Evaluation of Web-Based Digital Intervention to improve health outcomes of older adults: A secondary data analysis.

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Objective: The present sought to explore the efficacy and acceptability of a personalised mHealth application designed for older adults in terms of how it affected their well-being, mental and physical health, and relationship with food.

Methods: This study is a secondary data analysis of the outcomes of real-world Holly Health users who signed up for the Holly Health program between August 2022 to January 2023.

Results: Results showed that post-intervention, self-reported ratings of self-confidence, energy, mindfulness, health mindset, and short-and-long-term mindset all improved. Furthermore, the personalised mHealth application showed a good level of acceptability amongst the participants.

Conclusions: These results demonstrate that engaging with a digital health intervention can help improve several aspects of physical and mental health and adds to existing evidence highlighting the need for effective and accessible interventions to promote healthy ageing. Clinical Trial: The current analysis was approved by the London South Bank University Research Ethics Committee (Ref: ETH2223-0097) and was pre-registered on Open Science Framework (https://osf.io/rbk36).

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Original Manuscript

Original Paper

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Keywords: mHealth strategies; mHealth; Digital health; healthy ageing

Introduction

The global population is ageing at a rapid pace, with the World Health Organisation (WHO) predicting a doubling in the number of people aged over 60 years old between 2015 and 2050, to an estimated 2.1 billion (World Health Organization, 2022). This is in part due to increases in life expectancy, especially in high-income countries (Beard et al., 2016). However, research suggests that this increased life expectancy is not resulting in people having more years where they are in ‘good health’(Beard et al., 2016). Instead, as we age, we tend to experience a decline in mobility and mental health, along with an increase in multiple co-existing health conditions such as cardiovascular

diseases (CVD) and other non-communicable diseases (NCDs) (Beard et al., 2016; Diehr et al., 2013; World Health Organization, 2017). This not only has implications for the well-being of an increasingly large subset of the population but also for the health and social care systems caring for them. Consequently, the health of ageing populations is amongst the top challenges facing global health systems currently.

Despite research suggesting that the average adult's physical and mental health deteriorates with ageing, significant variation exists, with many people reporting good functioning and health well into older age (World Health Organization, 2022). The concept of 'healthy ageing' has been developed to reflect this. 'Healthy ageing' refers to the ongoing development and maintenance of functional capabilities that promote well-being in older age (Beard et al., 2016) and encompasses the modifiable factors associated with ageing and physical and mental well-being. Numerous factors have been associated with variations in healthy ageing, including income; environmental factors; and health and lifestyle behaviours (Beard et al., 2016; Potempa et al., 2010). Health and lifestyle behaviours (e.g., diet or physical activity) can impact healthy ageing through two main routes: first, by reducing the incidence of chronic NCDs; and secondly, by directly improving physical and mental health, and overall quality of life. Systematic reviews and meta-analyses have shown that positive health behaviours including performing physical activity (Lacombe et al., 2019), eating healthily (Grosso et al., 2017; Pant et al., 2023), not smoking (Pant et al., 2023), or having a moderate alcohol intake (Pant et al., 2023) can reduce the incidence of NCDs such as CVD, cancer, and diabetes when performed throughout the lifespan. Additionally, they can directly impact wellbeing in older age, with studies suggesting that increased physical activity (Cunningham et al., 2020), dietary improvements (Ghosh et al., 2020), and sleep hygiene (Gothe et al., 2020) (i.e., habits that promote good sleep) have the potential to influence physical and mental health and overall wellbeing amongst older adults. Given these benefits, and the fact that it can help to target NCDs which are responsible for a large portion of morbidity, mortality, and cost in older age (World Health Organization, 2015), more research is needed to see how to promote positive health behaviours in an ageing population.

Despite the evidence that performing positive health behaviours is vital for healthy ageing, research has demonstrated that many older adults do not perform these behaviours. For example, the WHO recommends that adults over the age of 65 years complete at least 150 minutes of moderate-intensity exercise, or 75 minutes of vigorous-intensity exercise per week, but if this is not possible, they should be as physically active as they can (Taylor, 2014; World Health Organization, 2010). However, in the UK it is estimated that only around 65% of people between 65 and 74 years old can be classed as 'active' under these recommendations, with this declining further over the age of 75

(NHS Digital, 2019). Similarly, average diet quality amongst older adults has been found to be poor both in the EU (Irz et al., 2014) and in the US, where a recent study found more than 50% of older adults had low dietary quality (Long et al., 2022). Furthermore, sleep quality has been shown to decline with age (Li et al., 2018), with an estimated 40% to 70% of older adults having persistent sleep issues (Newsom & DeBanto, 2020). All of these factors are potentially modifiable influences that may hamper healthy ageing. Consequently, addressing health behaviours in older adults and adults approaching older age is a potential strategy to help contribute to healthy ageing and improve wellbeing.

Due to the rise in mobile phone and internet usage across the past few decades, mobile health (mHealth) approaches are increasingly being used to deliver interventions (Dugas et al., 2020). mHealth is defined as healthcare interventions delivered using mobile or wireless technology (Dugas et al., 2020) and includes text messaging, wearable devices, and app-based interventions. mHealth interventions have been found to be effective in prompting changes across a range of health behaviours and in populations with a range of NCDs (Fedele et al., 2017; Kitsiou et al., 2017; Sousa et al., 2020). Whilst a lot of research has investigated mHealth interventions for younger age groups, there is evidence that mHealth interventions may also be a useful tool in older age groups. For example, recent statistics have suggested that mobile phone ownership amongst this group is growing, with now an estimated 78% of adults over the age of 55 in the UK owning a smartphone (Baker, 2023). Additionally, a scoping review of mHealth interventions for adults aged over 60 years found reported increases in physical activity, chronic disease management and medication adherence across studies, suggesting this intervention type can be effective for older age groups (Zaslavsky et al., 2020). As such, mHealth interventions may offer a potentially valuable tool to enhance health behaviours amongst older adults.

Whilst mHealth interventions for older adults have been shown to have positive effects, many studies highlight that effect sizes for the observed behaviour change tend to be small (Arnautovska et al., 2018). As such, it is important to consider how to maximise effectiveness when designing interventions for this age group. One way to do this is through personalisation, which refers to the intervention being dictated by the choices of the individual on how their care is delivered (Johnson et al., 2023; Lustria et al., 2013).

Several reviews have shown that personalised mHealth interventions are largely acceptable (Borghouts et al., 2021; Patel et al., 2020; Perski & Short, 2021), and more effective for prompting behaviour change (e.g., increasing physical activity, reducing smoking etc.) when compared to non-personalised interventions (Laranjo, DIng, et al., 2021; Lustria et al., 2013; Tong et al., 2021). These

findings suggest that considering personalisation when designing a mHealth intervention may be a useful approach when attempting to improve health behaviours, however, more research is required to explore this. The current study aims to do this through the evaluation of a personalised mHealth application for older adults called the Holly Health app. The Holly Health app targets four main health behaviours and related constructs for older people (sleep, mental health, exercise, and relationship with food) through various personalised features and content. The app incorporates elements of mindfulness therapy, cognitive behavioural therapy (CBT), and acceptable and commitment therapy (ACT). Features of the app include personalised goal setting; progress tracking (otherwise termed 'self-monitoring'); habit recommendations; personalised nudges and reminders; and video content and exercises, all aimed at improving attitudes around health behaviour and promoting changes in behaviours. The app both tailors these features for each user, and continuously updates content based on their usage of the app. This study aims to explore the efficacy and acceptability of the Holly Health app for use in older adults, in terms of changes in personal well-being; changes in mental and physical health; changes in relationship with food; and thoughts and opinions about the app.

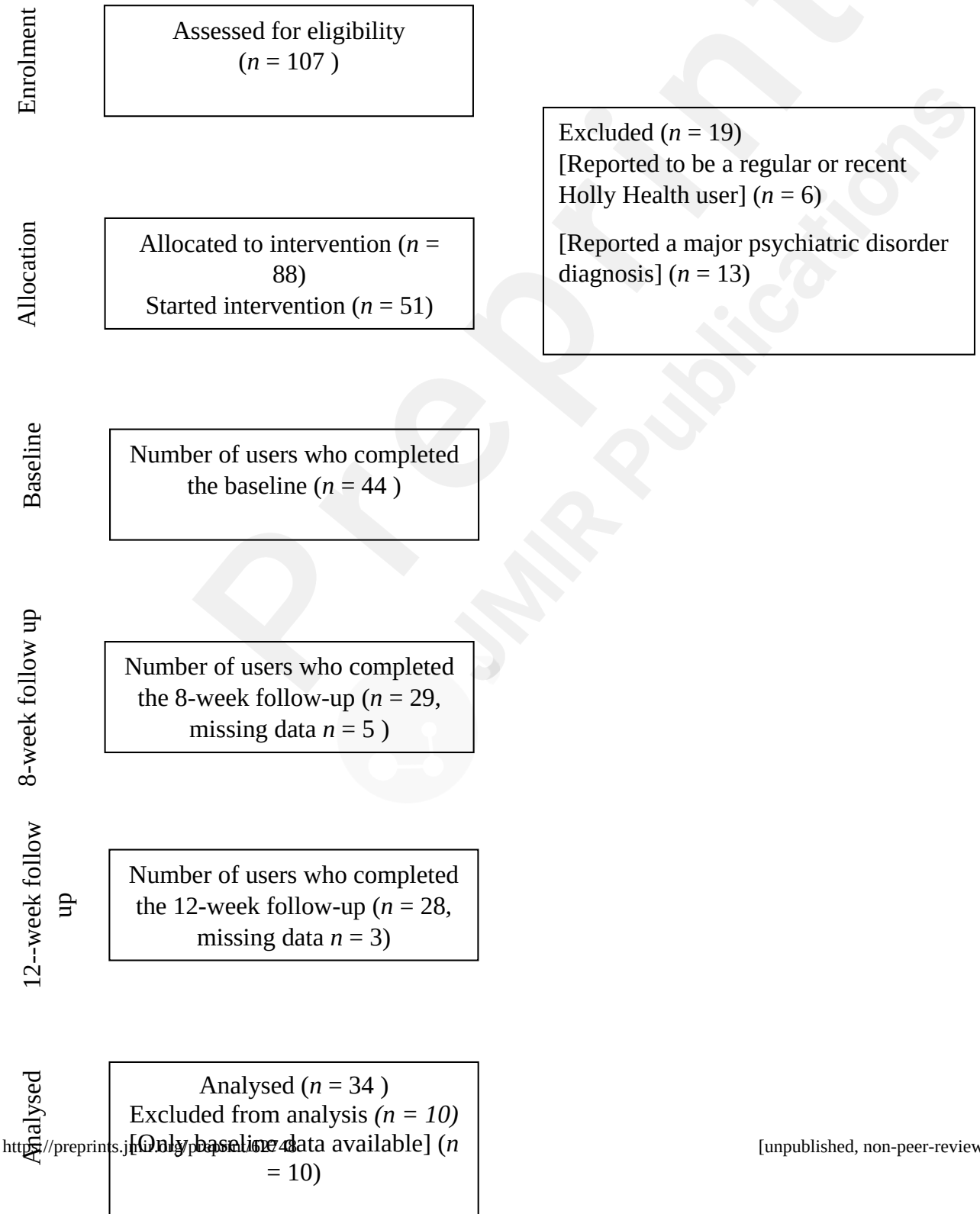
Methods

Recruitment

Participant flow is shown in Figure 1. Individuals were recruited by Holly Health via newsletters, in-person outreach and poster sharing at local community centres, services and charities in Lewisham and Southwark, and social media adverts. Interested users were directed to a landing page and were prompted to complete a screening questionnaire. Users were deemed eligible if they were: 50 years old or older, fluent in English, had an email address, had access to a phone or tablet with internet access, and were motivated to either increase their mobility or manage their weight sustainably. Users were excluded if they reported having: a current major psychiatric disorder needing treatment in its own right, any major physical impairments, and any visual impairments which cannot be corrected with contact lenses or glasses. Eligible users were then sent an information sheet which contained an explicit mention of the role of LSBU as an external evaluator of the project and were prompted to complete an onboarding questionnaire. This questionnaire inquired about their current health and well-being habits, intended to help tailor the program for individual users. Upon completing this questionnaire, users must agree to the terms of the service and privacy policy, which included language indicating that their data would be used for research

purposes.

Figure 1. Study flow chart



Intervention

The Holly Health is a smartphone application which offers daily health and wellbeing coaching. It aims to help users prioritise, achieve, and sustain daily health habits across several domains, including exercise, sleep, mental health, and their relationship with food. It includes features such as personalised habit recommendations, a chatbot for reflection exercises and tailored coaching, motivational nudges and reminders, and tailored content in the form of videos articles and exercises. The application and its recommendations (including habits reminders, articles, challenges, and reflective exercises) are personalised to each person and the personalisation adapts throughout the time user engage with the service. Users were asked to use the application 3-4 times a week and were prompted to complete measures online at baseline, 8, and 12 weeks.

Outcome Measures

The schedule of measures can be found in Table 1.

Office of National Statistics personal wellbeing questions (ONS-4)

The ONS-4 measures subjective well-being. The measure consists of 4 scales developed to assess life satisfaction, worthwhileness, happiness, and anxiety. Each item is rated from 0 (not at all) to 10 (completely). *Cronbach's alpha* was 0.83 in this study.

Food Choice Questionnaire (FCQ)

The FCQ is comprised of 36 items which are designed to assess the health and non-health motives influencing an individual’s food choices. This measure consists of 9 scales developed to assess Health, Mood, Convenience, Sensory Appeal, Natural Content, Price, Weight Control, Familiarity, and Ethical Concerns as factors relating to food choice.

Health survey

The Health Survey is a tailor-made questionnaire developed by Holly Health and is comprised of 8 scales aimed at measuring different aspects of an individual’s health: physical activity, self-confidence, relationship with food, energy levels, mindfulness, short vs long-term mindset, health mindset, and self-kindness. This measure is not designed to provide an aggregate score, but rather to illustrate different aspects of an individual’s health. This questionnaire is

presented in Appendix A.

Retrospective usage and UX questions

At weeks 8 and 12, users were asked 4 questions regarding how often they used the Holly Health application and how useful they found the application. These were summarised descriptively. At week 12, users were asked 2 questions about the acceptability of the application. These questions are presented in Appendix B.

Table 1. Schedule of Measures.

	Study Stage		
Outcome Measure	Baseline	Week 8	Week 12
ONS-4	X	X	X
FCQ	X	X	-
Health survey	X	X	X
Retrospective questions	X	X	X

Statistical Analysis

To evaluate the efficacy of the application on improving people's attitude towards their health and food choices, changes in scores on the health survey and food choice questionnaire compared to baseline were assessed using repeated measure t-tests for all continuous data, and Wilcoxon Signed Rank test of differences for all categorical data. Subscales 1 (physical activity), 2 (self-confidence), 4 (energy), 5 (mindfulness), 7 (health mindset), and 8 (self-kindness) on the health survey, and the food choice questionnaire were coded as continuous data. Subscales 3 (Relationship with food) and 6 (short-and-long-term mindset) on the health survey were coded as categorical data. To assess if user's attitudes towards their health and food choices predicted life satisfaction, logistical regressions on the ONS-4 were conducted at 8 and 12 weeks, predicted by scores on the health survey and food choice questionnaire (collected at baseline). A sensitivity analysis was undertaken on all continuous data by analysing the number of times the app was used over the course of the trial as a moderator variable. This was achieved using the Haye Process macro (Hayes, 2022). The sensitivity analysis was not conducted on categorical data. Finally, participant's responses to the retrospective questions (whether participants report using the app at least once a week or not, and if they report that they have started to do any of the habits automatically or not) will be used to assess the acceptability of the application.

Results

Baseline demographics

The majority of users were female, aged between 50-59 years old, Caucasian, and reported having hypertension. Table 2 presents the samples demographics.

Table 2. User characteristics at baseline

Variable	*N* (%)
Gender	
Female	28 (77.7)
Male	8 (22.3)
Age range (years)	
50-59	18 (50)
60-65	6 (16.7)
66-70	6 (16.7)
70-75	6 (16.7)
Ethnicity	
Caucasian	25 (69.4)
Asian British	3 (8.3)
Black/African/Caribbean/Black British	5 (13.9)
Mixed/Multiple ethnic groups	1 (2.8)
Other	1 (2.8)
Not disclosed	1 (2.8)
Medical condition	
Hypertension	11 (30.6)
Arthritis	10 (27.8)
Asthma	4 (11.1)
High cholesterol	11 (30.6)
Type 2 diabetes	6 (16.7)
Heart disease	1 (2.8)
Stroke	1 (2.8)
Chronic obstructive pulmonary disease (COPD)	1 (2.8)
Osteoporosis	1 (2.8)
Fibromyalgia	1 (2.8)
Cancer	1 (2.8)
Anxiety	10 (27.8)
Depression	8 (22.2)
Other	3 (8.3)
None reported	5 (13.9)

Evaluation Outcomes

Health Survey

Post hoc comparisons using paired samples t-test with Bonferroni correction indicated that

the mean score on the 'Self-confidence' sub-scale of the Health Survey at 12 weeks (*M*= 3.77, *SD*= .77) was significantly higher than at baseline (*M*=3.31, *SD*= 1.09), *MD*= -0.46, *p*=.023, showing that people rated their self-confidence more positively after 12 weeks of using the Holly Health app. Additionally, the mean score on the 'Energy' subscale of the Health Survey at 12 weeks (*M*=3.46, *SD*=1.03) was significantly higher than at baseline (*M*=2.85, *SD*=1.12), MD=-0.62, *p*<.001, demonstrating that people rated their energy levels significantly more positively after 12 weeks of using the Holly Health app. Finally, it was found that mean scores on the 'Mindfulness' subscale of the Health Survey at 8 weeks (*M*=3.39, *SD*= 1.20) were significantly higher than at baseline (*M*=3.00, *SD*= 1.06), *MD*=-.39, *p*=.046, demonstrating that people reported that they were 'running on automatic' less frequently after 8 weeks of using the Holly Health App. Table 3 presents these findings. A Wilcoxon signed rank test revealed that scores on the 'Short vs long term mindset' subscale were significantly higher at 8 weeks (*n*=29, *M*=3.14, *SD*=1.22) compared to baseline (*n*=34, *M*=2.65, *SD*=1.25, *z*= -.203, *p*= .042, and 12 weeks (*n*=31, *M*=3.13, *SD*=1.28) compared to baseline (*n*=34, *M*=2.65, *SD*=1.25), *z*= -2.45, *p*= .014, both with a moderate effect size, (*d* = 0.38, *d*= 0.44).

Table 3. Paired Samples T-tests with Bonferroni correction for Health Survey at Baseline, 8 and 12 weeks.

Health Survey Subscale	Time Points	MD	*p*	95% CI
Physical activity	Baseline x 8 weeks	-.231	.41	-.616, .154
	Baseline x 12 weeks	-.154	1	-.619, .312
	8 weeks x 12 weeks	.077	1	-.166,.320
Self-confidence	Baseline x 8 weeks	-.269	.27	-.661, .122
	Baseline x 12 weeks	-.462*	.02*	-.870, -.053
	8 weeks x 12 weeks	-.192	.61	-.569, .185
Energy	Baseline x 8 weeks	-.462	.00	-.787, -.136
	Baseline x 12	-.615**	<.001**	-.994, -.237

	weeks			
	8 weeks x 12 weeks	-.154	.77	-.493, .186
Mindfulness	Baseline x 8 weeks	-.385*	.05*	-.763, -.006
	Baseline x 12 weeks	-.423	.21	-.995, .149
	8 weeks x 12 weeks	-.038	.21	-.149, .995
Health Mindset	Baseline x 8 weeks	-.231	.68	-.709, .248
	Baseline x 12 weeks	-.308	.22	-.729, .114
	8 weeks x 12 weeks	-.077	1	-.393, .239
Self-Kindness	Baseline x 8 weeks	-.385	.29	-.955, 186
	Baseline x 12 weeks	-.154	1	-.597, .289
	8 weeks x 12 weeks	.231	.48	-.179, .641
*Note: MD= Mean Difference; * p <.05, **p<.01*				

Food choice questionnaire

Paired samples t-tests were run to compare scores on the Food Choice Questionnaire between baseline and 8 weeks. It was found that scores on the 'motivation' subscale were significantly higher at 8 weeks (M= 2.60, SD= 0.78) compared to baseline (M= 2.16, SD= 0.60) $t(26)$= -5.03, p<.001, with a large effect size (d = -.97). Table 4 presents these findings.

Table 4. Paired Samples T-tests for Food Choice Questionnaire at Baseline and 8 weeks.

Food Choice Questionnaire Subscale	MD	*t*	*p*	95% CI
Health	-0.048	-8.19	.42	-.169, .073
Motivation	-0.441**	-.503**	<.001**	-.621. -.261

Convenience	0.022	0.178	.86	-.235, .279
Sensory appeal	-0.10	-1.335	.19	-.254, .054
Natural content	0.052	0.485	.63	-.168, .272
Price	0.026	0.268	.79	-.173, .225
Weight control	-0.015	-0.125	.90	-.259, .229
Familiarity	0.004	0.027	.98	-.282, .290
Ethical concern	-0.015	-0.115	.91	-.278, .249
*Note: * p <.05, **p<.01*				

Regression analyses

Hierarchical regressions were used to investigate which factors (scores on the health survey and FCQ at baseline) predicted scores on each of the ONS-4 scales (life satisfaction, worthwhileness, happiness, and anxiety) at 8 and 12 weeks. Scores on the health survey at baseline were found to be a significant predictor of ‘life satisfaction’, ‘worthwhile’, and ‘happiness’ scores on the ONS-4 at 8 weeks, accounting for 65%, 66%, and 60% of the variance respectively. These regression models are presented in Table 5. Similarly, scores on the health survey at baseline were also revealed as a significant predictor of scores on the ONS-4 ‘worthwhile’ scale at 12 weeks, accounting for 51% of the variance. These regression models are presented in Table 5.

Regression analysis revealed that scores on the health survey and FCQ at baseline significantly predicted scores on the ONS-4 'happiness' scale at 12 weeks, accounting for 84% of the variance. Additionally, both scores on the health survey at baseline alone, and scores on the health survey and FCQ at baseline combined were predictive of scores on the ONS-4 'anxiety' sub-scale at 12 weeks, accounting for 58% and 83% of the variance, retrospectively. These regression models are presented

in Table 5.

Table 5. Hierarchical multiple regression analysis of ONS-4 scales as a function of scores on the health survey and FCQ at baseline

Predictors	Step 1 (β)	Step 2(β)
ONS4 Overall Life Satisfaction at 8 weeks		
Health Survey		
Physical activity	-.02	-.02
Self-confidence	.39	.31
Relationship with food	-.32	-.41
Energy	.68**	.74*
Mindfulness	.08	.27
Short vs Long-term mindset	.10	.16
Health Mindset	-.18	-.36
Self-Kindness	-.30	-.26
Food Choice Questionnaire		
Health		.280
Motivation		.04
Convenience		.35
Sensory appeal		.09
Natural content		.14
Price		-.09
Weight control		-.28
Familiarity		-.30
Ethical concern		-.25
R^2	.65	.83
Adjusted R^2	.49	.52
F	4.10**	2.64
p	.01**	.07
ΔR2		.19
F change		1.12
p		.43

ONS4 Overall Life Satisfaction at 12 weeks		
Health Survey		
Physical activity	-.28	-.32
Self-confidence	.42	.36
Relationship with food	-.14	-.22
Energy	.36	.34
Mindfulness	-.02	.01
Short vs Long-term mindset	.11	-.01
Health Mindset	.17	.14
Self-Kindness	-.19	.12
Food Choice Questionnaire		
Health		.45
Motivation		-.50
Convenience		.59*
Sensory appeal		.12
Natural content		.00
Price		-.36
Weight control		-.04
Familiarity		-.28
Ethical concern		-.34
R^2	.46	.78
Adjusted R^2	.24	.44
F	2.11	2.31
p	.08	.08
ΔR2		.32
F change		1.81
p		.18
ONS4 Overall Worthwhile at 8 weeks		
Health Survey		
Physical activity	.01	-.02
Self-confidence	.51*	.39
Relationship with food	-.22	-.32
Energy	.58*	.61

Mindfulness	-.01	.11
Short vs Long-term mindset	-.13	-.08
Health Mindset	.02	.03
Self-Kindness	-.10	-.10
Food Choice Questionnaire		
Health		.16
Motivation		.10
Convenience		.18
Sensory appeal		-.08
Natural content		.12
Price		.04
Weight control		-.14
Familiarity		-.05
Ethical concern		-.30
R^2	.66	.75
Adjusted R^2	51	.27
F	4.33**	1.56
p	.01**	.25
ΔR2		.09
F change		.35
p		.94
ONS4 Overall Worthwhile at 12 weeks		
Health Survey		
Physical activity	-.15	-.15
Self-confidence	.27	.26
Relationship with food	-.13	-.11
Energy	.46	.45
Mindfulness	.20	.07
Short vs Long-term mindset	.01	-.24
Health Mindset	.09	.25
Self-Kindness	-.12	.11
Food Choice Questionnaire		
Health		.24

Motivation		-.21
Convenience		.16
Sensory appeal		.08
Natural content		.25
Price		-.16
Weight control		.09
Familiarity		-.31
Ethical concern		-.40
R^2	.51	.74
Adjusted R^2	.32	.34
F	2.63*	2.84
p	.04*	.15
ΔR2		.23
F change		1.07
p		.45
ONS4 Overall Happiness at 8 weeks		
Health Survey		
Physical activity	-.07	-.13
Self-confidence	.23	.15
Relationship with food	-.22	-.37
Energy	.84*	.97*
Mindfulness	-.02	.04
Short vs Long-term mindset	-.02	.09
Health Mindset	-.19	-.15
Self-Kindness	-.15	-.11
Food Choice Questionnaire		
Health		.075
Motivation		.04
Convenience		.28
Sensory appeal		.19
Natural content		.28
Price		.19
Weight control		-.36

Familiarity		-.22
Ethical concern		-.16
R^2	.60	.76
Adjusted R^2	.42	.31
F	3.36*	1.69
p	.02*	.21
ΔR2		.16
F change		.68
p		.71
ONS4 Overall Happiness at 12 weeks		
Health Survey		
Physical activity	-.30	-.62*
Self-confidence	.39	-.01
Relationship with food	-.12	-.29
Energy	.37	.43
Mindfulness	-.02	.24
Short vs Long-term mindset	.24	.12
Health Mindset	-.20	.23
Self-Kindness		-.17
Food Choice Questionnaire		
Health		.74*
Motivation		-.26
Convenience		.44*
Sensory appeal		.28
Natural content		-.17
Price		-.18
Weight control		-.21
Familiarity		-.10
Ethical concern		-.63**
R^2	.37	.84
Adjusted R^2	.12	.58
F	1.48	3.27*
p	.23	.03*

ΔR2		.46
F change		3.42*
p		.03*
ONS4 Anxiety at 8 weeks		
Health Survey		
Physical activity	-.25	-.26
Self-confidence	-.24	-.46
Relationship with food	.20	.03
Energy	-.47	-.39
Mindfulness	-.16	-.26
Short vs Long-term mindset	.06	.15
Health Mindset	.53	.66
Self-Kindness	-.05	.20
Food Choice Questionnaire		
Health		-.18
Motivation		-.39
Convenience		.04
Sensory appeal		.68
Natural content		-.16
Price		-.03
Weight control		-.16
Familiarity		-.26
Ethical concern		.00
R^2	.37	.60
Adjusted R^2	.10	-.17
F	1.34	.78
p	.29	.69
ΔR2		.22
F change		.55
p		.81
ONS4 Anxiety at 12 weeks		
Health Survey		
Physical activity	.37	.62*

Self-confidence	.09	-.11
Relationship with food	-.32	-.36
Energy	-.05	-.05
Mindfulness	-.46	-.40
Short vs Long-term mindset	-.03	-.14
Health Mindset	.11	.01
Self-Kindness	-.15	.11
Food Choice Questionnaire		
Health		-.09
Motivation		.03
Convenience		.26
Sensory appeal		-.06
Natural content		-.20
Price		-.38
Weight control		.36
Familiarity		-.26
Ethical concern		-.34
R^2	.58	.83
Adjusted R^2	.41	.55
F	3.43*	3.05*
p	.01*	.03*
ΔR2		.25
F change		1.72
p		.20
Note: *p<.05, **p<.01		

Sensitivity analysis

A series of moderated multiple regressions were conducted to predict scores on all outcome measures at 12 weeks from baseline scores (or 8 weeks for the FCQ), with the number of times the app was used serving as a moderator variable. No interaction terms were statistically significant in the models.

Responses to the retrospective usage and UX questions

The majority of individuals used the Holly Health app at least once per week at both 8 and 12 weeks (79.41% and 88.24% retrospectively. Of those who reported using the Holly Health app at least once per week, the majority reported that they had started to do some of their habits automatically without relying on the app to remind them at both 8 and 12 weeks (70.59% and 82.35% respectively). The majority of respondents indicated that they found the Holly Health app useful at both 8 and 12 weeks (76.47% and 79.41% respectively). At 8 weeks, the majority of users (85.29%) stated that they would like their local council to provide more services like this in the future. Finally, at 12 weeks, the majority (47.06%) of users stated that they found the app to be a very appropriate tool for older adults to keep up with their healthy ageing goals and that it would be extremely likely for them to recommend the app to other people with similar health and wellbeing goals as themselves. Table 6 presents these findings.

Table 6. Responses to retrospective questions

Question	Timepoint	Yes	No	No Response
Have you been using the Holly Health app at least once a week?	Week 8	27	2	5
	Week 12	30	1	3
Have you started to do any of your habits automatically?	Week 8	24	3	7
	Week 12	28	2	4
Overall, have you found Holly Health useful?	Week 8	26	1	7
	Week 12	27	3	4
In the future, would you like to see more services like this provided by your local council?	Week 8	29	0	5

Discussion

This study presents a secondary data analysis of the ‘Holly Health’ app. There were significant positive outcomes on the health survey over the trial duration. Specifically, the sub-scales of self-confidence, energy, mindfulness, health mindset, and short-and-long-term mindset scores

were all higher post-intervention. Participants also rated ‘mood’ as significantly more important on the Food Choices Questionnaire at eight weeks compared to baseline. Moreover, these effects were not influenced by the level of engagement with the app.

Importantly, the intervention showed a good level of acceptability amongst the participants. Most participants reported using the app at least once per week at both 8- and 12-week time points. Participants also reported beginning to carry out their habits automatically at 8 and 12 weeks. Almost all respondents reported that they would like to see more similar services like this one provided by their local council. The findings suggest older adults can achieve positive health outcomes through engaging with a health platform. These findings are consistent with research indicating the potential for older adults to utilise mHealth interventions (Zaslavsky et al., 2020). A systematic review identified that digital health interventions focused specifically on physical activity have been shown to improve balance and mobility and reduce falls in older adults (Solis-Navarro et al., 2023). Meanwhile, research suggests that older adults may engage with digital coaching programs at higher rates than their younger adult counterparts(Graham et al., 2021). As such, the present findings add to an emerging body of literature that suggests that not only will older adults engage well with mHealth initiatives, but that they can experience positive health outcomes from doing so. A scoping review into digital health literacy (DHL) in older adults indicates that many factors can influence DHL amongst this population (Wang & Luan, 2022). This includes whether they already own a digital device, having more positive attitudes towards health knowledge and greater confidence in their ability to manage their health through their digital device (Wang & Luan, 2022).

In order to be eligible to take part in the study, participants were required to have access to a phone or tablet with internet access. Additionally, that they would like to see similar services rolled out by their local council suggests that amongst this sample at least, there is a clear interest in using digital devices to monitor one’s health. Moreover, our results add to the literature suggesting personalised content in particular is beneficial (Laranjo et al., 2021; Tong et al., 2021).Qualitative research on perceptions of mHealth interventions highlights that users particularly value personalised and tailored content (Peng et al., 2016). Similarly, research in the domain of weight loss indicates that tailored content is more effective than content that was either a moderate or poor fit for the user (Kreuter, 2000). Thus, Holly Health’s personalised features and content are beneficial for user experience. However, future research could look into which elements of Holly Health offer the most benefit to its users.

The health survey measures showed significant improvements post-intervention. Domains including self-confidence, energy, mindfulness, short-and-long-term mindset scores were all higher

post-intervention as compared to pre-intervention. Thus, after engaging in the intervention, participants were more likely to endorse the importance of longer-term outcomes as opposed to motivation dwindling when short-term goals do not reap immediate outcomes. Research into physical activity in older adults identified that participants were likely to set goals related to maintaining physical activity and preventing ageing decline. Thus, the authors concluded that apps that encourage goal setting are likely to give rise to stronger internal motivation which may increase the intervention's effectiveness (Lynch et al., 2023). The present findings are in line with this; whereby participants were more likely to endorse a long-term mindset after engaging with the Holly Health app. This is important for ensuring healthy behaviour change is sustained. Participants also reported higher levels of mindfulness after engaging in the Holly Health intervention. Mindfulness refers to an awareness – both of one's internal states and one's surroundings (Siegel et al., 2009). Mindfulness stress reduction interventions have been shown to improve health-related behaviours (Salmoirago-Blotcher et al., 2013) and improve quality of life and health behaviours among a sample of adults with hypertension (Sangprasert et al., 2019). As such, the significant increase in self-reported mindfulness in the present study is a positive indicator that participants will be better able to engage in healthy behaviour change after using the Holly Health app.

Participants' Heath Survey and FCQ scores at baseline significantly predicted the ONS-4 'happiness' scale at twelve weeks demonstrating the link between physical health, food choices and well-being. This is consistent with research finding positive relationships between physical exercise, physical health, and well-being amongst adults in midlife (Bae et al., 2017).As research indicates that diet quality is poor amongst older adults in the EU and America (Irz et al., 2014), the present findings suggest that engaging with a digital health intervention that can help improve physical health and nutrition and may even have positive benefits beyond physical health. Given the importance of nutrition for healthy ageing, the findings present promising initial evidence as to the potential for Holly Health to be effective in promoting healthy ageing.

There some are limitations to this study which must be noted. First, this study can be considered a pilot study (focusing on the acceptability of the app as well as efficacy) and as such, had exploratory aims and a relatively small, underpowered sample (n=34). Consequently, the conclusions that can be drawn from the study findings are limited. Additionally, the study utilised a pre/post-test design and did not contain a control group. This limits our ability to attribute the effects observed in this study to participants' use of the Holly Health app and also limits our ability to rule out regression to mean effects(Linden, 2013). As such, the potential benefits of the Holly Health app need to be explored in future randomised controlled trials which have suitable statistical power and an adequate

control group.

Additionally, the volunteer sampling method of recruitment may have resulted in a population of adults who were more interested in healthy lifestyle behaviours and more motivated to change than the general population of older adults (Walters, 2021). Similarly, the population of this study were somewhat homogenous in terms of some demographics, for example, 69.4% of people identified themselves as Caucasian, and 77% of the sample identified as female. Therefore, caution must be drawn when generalising the results of this study both within the population of older adults more generally and across different socio-demographic groups within this population.

Finally, this study utilised some study-specific measures (such as the ‘Health Survey’ and ‘retrospective questions’) which have not been pre-validated. This was chosen due to the exploratory aims of this study and the resulting need to create tailored, study-specific questions to assess desired factors and outcomes. However, this does mean that the reliability and validity of these instruments have not been explored, meaning that interpretation of data arising from these materials should be done with caution. Despite this, many of the questionnaire items contained in these materials are from validated questionnaires (for example the ONS-4), somewhat enhancing the reliability and validity of the data (Hyman et al., 2006).

The present study demonstrated that the Holly Health app is effective in improving health outcomes in a sample of older adults. It also indicated that digital health apps have a good degree of acceptability amongst an older population, with almost all of the participants reporting that they would like their local health service to provide a similar service. These findings have wider implications for healthy ageing as it suggests that not only are older adults willing to use a digital health app to self-manage their health, but that doing so is an effective method of improving self-confidence, energy, and mindfulness amongst other outcomes. Future research should seek to compare outcomes associated with using the Holly Health app with a control condition to establish whether using the app is more effective in improving health outcomes than treatment as usual. Future research should also consider using validated metrics to compare the findings to existing research looking at health ageing and digital health.

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Conflicts of Interest

None declared.

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Supplementary Files

Untitled.
URL: http://asset.jmir.pub/assets/4745db6abcf8733dd46e1a675ece5a0e.pdf

Figures

Study flow chart.