=69)	**Control group** (n=26)	**P value**
Age (years) [Median (IQR)]	44 (17)	43 (23)	0.78
Sex [n (%)]			0.68
Female	54 (78)	20 (77)	
Male	11 (16)	4 (15)	
Other	2 (3)	0 (0)	
Not reported	2 (3)	2 (8)	
Quality of life [n (%)]			0.04*
The best it has been	3 (4)	2 (8)	
Good	37 (54)	4 (15)	
Neither bad nor good	20 (29)	15 (58)	
Bad	8 (12)	2 (8)	
The worst it has been	1 (1)	1 (4)	
Unreported	0	2 (8)	
Smoking [n (%)]			0.32
Never smoked	50 (74)	16 (62)	
Ex-smoker	11 (16)	3 (12)	
Current smoker	7 (9)	6 (23)	
Unreported	1 (1)	1 (4)	
Alcohol [n (%)]			0.31
Does not drink	37 (54)	16 (62)	
Less than 14 drinks per week	31 (45)	9 (35)	
More than 14 drinks per week	0 (0)	1 (4)	
Unreported	1 (1)	0 (0)	
Sleep (hours) [Median (IQR)]			
Weeknight	6 (2)	6.5 (1)	0.73
Weekend night	7 (2)	7 (1)	0.14
Sitting time (hours) [Median (IQR)]			
Weekday	5 (5)	6 (4)	0.44
Weekend day	4 (3)	6 (5)	0.19
Physical activity			
Minutes per week [Median (IQR)]	90 (150)	80 (129)	0.37
Meeting WHO guidelines [n (%)]	24 (35)	8 (30)	0.68
Healthy eating scores (out of 5) [Median (IQR)]			
Fruit and vegetable intake	4 (1)	3 (1)	0.13
Wholegrain food intake	3 (1)	3 (1)	0.33
Protein intake	3 (2)	3 (1)	0.08
Fizzy drink restriction	4 (1)	3 (1)	0.01*
Takeout food restriction	4 (1)	3 (1)	0.01*
Total score (out of 25)	18 (5)	16 (5)	0.02*
Blood pressure[a] (mmHg) [Median (IQR)]			
Systolic	120 (18)	121 (19)	0.55
Diastolic	80 (15)	80 (9)	0.95

BMI[b] (kg/m^2) [Median (IQR)]	28 (11)	29 (10)	0.76
BMI category [n (%)]			
Underweight	1 (2)	0 (0)	
Normal weight	8 (12)	4 (15)	
Overweight	14 (20)	6 (23)	
Obese	23 (33)	9 (35)	
Unreported	23 (33)	7 (27)	
Diabetes [n (%)]	10 (15)	1 (4)	0.38
High blood pressure [n (%)]	20 (29)	6 (23)	0.54
Health goal [n (%)]			0.99
Healthy weight	38 (55)	14 (54)	
Healthy diet	8 (12)	3 (12)	
Increase fitness	13 (19)	3 (12)	
Reduce stress	5 (7)	4 (15)	
Improve sleep	2 (3)	1 (4)	
Reduce smoking	2 (3)	1 (4)	
Unreported	1 (2)	0	
Health barriers [n (%)]			0.96
Lack of knowledge	14 (20)	7 (27)	
Lack of enough time	41 (59)	11 (42)	
Lack of support	7 (10)	2 (8)	
Lack of resources	10 (14)	3 (12)	
Lack of confidence	14 (20)	10 (39)	
Difficulty prioritising change	52 (75)	19 (73)	

*Data is presented as median (interquartile range) for continuous variables, and number (percentage) for categorical variables. Values are rounded to nearest whole number; thus percentages may not add up to 100. For health barriers, percentages add up to 200 due to participants choosing 2 barriers each. Health eating score: Likert scale from 1 to 5: 1-Never, 2-Rarely, 3-Sometimes, 4-Often, 5-Always. P values from Mann Whitney U test, *=p<0.05: statistically significant differences between quality of life and healthy eating scores.*

a: Blood pressure n=46

b: BMI n=66

WhatsApp Bot Messages

A total of 1331 messages were successfully sent to participants during the intervention period. Of these messages, an average of 83% of messages were 'read' (i.e. opened on WhatsApp) by participants. A total of 24 participants failed to read some of their messages, with an average of seven out of 24 messages not being read. Eight participants read less than half of the received messages. The least number of unread messages were during week 1. However, the number of unread messages increased significantly from week 1 to week 2 ($p<0.01$), thereafter remaining relatively consistent (Figure 4.2).

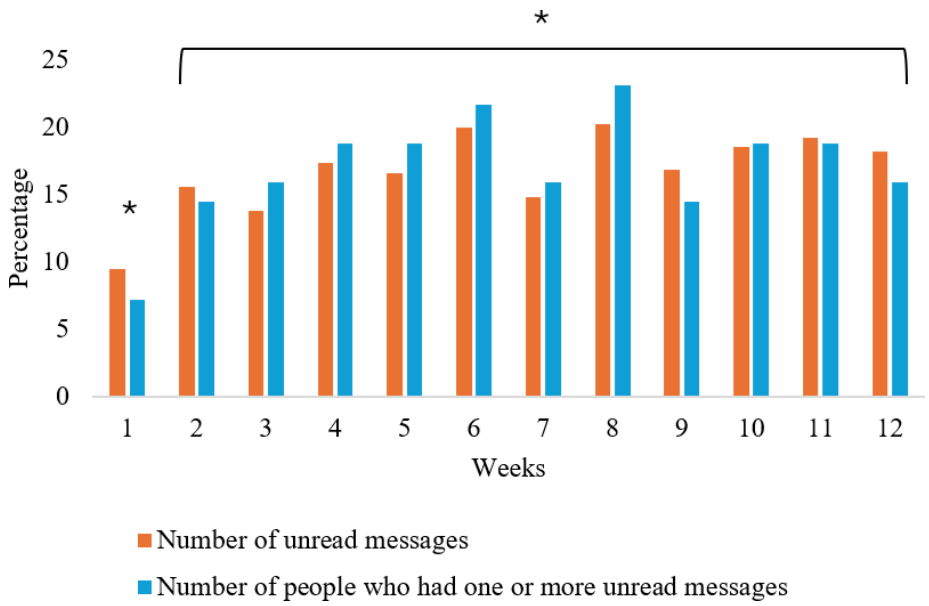

Figure 4.2 showing the percentage of unread messages and number of participants who had unread messages

**Statistically significant difference in number of unread messages/participants with unread messages, between week 1 and week 2 to 12, p<0.01*

There were no differences in baseline health data (excluding sleep and sitting time), health barriers and health goals of participants that did not read all their messages, compared to the participants who read all their messages. (p=0.51) (Table 4.2 and 4.3)

Table 4.2 showing the baseline data of participants that read all messages versus participants that did not read all messages

Baseline data [Median (IQR)]	**Read all messages** (n=45)	**Did not read all messages** (n=24)	**P value**
Physical activity (Minutes per week)	150 (168)	120 (105)	0.27
BMI (kg/m^2)	26 (14)	28 (13)	0.87
Sleep (hours)	7 (2)	6 (1)	0.04*
Sitting time (hours)	6 (5)	5 (5)	0.01*
Blood pressure (mmHg)			
Systolic	120 (16)	125 (16)	0.96
Diastolic	83 (17)	78 (13)	0.10
Healthy eating scores (out of 5)			
Fruit and vegetable intake	4 (1)	4 (1)	0.91
Wholegrain food intake	3 (1)	3 (2)	0.87
Protein intake	4 (1)	3 (1)	0.05
Fizzy drink restriction	4 (2)	4 (2)	0.10
Takeout food restriction	4 (2)	4 (1)	0.85
Total score (out of 25)	18 (3)	20 (5)	0.22

*Data is presented as median (interquartile range). Values are rounded to nearest whole number. P values from the Mann Whitney U test, *=p<0.05*
Healthy eating score: Likert scale from 1 to 5: 1-Never, 2-Rarely, 3-Sometimes, 4-Often, 5-Always

Table 4.3 showing health goals of participants that read all messages versus participants that did not read all messages

Health goal	**Read all messages** (n=44)	**Did not read all messages** (n=24)	**P value**
Healthy weight	26 (59)	12 (52)	0.68
Healthy diet	3 (7)	5 (17)	
Increase fitness	9 (20)	4 (17)	
Reduce stress	3 (7)	2 (9)	
Improve sleep	1 (2)	1 (4)	
Reduce smoking	2 (5)	0 (0)	

*Data is presented as frequency (percentage). Values are rounded to nearest whole number. P values from Pearson Chi squared test, *=p<0.05. Sample size equals 68, due to one participant's goal being unreported.*

Although the bot was tested multiple times prior to study commencement, a group of 37 participants failed to receive some of the messages across the 12 weeks. The average number of messages failing to send to these participants was 4 out of the 24 messages. Most messages failed due to the message template uploaded on Twilio being later rejected by WhatsApp (40%), despite initially being accepted. The remaining messages failed due to some numbers being chosen by the

WhatsApp company *Meta*, for an internal experiment, and users unsubscribing from the bot (approximately 30% each). The bot had the least number of message failures in the first 5 weeks, with an average of 5 messages failing to send per week across all participants. Thereafter, there was an increase in the number of messages failing to send between week 5 to week 6 ($p<0.03$) (Figure 4.3).

Seven participants unsubscribed from the bot to stop receiving messages, between week 6 and week 11 of the intervention.

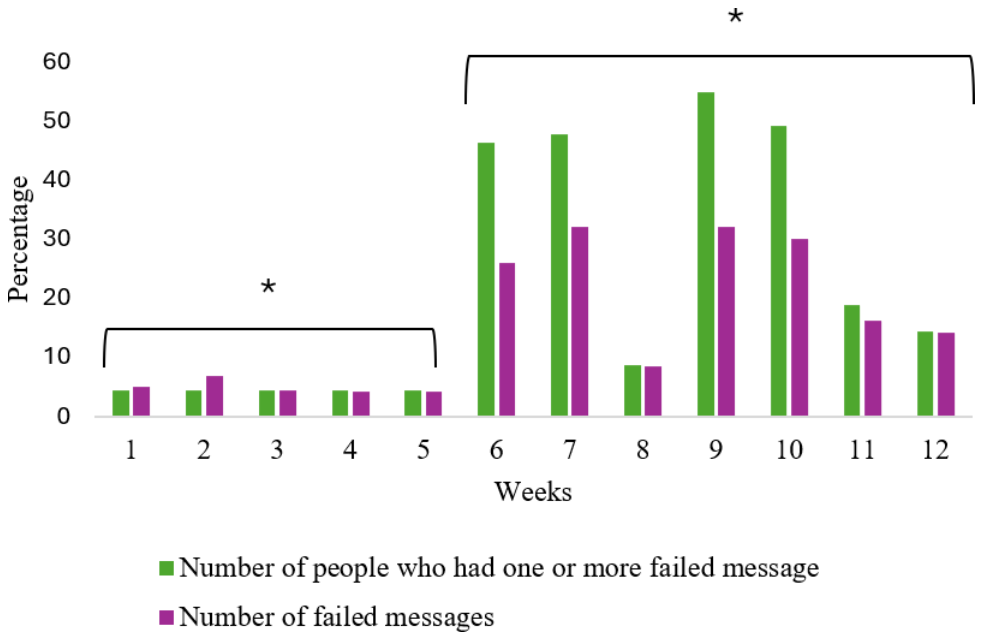

Figure 4.3 showing the percentage of failed messages and participants with failed messages

**Statistically significant difference in number of failed messages/participants with failed messages, between weeks 1 to 5 and weeks 6 to 12, p<0.03*

WhatsApp Bot Intervention Effect and Acceptability.

Health outcomes pre and post intervention are presented in Table 4.4 and 4.5. Only 25% of participants completed the follow-up health questionnaire (intervention group: n=17 (25%), control group: n=8 (31%). Of participants in the intervention group that completed the follow-up questionnaire, no statistically significant changes were detected in self-reported health

characteristics such as BMI, physical activity, blood pressure, and overall healthy eating score. The only statistically significant change present was an increase in takeout food restriction (p=0.03). While in the control group (n=8), the only statistically significant difference found was an increase in healthy eating score (p=0.04). No between group differences were found in outcomes post intervention (Table 4.6).

Table 4.4 showing the health outcomes of participants in the intervention group, before and after the WhatsApp Bot intervention. (n=17)

Health outcome	Pre intervention	Post intervention	P value
Physical activity[a] (Minutes per week)	120 (195)	150 (205)	0.95
BMI[b] (kg/m^2)	35 (12)	33 (13)	0.53
Sleep (hours)	7 (3)	7 (1)	0.73
Sitting time (hours)	8 (4)	4 (5)	0.11
Blood pressure[c] (mmHg)			
Systolic	125 (13)	120 (11)	0.21
Diastolic	80 (12)	80 (12)	0.24
Heathy eating scores[d] **(out of 5)**			
Fruit and vegetable intake	3 (1)	3 (2)	1
Wholegrain food intake	3 (2)	4 (3)	0.12
Protein intake	3 (2)	3 (4)	0.76
Fizzy drink restriction	4 (1)	4 (3)	0.32
Takeout food restriction	3 (1)	4 (1)	0.03*
Total score (out of 25)	18 (6)	18 (6)	0.79

a: Physical activity n=15
b: BMI n=11
c: Blood pressure n=9
d: Eating score n=15

Table 4.5 showing the health outcomes of participants in the control group pre and post intervention. (n=8)

Health outcome [Median (IQR)]	**Pre intervention**	**Post intervention**	**P value**
Physical activity (Minutes per week)	105 (199)	140 (346)	0.12
BMI[a] (kg/m^2)	26 (6)	27 (6)	0.07
Sleep[b] (hours)	6 (1)	6 (1)	1
Sitting time (hours)	4 (4)	4 (3)	0.34
Blood pressure[c] (mmHg)			
Systolic	123	131	0.18
Diastolic	78	77	0.29
Healthy eating scores (out of 5)			
Fruit and vegetable intake	3 (2)	4 (2)	0.18
Wholegrain food intake	3 (1)	4 (2)	0.58
Protein intake	3 (2)	4 (3)	0.10
Fizzy drink restriction	4 (1)	4 (2)	0.32
Takeout food restriction	4 (1)	4 (1)	0.16
Total score (out of 25)	18 (3)	19 (6)	0.03*

a: BMI n=5
b: Sleep n=7
c: Blood pressure n=3

Table 4.6 showing the health outcomes of participants in the intervention versus control group after 12 weeks.

Health outcome [Median (IQR)]	**Intervention** (n=17)	**Control** (n=8)	**P value**
Physical activity (Minutes per week)	150 (205)	140 (346)	0.98
BMI (kg/m^2)	33 (13)	27 (6)	0.26
Sleep (hours)	7 (1)	6 (1)	0.42
Sitting time (hours)	4 (5)	4 (3)	0.71
Blood pressure (mmHg)			
Systolic	120 (11)	131	0.08
Diastolic	80 (12)	77	0.96
Healthy eating scores (out of 5)			
Fruit and vegetable intake	3 (1)	4 (2)	0.44
Wholegrain food intake	3 (2)	4 (2)	0.75
Protein intake	3 (2)	4 (3)	0.37
Fizzy drink restriction	4 (1)	4 (2)	1
Takeout food restriction	3 (1)	4 (1)	0.89
Total score (out of 25)	18 (6)	19 (6)	0.51

*Data is presented as median (interquartile range). Values are rounded to nearest whole number. P values from the Mann Whitney U test, *=p<0.05, IQR omitted for blood pressure due to small sample size, due to missing data. Healthy eating score: Likert scale from 1 to 5: 1-Never, 2-Rarely, 3-Sometimes, 4-Often, 5-Always.*

Figure 4.4 shows participants' attitudes towards the WhatsApp messages. All participants that completed the evaluation of the messages (20%) agreed that the messages were understandable. More than half the participants agreed that the messages were relevant and meaningful (65%), while 35% neither agreed nor disagreed. Several participants reported that some of the messages were very generalised.

Half of the participants were satisfied with the number of messages they received, while the rest reported that the message number could be increased. Most participants were satisfied with the length of the messages, while two participants reported that they were a little short. All but one participant reported reading all the messages they received. However, some reported that although the messages prompted them think about lifestyle changes, it did not motivate them to make any changes.

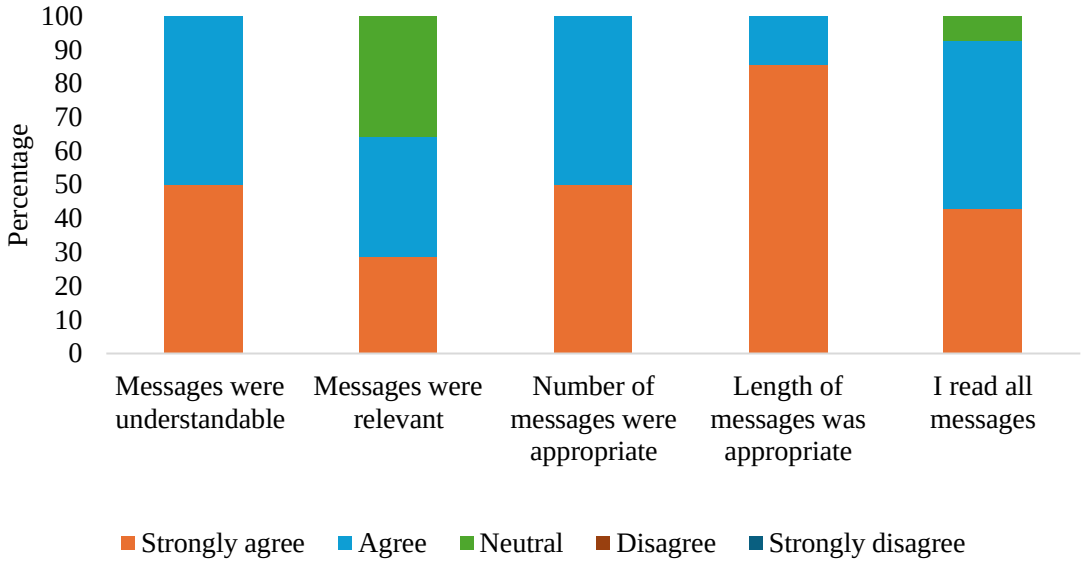

Fig. 4.4 showing participant evaluation of the WhatsApp messages.

Follow-up Participants Versus Participants Lost to Follow-up

No differences were found in the baseline health data and health goals of participants that responded to the post intervention questionnaire, compared to the non-responders (Table 4.7 and 4.8). Furthermore, i) having some messages fail to send, and ii) participants not reading some of their messages, were not associated with participant non-response (p=0.76 and p=0.46) (Appendix F).

Table 4.7 showing the baseline health data of follow-up participants versus participants lost to follow-up

Baseline health data [Median (IQR)]	**Follow-up** (n=25)	**No follow-up** (n=70)	**P value**
Physical activity (Minutes per week)	150 (1160)	120 (1141)	0.22
BMI (kg/m^2)	30 (13)	26 (18)	0.08
Sleep (hours)	6 (1)	6 (1)	0.63
Sitting time (hours)	5 (5)	6 (5)	0.73
Blood pressure (mmHg)			
Systolic	130 (14)	120 (12)	0.22
Diastolic	80 (11)	80 (10)	0.78
Healthy eating scores (out of 5)			
Fruit and vegetable intake	4 (1)	4 (1)	0.89
Wholegrain food intake	3 (2)	4 (1)	0.23
Protein intake	4 (1)	3 (1)	0.49
Fizzy drink restriction	4 (1)	4 (1)	0.20
Takeout food restriction	4 (1)	4 (1)	0.85
Total score (out of 25)	18 (6)	17 (6)	0.81

*P values from the Mann Whitney U test, *=p<0.05*

Table 4.8 showing the health goals of follow-up participants versus participants lost to follow-up

Health goal	Follow-up (n=25)	Lost to follow-up (n=70)	P value
Healthy Weight	9 (39)	43 (60)	0.28
Diet	5 (22)	5 (8)	
Fitness	4 (17)	12 (17)	
Stress	4 (17)	5 (7)	
Sleep	1 (4)	2 (3)	
Smoking	0	3 (4)	

*Data is presented as frequency (percentage). Values are rounded to nearest whole number. P values from Pearson Chi squared test, *=p<0.05. Healthy eating score: Likert scale from 1 to 5: 1-Never, 2-Rarely, 3-Sometimes, 4-Often, 5-Always*

Discussion

WhatsApp Intervention

Although the participants that completed the evaluation found the WhatsApp messages understandable and acceptable, the 12-week intervention had little to no effect on their self-reported lifestyle and health characteristics. This lack of an intervention effect of a unimodal one-way message-based intervention is similar to the results of our systematic review and meta-analysis. In our review, no effect on BMI was observed, and a marginal effect on physical activity was observed in studies using unidirectional text messages or instant messages.

However, our study results contrast with several existing WhatsApp-based mHealth studies that have shown improvements in diet and weight of participants receiving education messages and materials via WhatsApp. A study by Ng et al. reported improvements in fruit and vegetable intake in participants receiving educational materials via WhatsApp for 8 weeks ($p=0.002$).[67] Additionally, Jarrar and colleagues reported a reduction in salt intake in participants receiving educational messages via WhatsApp for 6 weeks ($p<0.001$).[66] However, these changes were also observed in the control group. Similarly, a decrease in energy intake was observed in both the WhatsApp intervention and control groups in a study by Al-Hamdan et al.[64] In the same study, a modest decrease in weight was observed in the WhatsApp intervention group ($p=0.004$), and in a group that received in-person education.[64] Although these studies showed improvements in participants receiving educational messages via WhatsApp, these changes were not exclusive to the intervention group. Therefore, more research is required to demonstrate the potential benefits of using WhatsApp to promote healthy lifestyle changes.

Another area of research with inconsistent results, is the role of theory in message development. Although our messages were based on the COM-B model, motivational interviewing and brief behaviour counselling principles, the messages were unable to elicit health changes. The impact of theory on mHealth interventions vary, with some reviews reporting increased intervention effects when using theory.[104] A study by Bhandari et al. and Farmer et al. used text messages based on the COM-B model and found statistically significant improvements in blood pressure in the intervention groups compared to the control groups.[61,91] However, Farmer found no

differences in participants' BMI.[61]

The absence of an intervention effect on lifestyle behaviours in our study may be due to several factors. Firstly, the WhatsApp messages alone may not have been effective or tailored enough to elicit lifestyle changes. One participant expressed that although the messages made him ponder over lifestyle modification, the messages were not enough to encourage him to apply the advice practically. Furthermore, several participants reported that some messages were still too generalised, despite messages being tailored to their pre-selected health goals and barriers. About 30% of participants who completed the evaluation did not agree that the messages were relevant to them. Additionally, while the messages were approved by the Department of Health employees who lead the WoW! initiative, the messages were not evaluated by a subpopulation of WoW! members. Testing the readability, salience, and validity of the messages on a group of WoW! members may have improved intervention effectiveness and relevance.

Although participants who completed the evaluation survey found the length of the WhatsApp messages acceptable, the messages were considerably longer compared to messages from other mHealth studies, which could have also reduced the effectiveness of the intervention. The bot's WhatsApp messages ranged from approximately 200 to 350 characters, while several previous text message-based mHealth studies had character limits of 160 characters or less.[108,134,137] However, in most cases, this character limit was used due to the 160 character restriction of traditional text messaging.[137] This highlights a potential benefit of using instant messaging, at is allows more flexibility in developing messaging content, while the character limitation of traditional SMS may make it difficult to construct appropriate tailored messages.[137]

Another potential reason for a lack of an intervention effect is the potential "information overload" of participants. In addition to the tailored intervention messages sent on Tuesdays and Thursdays, participants also received generic weekly WhatsApp group messages from WoW! on Mondays, Wednesdays, and Fridays. Thus, participants may have been overloaded with information, which may have reduced their ability to implement the advice received in the tailored messages. Reducing the total number of generic group messages received may have helped participants focus more on the tailored intervention messages.

Another potential factor that may have influenced the results, is that a portion of the intervention was conducted during the end of year festive period. This may have negatively influenced the engagement level with the bot and minimised the practical application of the message content, with literature showing a higher risk of weight gain during the holiday season.[181] Furthermore, many participants completed the post intervention health questionnaire several days to weeks after the intervention ended, instead of completing it immediately after the cessation of the intervention. Thus, health changes may have occurred immediately post intervention, but not been maintained once the health questionnaire was completed a second time.

Additionally, the quality of the results may have been affected by the low participant response rate post intervention. Only 26% of participants completed the follow-up survey, after several reminders were sent via the WhatsApp bot, direct message, and email. Thus, the results may not be generalisable to the entire study group. However, there were no differences in the baseline characteristics of follow-up participants compared to those lost to follow-up.

The poor follow-up rate may be due to several factors. Firstly, many participants may have stopped engaging with the bot during the intervention, either ignoring the messages or opening the notification without reading the messages. A loss of interest in the intervention may have occurred due to participants not finding the messages helpful in reaching their health goals. This may be evident from an increase in number of unread messages by some participants from week 1 onwards. Alternatively, participants may have completed the intervention, but simply failed to complete the post intervention survey, due to not having made any health changes.

Another potential reason for lack of response post intervention is survey fatigue.[182] The questionnaire may have been too long or not user friendly enough to encourage completion for a second time. Completing the survey also required mobile data, which participants might not have had or be willing to spend.

High attrition rates for mHealth studies have been previously documented, with many participants stopping the use of mHealth applications before study completion.[183] Furthermore, meta-analyses have estimated a 12% lower response rate for online surveys compared to other survey mediums[184,185], with an average response rate between 10% of 44%.[186,187]

It is easier for participants to discontinue the use of mobile health interventions, especially when communication with researchers is conducted remotely.[183] Participants could easily stop reading their messages and ignore the bot as the intervention progressed. Thus, although having a remote intervention allows for a wider reach, is convenient, and cost effective, the lack of physical and personal contact makes it challenging to build a rapport with participants and encourage intervention participation.[188]

To improve on study retention, the health questionnaire could be redesigned to be more user friendly and a shorter in length, to prevent survey fatigue and encourage a higher survey response rate.[189,190] Furthermore, the questionnaire and intervention should be piloted for a group of individuals similar to the target population before beginning the study. Incentives may also promote participant follow-up post intervention, such as mobile data reimbursement.[188] Unfortunately, no data reimbursements could be provided to the current participants due to the Western Cape Department of Health and Wellness restrictions.

Additionally, having direct, personal contact with participants either through WhatsApp message or phone call before or during the intervention, may also help build rapport with participants and improve follow-up rates.[183] One participant reported that contacting the researcher directly at the beginning of the intervention, helped make the intervention feel "more personal and not like it was just a bot with generic messages". Studies have shown that using personalised invitations, increase participation response rate by 1.5 times compared to non-personalised invitations.[191] Using a bidirectional bot may also assist with personalising the intervention experience and making it more interactive. In systematic review and meta-analysis of mHealth interventions promoting hypertension management, there was a statistically significant improvement in blood pressures for studies using interactive mHealth modalities. However, no significant improvements were found in non-interactive studies.[192] Similarly, a meta-analysis by Saffari et al. observed a greater improvement in glycaemic control in studies using two-way messaging compared to unidirectional messaging (-0.597 vs -0.314).[102]

In contrast, in a systematic review and meta-analysis on tailored text message interventions for diabetes management, one-way messaging had a larger effect size (d=0.79) compared to bidirectional messaging (d=0.27).[152] Thus, although our unidirectional pilot study was not

effective in eliciting behaviour changes, evidence does exist for the utility of one-way messaging interventions.

WhatsApp Bot Feasibility

Although WhatsApp was a convenient instant messaging platform to deliver our message-based mHealth intervention, due to its popularity and simplicity, there were many policies that restricted its use. For example, WhatsApp does not allow researchers to send health data to its users, and thus the questionnaire which included a health summary sent to participants, needed to be hosted via Amazon Web Services as an alternative. This resulted in unforeseen study costs (± $50 per month) in addition to the fee of sending the WhatsApp messages to participants via Twilio, (± 0.04 dollars per message=$70 in total). Thus, the total cost of hosting the WhatsApp bot was $354, for 12 weeks, for 69 participants. Although this cost is not high, the intervention was conducted on a small scale. If upscaling the intervention and making technical improvements, this cost will significantly increase. This may not be feasible for community-based interventions with limited resources, or in LMICs, where mobile data may be even more costly. Furthermore, this cost does not account for the service fees of the staff that developed and programmed the bot. Thus, funding for community health mHealth initiatives is essential.

WhatsApp Bot Functionality

Although the bot was tested several times before study commencement, there were some technical issues with the WhatsApp bot's functioning during the intervention.The bot stopped functioning twice during the initial recruitment and implementation of the intervention. As a result, some participants had to re-register, which resulted in a loss of participants who did not choose to register again. Secondly, several participants failed to receive their health results summary after completing the questionnaire. When this occurred, the researchers produced the health results manually for each participant based on the participants' saved data. These functionality issues may have been as a result of the bot being unable to handle the number of users adequately, as the bot was tested on a smaller sample size compared to the actual study sample.

Additionally, the WhatsApp bot's functioning was inconsistent and unstable, with some messages

failing to send to a select group of participants. The bot was functioning most effectively and consistently from week 1 to week 5, with its functioning decreasing thereafter.

Study Limitations

The study had several limitations, which may have affected the validity of the results. Firstly, the study sample size was small and disproportional and thus not adequately powered to detect meaningful differences in the intervention outcomes. There was also a potential of selection bias due to the non-randomised sampling of participants. Additionally, the participants that found the intervention acceptable may have been more likely to complete the follow-up questionnaire, as opposed to those who did not find the intervention useful.

Furthermore, the follow-up rate of participants was poor, with only 25 participants completed the post intervention health questionnaire. Thus, the results may not be representative of the entire study sample. Additionally, many participants that completed the post intervention questionnaire, only did so days to weeks post the intervention, and thus results may not be reflective of the health status of participants immediately post intervention.

The study also used self-reported health outcomes, which may result in underestimations of health data. Previous studies have shown clear underestimations of health data such as overweight and obesity levels, elevated cholesterol, hypertension, and diabetes.[193] Furthermore, the study had missing data due to some participants not completing all survey questions, and used non-parametric tests for data analysis. Non-parametric tests have less statistical power than parametric tests and increase the risk of type 2 errors.[194] While missing and self-reported data increase the risk of selection and information bias in the study, decreasing the validity of the study's results.[195]

Although the study had many limitations, there are several positive factors to highlight. Firstly, using an online wellness questionnaire with automated health results sent via the WhatsApp bot, was much more convenient for the WoW! programme. Usually, WoW! members would be required to complete a physical copy of the wellness monitor questionnaire at in-person events, and would not have access to immediate health results. Thus, the use of a bot may save WoW! time and resources that can be used for other community projects. Additionally, although no lifestyle

changes were observed, many participants had a positive attitude toward the message content and structure. Thus, although the results of our study should be taken with the limitations in mind, it is important to acknowledge the importance and potential of mHealth interventions in communities at risk of NCDs.

Conclusion

Although the WhatsApp messages were tailored to the participants' health goals and barriers, were acceptable to some participants, and were theory-based, the messages failed to elicit improvements in lifestyle behaviours and health characteristics. This may be due to several reasons including 'intervention fatigue', as the pilot study was an addition to an already existing message intervention, the intervention being conducted during the festive period or a lack of an interactive intervention component. However, due to a low follow-up rate and small sample size, the results may not accurately reflect the utility of the intervention. Future interventions may improve study uptake and follow-up rates by offering incentives and having additional interactive intervention components, such as phone calls or in-person sessions.

The functionality of the WhatsApp bot also requires further technological refining for improved functionality. This may require more expenses, which community public health intervention groups such as WoW! may not have available. Thus, funding for community health projects is vital to ensure the improvement and development of mHealth interventions targeting NCDs, to ultimately reduce the burden of NCDs in South Africa.

CHAPTER 5: Summary and Future Considerations

Summary

Non-communicable diseases place a significant burden on morbidity and mortality globally, resulting in a substantial strain on public health resources, specifically in low resourced health settings.[4] In South Africa, NCDs contribute to over half of the country's mortality.[1,2] Fortunately, the prevention and management of NCDs are achievable through lifestyle modifications, such as increased physical activity and diet changes.[2] Numerous efforts have been made to promote lifestyle changes to manage NCDs in communities, such as the Western Cape on Wellness (WoW!) programme.

WoW! is a governmental, community-based initiative that was established to make sustainable and scalable improvements in the health and wellbeing of community members across the Western Cape.[43] This is accomplished through training and deploying a group of largely volunteer wellness champions, along with numerous health promotion initiatives, such as monthly newsletters and weekly WhatsApp group messages with educational health.[42]

Using WhatsApp for health promotion can be categorised as a mobile health or mHealth intervention. Using mobile technology to promote health support enables lifestyle changes to be promoted on a large scale and has been used by many health initiatives and research studies.[94] Studies show promise in using mHealth interventions to encourage behaviour change to reduce NCD risk factors such as obesity and sedentary activity.[45,94,155] Furthermore, studies show that interventions using behaviour change theory are necessary to improve intervention effects.[58,69]

Considering the above, we conducted a pilot study on a small cohort of WoW! champions and members, which involved the use of a WhatsApp bot programmed to send messages tailored to participants pre-selected health goals and barriers. We used the COM-B model, motivational interviewing and the5 A's of Brief Behaviour Change Counselling for message development.

Prior to conducting the intervention study, formative research was performed to support the development and evaluation of our study, which included i) a systematic review and meta-analysis on mobile-messaging studies, and ii) a descriptive study on the health of participants which our

study would be piloted.

The systematic review and meta-analysis on unidirectional mobile message-based mHealth interventions showed that although many participants found the messages acceptable and helpful, there was a very small improvement in physical activity and no improvement in weight-related outcomes. Thus, one-way messages alone may not be effective enough to elicit lifestyle changes. The review also found no differences in the effect of theory versus non-theory-based messages.

The descriptive study showed that WoW! members had several risk factors for NCDs, including overweight and obesity, insufficient physical activity levels, and high blood pressure. Most participants had the goal of achieving a healthy weight, which was an appropriate health goal considering the high levels of overweight participants. The most frequently chosen barriers were difficulty in prioritising lifestyle changes and lack of time. These barriers belong to the "Motivation" and "Opportunity" categories of the COM-B model. This suggested that participants felt that they had the capability of reaching their health goals (i.e. had the necessary knowledge and resources). However, they did not have the drive to commit to lifestyle changes.

Our pilot study mirrored the results of the systematic review and meta-analysis, with no self-reported lifestyle and health outcome changes being observed in the post intervention results. This may be due to several reasons, including an underpowered sample size, and the one-way messages alone not being effective enough to elicit health changes. Furthermore, the follow-up rate post intervention was low, which may have also influenced study results.

Future Considerations

Our study

Based on our study and review results, future studies should consider using multimodal mHealth interventions, such as bidirectional messaging plus phone calls or in-person sessions. This may not only increase intervention effectiveness, but also make the intervention more personal, which may increase intervention engagement and follow-up rates.[102,183,192] Other factors that may increase participant retention in future studies include designing a more user-friendly questionnaire that has been extensively piloted prior to the start of the intervention, with possible incentives for completing the questionnaire.[182,184] Furthermore, the intervention effect may be improved, by including more messages that are designed to increase motivation and drive, as opposed to educational messages, as suggested by participants' health barrier selections. Additionally, reducing the number of generic group message that WoW! members receive weekly may reduce the message burden and improve interaction with intervention messages.

Another area of potential improvement is the WhatsApp bot's functionality. The WhatsApp bot had several technical issues that need to be improved for the intervention to be upscaled, such as some messages failing to send. Using WhatsApp as a mHealth medium also presented unexpected challenges, due to several WhatsApp restrictions imposed by the Meta technology company. Using another mobile message medium may help overcome these challenges, such as traditional text messaging/SMS. Using text messaging may also be more cost effective than using an instant messaging application.[105] However, as mentioned previously, SMS use has declined considerably and is limited in its functionality, [94] and thus using a different instant messaging application that is not restricted by Meta's policies may also be considered.

In summary, our study highlighted several improvements that can be made to future studies using mobile messaging. Furthermore, although the results from our review and research study show that mobile messaging alone may not be effective enough to elicit lifestyle modifications, using mHealth remains a promising medium for health promotion and behaviour change, especially for community-based health initiatives like WoW! However, more research is needed to further strengthen the evidence for the use of mHealth messaging intervention for the management of

NCDs. This requires more funding and collaboration on a national level.

mHealth and South Africa

Due to the COVID-19 pandemic, the use of digital technology and implementation of mobile health services have increased.[169] Almost three quarters of South Africa's population engaged in internet usage in 2021,[49] with almost 10 million people using WhatsApp.[54] Thus, mHealth has the potential to make a significant contribution to the management of the NCDs in South Africa.

Although using mHealth has the potential to be more cost effective than in-person health interventions, it does come with a price. For mHealth interventions to be upscaled and implemented effectively, stable digital infrastructure is required, such as reliable network connectivity, broadband access, and affordable access to mobile data. This may not be available to all South Africans, especially those living in poverty or in rural areas, where network coverage may be poor.[196]

Several other potential barriers to mHealth success in low-resourced settings must be considered when developing interventions, including low digital literacy, lack of public policy, language barriers and psychosocial stressors.[45,47,72] Thus, a cost to benefit analysis should be considered when developing an mHealth intervention for behaviour change in low-resourced settings. Additionally, high quality research on the effectiveness of mHealth interventions for the NCD management in LMICs is essential, to encourage and acquire funding to address the various economic and psychosocial barriers that may prevent mHealth interventions from being effective.

The South African government recently launched the South African National Strategic Plan for the Prevention and Control of Non-Communicable Diseases (2022–2027). The plan's strategies include supporting research for the prevention and control of NCDs, and increasing stakeholder collaboration.[34] The plan may benefit by allocating funds towards research on mHealth interventions for NCDs, and improving digital infrastructure for the development, implementation, and evaluation of upscaled mHealth interventions. This has the potential reduce the burden of NCDs, decrease the strain placed on health services, and ultimately improve and protect the lives of thousands of South Africans.

CHAPTER 6: References

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CHAPTER 7: Appendices

Appendix A

Table 2.1 showing Boolean search terms for each outcome.

Outcome 1	**Physical activity**
Search 1	(((((((("physical activity") OR (exercise)) OR ("exercise training")) OR ("physical exercise")) OR ("physical training")) OR (steps)) OR ("sedentary lifestyle")) OR ("sedentary time")) OR ("physical inactivity")
Search 2	(((((((((mHealth) OR (m-health)) OR ("mobile health")) OR (eHealth)) OR (SMS)) OR ("text messag*")) OR ("instant messag*")) OR (WhatsApp)) OR (WeChat)) OR (messenger)
Search 3	(((intervention) OR (programme)) OR (program)) OR (initiative)
Search 4	(((#1) AND (#2) AND (#3) NOT (systematic review) NOT (meta-analysis) NOT (reviews) NOT (protocol)) Filters: English, Adult: 19+ years, from 2010 - 2022
Outcome 2	**Weight loss**
Search 1	((((("weight loss") OR (BMI)) OR ("body mass index")) OR ("weight reduction")) OR ("body weight")
Search 2	(((((((((mHealth) OR (m-health)) OR ("mobile health")) OR (eHealth)) OR (SMS)) OR ("text messag*")) OR ("instant messag*")) OR (WhatsApp)) OR (WeChat)) OR (messenger)
Search 3	(((intervention) OR (programme)) OR (program)) OR (initiative)
Search 4	(((#1) AND (#2) AND (#3) NOT (systematic review) NOT (meta-analysis) NOT (reviews) NOT (protocol)) Filters: English, Adult: 19+ years, from 2010 - 2023

Appendix B

Table 2.3 showing message content and examples, and participant evaluation of messages.

First Author	Message content and examples	Participants evaluation of intervention
Kim et al.[123]	Motivational	N/A
Tamban et al.[127]	Education and reminders on diet, exercise, and health consequences E.g., "*Brisk walking and running are forms of exercise that diabetics can do 30 minutes everyday."*	N/A
Shaw et al.[112]	Education and advice on physical activity, diet, and body weight monitoring.	Participants expressed an overall positive response to the intervention. Most participants expressed preferring receiving at least one message per day (98%), with half reporting preferring 2 messages per day. Participants also expressed how receiving messages in the morning assisted with motivation for the day
Munoz et al.[135]	Advice and motivation on physical activity and diet E.g.: *"You are doing great! Take the stairs to class this morning"*	N/A
Ahn et al.[106]	Education and motivation on exercise, diet, and general obesity management information	N/A
Chow et al.[125]	Education, advice and motivation on diet, physical activity, general cardiovascular information E.g. *"Hi [NAME], don't forget physical activity is good for you! It reduces your risk of diabetes, heart attack, stroke, and their complications."*	Most participants found text messages useful (96%) and easy to understand (98%). Most participants read over 75% of the messages and saved 69% of the messages for further learning. 95% of participants were interested in continuing to receive the messages
Kim et al. [131]	Education, advice, reminders on diet and exercise E.g.: *"Make your meal with colorful vegetables and protein-rich foods."*	Two-thirds of participants showed satisfactory responses to the intervention, with 60% finding messages helpful, 75% finding them reliable and 65% finding them convenient. More than half participants reported interest in receiving messages in future.
Gell et al.[136]	Education, advice, motivation on physical activity	81% of participants were satisfied with the text messages received, and

	E.g., *"People who write down a goal and more likely to achieve it than those that don't. What's your exercise goal for the next 3 months?"*	56% reported that the messages motivated them to be active or very active
Martin et al.[122]	Motivation-on reaching step goals	N/A
Cotton et al.[128]	Education and advice-on sedentary behaviour E.g., "*Don't forget to get up every hour today and walk around for 5 minutes."*	N/A
Kinnafick et al.[137]	Education, advice, motivation on physical activity E.g.: "*Hi…! We understand that you may not always feel like going to your exercise class; if you are busy or the weather is bad. Perhaps try and think about the elements you enjoy, whether it's your favourite exercise or instructor?"*	N/A
Peimani et al.[132]	Education and advice on diet, exercise, blood glucose monitoring, medication adherence.	N/A
Abaza et al.[117]	Education, advice, reminders on diet, physical activity, health complications	All participants expressed satisfaction with the intervention, would continue with the program should it continue, and would recommend to others
McCoy et al.[130]	Education and advice on physical activity. E.g., *"High intensity activities require less time than low intensity activities to burn the same amount of calories. Go higher! Race walk, jog, run, swim, cycle!"*	Most participants found the text messages to be effective in increasing their physical activity. 39% of participants reported that the text messages helped them believe that they could increase their physical activity and increased their knowledge on physical activity. 33.3% of participants strongly agreed that the health text messages helped toward their weight loss goal, and 5.9% disagreed.
Fang et al.[138]	Education, advice, reminders regarding diabetes and CVD risk factors, frequency of blood glucose self-monitoring, reducing carbohydrate consumption, significance of body mass index, need for regular physical activity	N/A
Silina et al.[133]	Education and advice on physical activity and diet E.g., "*Use seasonal vegetables when they smell and taste the best" "always use stairs instead of an elevator"*	Most participants read, saved, understood, and were not disturbed by the messages. Half tried to implement the message advice. Most participants

		expressed willingness to continue to receive the text messages in the future.
Lemanu et al.[129]	Motivation-messages motivating patients to perform exercise as part of their rehabilitation prior to bariatric surgery.	N/A
Abbaspoor et al.[124]	Education on needs of pregnant women and guidelines for gestational diabetes	N/A
Boels et al.[139]	Education and advice on dietary habits, physical activity, prevention of hypoglycemia, and glucose control. E.g.: *"Fruit juices are not as healthy as many people think: they contain lots of sugar and calories. Try to consume fruit juices as infrequently as possible, eat fruit instead"*	61% of participants found the messages motivated them to live healthier; 44% found the messages applicable to them.
Owolabi et al.[60]	Education and motivation on diabetes management including sugar levels, healthy eating, exercise, stress management, foot care, smoking and alcohol and other general messages. E.g.: *"Set a goal to become more active most days of the week. Start slow by taking 10 minutes' walk, three times a day."*	Most participants found the text messages helpful (90%). Almost all participants showed readiness to continue receiving text messages. (95.9%)
Nepper et al.[126]	Education and advice on healthy eating, physical activity, diabetes self-care skills, taking medication, and increasing awareness of the risk of diabetes complications such as CVD. E.g. *"There are only three main types of nutrients in foods: carbohydrates, proteins, and fats.* *A healthy meal will include all three of these." "If you haven't exercised for a while, start with a five minute walk and increase gradually"*	Text messages were perceived as useful and beneficial by most participants (94%)
Gore et al.[118]	Education and advice on healthy eating, physical activity, weight loss. E.g., *"Save over 100 cal by making sandwich wraps for lunch using whole-wheat tortillas instead of bread."*	18% of participants who completed end survey found the text messaging both motivating and helpful in improving eating and exercise habits during the intervention.
Vinitha et al.[140]	Education and reminders on the diabetes management and complication, the benefits of healthy lifestyle, cues to initiate medication and to modify healthy lifestyle practices	N/A

	E.g., *"Brisk walking is more beneficial for burning calories than slow or relaxed walking"*	
Chan et al.[121]	Reminders and motivation regarding nutrition, exercise, and monitoring. E.g., *"Small diet changes add up. Eat breakfast every day. You will eat less during the day and it will help you reach your weight loss goals."*	Most participants did not find the intervention helpful.
Keating et al.[141]	Education and motivation-practical nutritional and physical activity in-formation, recipes, and meal planning, encouraging, supporting, and congratulatory messages. E.g.: *"Keeping track of what you eat,…every bite that goes in your mouth,…is very important for your weight loss efforts. Keeping a food diary instantly increases your awareness of what, how much, and why you are eating."*	Most participants were satisfied with the intervention and found the messages helpful (90%). Eighty-three percent were satisfied with receiving daily messages, and 68% believed that morning was the best time to receive the messages.
Huo et al.[120]	Education and advice on glucose monitoring, blood pressure control, medication adherence, physical activity, and lifestyle. E.g. "*Regular exercise is important for managing diabetes, physical activities such as aerobic exercise and strength training can help you to make your body use insulin better and reduce the risk for heart disease and osteoporosis."*	Most participants found the messages easy to understand (97%) and useful (94%) Over 80% of participants reported reading >75% of the messages during the study period, and 75% reported saving messages for further learning. About 94% of participants were willing to continue receiving the text messages
Nanditha et al.[59]	Education and advice on healthy diet and the benefits of enhanced physical activity.	Median acceptability score for the intervention was 3 out of 6 for participants in India. Fewer than 5% of the participants reported that receiving the messages was a disturbance. In the UK, the acceptability of SMS was 82%.
Bolmsjö et al.[142]	Education and advice on physical activity, diet, tobacco use and cardiovascular health. E.g.*: "Hi [NAME]. Regular physical activity improves both blood pressure and blood lipids. In addition, inflammation in the vessels may*	38% of participants reported that the intervention improved their physical activity and 24% reported that it helped them improve their diet. 93% of participants read all messages.

	decrease, which contributes to the reduced risk of cardiovascular disease."	
Holmes et al.[119]	Education and advice on energy intake and physical activity in pregnancy. E.g., "*Make half your plate fruits and vegetables. Choose a variety, like spinach, carrots, tomatoes, beans, and peas."*	N/A
Sadanshiv et al.[134]	Education on diet and exercise. E.g.: *"Have three meals and at-least one or two snacks each day, and don't skip breakfast"*	Most participants read text messages regularly and found the messages useful in improving their knowledge of diabetes and lifestyle changes in diabetes. 80% acted on the messages and followed the lifestyle interventions.
Ritchie et al.[143]	Motivation-promoting lifestyle change and weight loss.	N/A
Farmer et al.[61]	Education, advice, and motivation messages to encourage medication adherence (70% of the messages), and information to advise about healthy lifestyle and enhancing well-being (30% of messages)	Most participants found the intervention acceptable and useful for diabetes management. However, participants ability to act on the advice was limited.
Waller et al.[93]	Education and advice on nutrition (35%); physical activity and sedentary behaviour (35%); diabetes care and engagement in the diabetes Annual Cycle of Care (20%); and weight management (10%). E.g.: *"Eat 5 serves of vegetable per day for the best health. Try snacking on carrot, cucumber, capsicum or celery sticks with hummus"*	Most participants found the intervention acceptable and useful.
Saldivar et al.[113]	Education, advice, reminders on appointment times, health and wellness advice, and educational information related to diabetes care and disease management.	N/A
Bootwong et al. [144]	Education, advice, motivation on physical activity E.g., *"While going to work, increase physical activity with brisk walking or cycling."*	N/A
Singleton et al.[104]	Education on physical activity and healthy diet, social and emotional wellbeing, medication adherence and side effects management and general breast cancer information.	Most participants (89%) read 75% or more of the messages and reported that the messages were understandable (100%), useful (90%) and helped them change their lifestyle (67%).

Franco et al.[146]	Food based recommendations for diet	Most participants found the messages understandable (88%), with 52% in follow-up agreeing that the application helped them make dietary changes.
Campos et al.[147]	Educational information on diabetes and its complications, dietary guidance, tips on physical activity	Most participants found the messages understandable and acceptable.
Kellner et al.[149]	Prompts to interrupt sitting time, and suggestions on isotemporal substitutions	Most participants agreed that message length, content and frequency were acceptable and feasible.
Kellner et al.[148]	Prompts to interrupt sitting time, and suggestions on isotemporal substitutions	N/A
Golbus et al.[150]	Not specified	N/A
Acevedo et al.[108]	Educational and motivational messages on cardiovascular health E.g., "Work out TODAY: Take a briskwalk for 20 min every day this week. Advice from the Foundation of the Chilean Society of Cardiology"	N/A
Huang et al.[151]	Motivational and educational messages on Physical activity. E.g., "Sports makes life better. Exercising 30 minutes a day three times a week makes you fit and beautiful."	N/A

Appendix C:

Ethics approval letter

UNIVERSITY OF CAPE TOWN
Faculty of Health Sciences
Human Research Ethics Committee

Room 45 E-52-E-Floor- Old Main Building
Groote Schuur Hospital
Observatory 7925
Telephone [021] 406 6492
Email: hrec-submissions@uct.ac.za
Website: www.health.uct.ac.za/home/human-research-ethics

17 January 2023

HREC REF: 799/2022

Prof E Lambert
Division of Physiological Sciences (HPAL)
Human Biology-
Email: Vicki.lambert@uct.ac.za
Student: EMRANI001@myuct.ac.za

Dear Prof Lambert

PROJECT TITLE: WHATSAPP TAILORED MHEALTH INTERVENTION TO IMPROVE HEALTH RISKS AND BEHAVIOURS: A PILOT STUDY FOR THE WESTERN CAPE ON WELLNESS (WOW!) PROGRAMME-(MSC CANDIDATE-MS AMINAH EMERAN)

Thank you for submitting your study to the Faculty of Health Sciences Human Research Ethics Committee (HREC) for review.

It is a pleasure to inform you that the HREC has **formally approved** the above-mentioned study.

Approval is granted for one year until the 30 January 2024.

Please submit a progress form, using the standardised Annual Report Form (FHS016) if the study continues beyond the approval period. Please submit a Standard Closure form if the study is completed within the approval period.
(Forms can be found on our website: www.health.uct.ac.za/fhs/research/humanethics/forms)

The HREC acknowledge that the student: Ms Aminah Emeran will also be involved in this study.

Please quote the HREC REF 799/2022 in all your correspondence.

Please note that the ongoing ethical conduct of the study remains the responsibility of the principal investigator.

Please note that for all studies approved by the HREC, the principal investigator **must** obtain appropriate institutional approval, where necessary, before the research may occur.

Yours sincerely

PROFESSOR M BLOCKMAN
CHAIRPERSON, FACULTY OF HEALTH SCIENCES HUMAN RESEARCH ETHICS COMMITTEE

Appendix D

WoW! wellness monitor questions

1. **Tell me about yourself. What is your name?**

2. **How old are you?** Please type the number only

3. **Which of these terms below best describes you?**
   1) Male
   2) Female
   3) Other
   4) Prefer not to say

4. **What is your cell number?**

5. **What is your email?** Type N/A if you do not have an email.

6. **What suburb do you live?**

7. **What WoW! Group do you belong to?**

8. **On a scale of 1 to 5, how good is your overall quality of life (QOL)?** Please type in the corresponding number.

   1) The worst it can be
   2) Quite bad
   3) Neither bad nor good.
   4) Quite good
   5) The best it can be

9 **Please choose the number that best represents your smoking habits.**

1.Never smoked/nor used tobacco products.
2.Ex-smoker (less than 1 year).
3.Ex-smoker (more than 1 year).
4.Currentsmoker:
5.Current e-cigarette smoker.

10. **How many cigarettes do you smoke per day?** Please type the number only (Will appear only if answer is 4)

11. **How many drinks per day do you drink during the week?** Please type the number only
    1) I do not drink alcohol
    2) Less than 14 drinks per week
    3) More than 14 drinks per week

12. **Please choose the number that best represents in a usual week, on how many days doeither moderate (like brisk walking) or vigorous (like running or sports) physical activity?**

    1) None
    2)1 day
    3)2 days
    4)3 days
    5)4 days
    6)5 days
    7)6 days
    8)7 days

13. **When you do physical activity, how many minutes at a time, are you usually active?** Please type the number only

14. **On a usual weekday, how many hours do you spend sitting?** Please type the number only.

15. **On a usual weeknight, how many hours do you spend sleeping?** Please type number only

16. **On a usual weekend night, how many hours do you spend sleeping**? Please type number only

17. **How often do youeat at least 5 servings of vegetables and/or fruit every day?**

    Please type the number thatmatches the correct statement.

    1. Never or rarely

    2.Less than half the time

    3. Sometimes

4. Often

5. Always

18. **Are the bread and cereals that you eat mostly wholegrain?** Please type the number that matches the correct statement.
    1. Never or rarely
    2. Less than half the time
    3. Sometimes
    4. Often
    5. Always

19. **Do you eat at least a small serving of lean meat, chicken, fish, eggs, nuts, or legumes daily (such as lentils, beans)?** Please type the number that matches the correct statement.
    1. Never or rarely
    2. Less than half the time
    3. Sometimes
    4. Often
    5. Always

20. **Do you limit sugary drinks (such as fizzy drinks and fruit juices)?** Please type the number that matches the correct statement.
    1. Never or rarely
    2. Less than half the time
    3. Sometimes
    4. Often
    5. Always

21. **Do you limit your intake of takeaways and highly processed foods and salty foods to not more than one time per week?** Please type the number that matches the correct statement.
    1. Never or rarely
    2. Less than half the time
    3. Sometimes
    4. Often
    5. Always

22. **What is your average blood pressure?** Please type the top number, space, and the bottom number. Example: 120 80. If you do not know, please type "N/A"

23. **What is your height (in centimetres)?** Please type the number only, up to 1 decimal place. Type N/A if you do not know

24. **What is your weight (in kilograms)?** Please type the number only. up to 1 decimal place. Type N/A if you do not know

25. **Have you ever been diagnosed with diabetes?** Type yes or no

26. **Have you ever been diagnosed with high blood pressure?** Type yes or no

27. **Please choose one of the 6 health goals you want to achieve by typing in the corresponding number.**

    1. Achieve or maintain a healthy weight
    2. Eat a healthy diet
    3. Sit less and move more/increase fitness
    4. Improve my sleeping habits
    5. Manage my stress
    6. Stop or reduce smoking

28. **Great! Now please pick 2 of the following 6 health barriers that prevent you from achieving your selected health goal**. Please type the 2 numbers next to each other. E.g., 23

    1. Lack of knowledge about what to do and how to do it
    2. Not enough time
    3. Lack of support from family, friends, coworkers
    4. Lack of resources (e.g., Access to funds, transport, facilities)
    5. Lack in confidence with my ability to achieve my goal
    6. Difficulty with prioritizing lifestyle change.

Thank you so much for your participation! You have completed the WoW healthquestionnaire. We will share your results with you shortly.

Appendix E

Table showing examples of WhatsApp messages tailored to different goals and barriers

Goal	Barrier	Week 1	Week 2	Week 3	Week 4
Increase fitness, sit less, move more	Lack of knowledge about what to do and how to do it.	It may seem overwhelming to increase your fitness and become more active, but making the decision to start is the biggest hurdle to overcome. Well done! It doesn't have to be so complicated. Remember every extra step you take counts toward improving your fitness and well being!	We know 'getting fit' might sound quite frightening or difficult. But the good news is that it can be as easy as moving more by, for example, choosing to climb the stairs, walking around the block, doing some simple exercises or even gardening at home. Becoming more physically active can be considered a journey. So, you can start slowly and gradually. adding more activity to your day. Find out what works best for you!	Did you know that a healthy goal is to accumulate 30 minutes of moderate exercise on most days of the week? But, this does not have to take place all at once. Ten minutes here and 5 minutes there can all add up to 30 minutes.	Do you know that any exercise that gets your heart rate up and causes you to sweat (even lightly) - is in fact giving your heart a good workout? Whether this is walking, gardening, dancing, climbing stairs or carrying your groceries - they can all improve your fitness. It's as simple as that.

Eat a healthy diet	Not enough time.	We understand that life is very busy, and it may seem time consuming to prepare healthier meals. Luckily, we are here to help. Did you know that there are many healthy meal options that require minimal time and effort? Take breakfast for example. Have you tried having instant oats with honey, instead of sugary cereals? Or perhaps brown bread with peanut butter in place of white bread?	We understand that eating junk foods appear much more convenient than having a home-cooked meal. Luckily, there are many home-cooked meal options that will take only a little of your time, and give you a lot more nutrients and energy than fast foods. Have you tried having cooked chicken or fish with rice and veggies of your choice? This can be made in under 30 minutes and can be delicious after adding different herbs and spices.	It may seem time consuming to prepare healthier meals. Something that may help is 'meal prepping'. This involves planning and preparing meals ahead of time. If your week is very busy, perhaps you can set time aside during the weekend to write down a few meals that you want to make for the upcoming week, and prepare some of the ingredients needed for the planned meals. For example, peeling and cutting your veggies and storing in containers in your fridge.	Meal prepping can be used for all sorts of meals. Breakfast, lunch, supper, and snacks! Have you tried making a batch of cooked oats during the weekend, and storing in your fridge? This way, when the next morning comes, you can simply heat the oats in the microwave, and add some honey or fruit, and you have a delicious and nutritional breakfast.
Manage my weight; achieve a healthy weight	Lack of support from family, friends, co-workers	We can imagine how difficult it must be to be going through this weight loss journey alone. Have you tried speaking to your friends and family about how you are feeling and your need for their support?	Surrounding yourself with positive influences can really help one stay on track. Are the people that you are surrounded by stopping you from making the healthy changes required to lose weight? Perhaps spending less time with these people will be helpful? Can you think of people that you can spend time with that will be	Have you considered sitting down with family members or friends that you feel safe with, and explaining to them why you want to make health changes to improve your weight? Once they understand how important this journey is for you and why you are doing it, they may be more supportive.	Can you think of someone who can also benefit from losing weight? Perhaps talking to them about the benefits of losing weight (or the harms of being overweight) may motivate them to make some changes with you?

			positive influences in your weight loss journey?		
Manage my weight; achieve a healthy weight	Lack of confidence in my ability to achieve the goal.	Losing or maintaining a healthy weight takes discipline and motivation and may feel difficult in the beginning. That's why it is important to start small, and make realistic attainable goals for yourself to slowly build up confidence in yourself. Can you think of a weekly goal to start your weight loss journey? For example, exercising for 30 minutes, 3 times a week, or eating 3 servings of fruit and vegetables a day?	Exercise and healthy eating are the two important factors that help you lose weight. Perhaps starting with what appeals more to you will help you build more confidence in achieving your goals? What do you feel most confident in changing? Your exercise habits or your diet?	Being able to tick off small goals that you have achieved in your week can be very rewarding, and can boost one's motivation to keep going. Have you tried writing down your weekly exercise or diet goals on a page, and ticking them off once you have achieved them?	One way to increase your confidence in your ability to achieve your goal is by setting 'SMART' Goals. S=Specific goals (well defined, and clear); M=Measurable goals (put concrete numbers in your goals to know if you're on track); A=Achievable goals (within your reach); R for Realistic (you should be willing and able to work towards it) and T=Timely (give yourself enough time to achieve the goal).

Manage my stress	Difficulty with prioritising lifestyle change.	Life can be very busy, which may make it difficult to prioritise your goal of managing your stress better. Perhaps one way of helping to prioritise stress management, is to consider the impact of stress on your physical and emotional wellbeing. Once you have established how stress is impacting on a number of aspects of your health- managing your stress might move to the top of your to do list!	Some people believe that they will not be able to continue being there for others if they are spending too much time on themselves. But if this time is spent looking after a vital aspect of your health - such as managing your stress - you are in fact doing everyone a favour. Unless you take care of yourself, you won't be able to be there for others.	As time passes and effective stress management becomes a habit and part of your routine, you won't have to keep prioritising it - or worrying about it. Perhaps this is what you need to aim for.	In all likelihood, you are juggling competing demands related to work, family and other social commitments! The thought of trying to better manage your stress when there is so much else on the go may seem like a very daunting task! To help you get started - how about identifying a few key changes you can implement.
Improve my sleeping habits	Lack of knowledge about what to do and how to do it.	With everyone having unique sleep requirements - the good news is that you are your own best teacher in terms of how much sleep you need and how to get it. Good advice can certainly help - but so can your own experimentation with what works.	Research shows that adults require 6-8 hours pf sleep nightly. Do you keep track of how much sleep you get per night on average? Why not keep a sleep diary in which you record how much sleep you get; the quality of your sleep and whether you felt rested when you woke up.	There are a number of factors that can affect the quality of our sleep. Consider keeping notes in your sleep diary of things that might have affected your sleep such as noise, excess light, taking in too much fluid, drinking alcohol, too much caffeine, poor eating habits, stress or worry; your partner snoring or children interrupting your sleep. Make a note of the factors that you can control and how	Having identified factors that influence or interrupt your sleep - why not make a list in your diary of those that you can control. Brainstorm ways you can tackle each factor. Eliminate these disruptive factors as best as you can and continue to keep track of your nightly sleeping patterns.

				you can adjust them.	
Stop or reduce smoking	Lack of resources (e.g. funds, facilities, access to transport).	You may believe that in order to stop smoking you will need access to expensive medications or treatments. This is not necessarily the case. In fact, reducing your smoking could actually save you loads of money, as we all know cigarettes are quite expensive!	The first week can be tough but remember that this is temporary. Dig your heels in and go the distance. It's worth it in the long run. Look for support wherever you can find it, join the many online and freely available resources, use your social media, family and friend, or faith-based networks to give and receive support.	Have you ever sat down and calculated how much money you will save if you stopped smoking? Perhaps you can take the price of a cigarette, and multiply it by the number of cigarettes that you smoke every day? Then multiply by 7 to work out the expense per week, and then by 4 for the expense per month? It might surprise you to see how much money you spend on cigarettes per month.	Some treatments that people use to stop smoking include nicotine patches or gum. You might think of these things as extra expenses. However, if you account for the money you will save from buying less cigarettes, perhaps you will end up saving money!

Appendix F

Table 4.9 showing the number of follow-up and lost to follow-up participants, versus the number of participants that received all messages and failed to receive some messages

	Follow-up (n=16)	Lost to follow-up (n=53)	P value
One or more messages failed to send	10 (63)	30 (57)	0.09
All messages sent	6 (38)	23 (43)	

*Data is presented as frequency (percentage). Values are rounded to nearest whole number. P values from Pearson Chi squared test, *=p<0.05*

Table 4.10 showing the number of follow-up and non-follow-up participants, versus the number of participants that read all messages and had one or more unread messages

	Follow-up (n=16)	Lost to follow-up (n=53)	P value
One or more messages unread	5 (27)	20 (38)	0.46
All messages read	11 (73)	33 (62)	

*Data is presented as frequency (percentage). Values are rounded to nearest whole number. P values from Pearson Chi squared test, *=p<0.05*