

Adherence to and engagement with an mHealth intervention for physical activity after mild stroke or transient ischaemic attack: analysis of an experimental arm in a feasibility randomised controlled trial

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Abstract

Background: Regular physical activity is a crucial and an important modifiable lifestyle factor reducing the risk of recurrent incidents after stroke or transient ischemic attack (TIA). Mobile Health (mHealth) has emerged as a promising approach for providing long-term support for physical activity. However, little is known about how individuals post-stroke or TIA adhere to and engage with mHealth interventions.

Objective: This study aimed to: (1) describe adherence to supervised sessions in an mHealth intervention targeting physical activity, (2) describe engagement with self-managed mHealth support for physical activity during and after the intervention, (3) compare characteristics of participants with high and low adherence and engagement, and (4) examine whether high adherence and engagement were associated with maintained physical activity after having completed the intervention and at a 12-month follow-up.

Methods: In this study, a secondary analysis of data from the experimental arm of a feasibility randomized controlled trial was conducted. The experimental group received a 6-month mHealth version of the i-REBOUND program, which included supervised mHealth support for physical activity and behavior change, followed by a 6-month post-intervention period with access to self-managed mHealth support. Adherence outcomes included attendance at supervised exercise and counseling sessions, while engagement outcomes measured weekly interactions with self-managed mHealth support during and after the intervention. Participants' level of physical activity (steps per day) was measured using accelerometers at baseline, and at 6- and 12 months post-baseline. Logistic regression analysis examined the associations between high adherence and engagement during the intervention and post-intervention period and maintained physical activity (i.e. >7000 steps/day) across the 12-month study period.

Results: Of the 57 participants enrolled (67% female, average age 71), 96% had mild stroke symptoms, and 51 (89%) completed the intervention. Adherence to supervised mHealth support was high (supervised exercise sessions: 79%, counseling: 98%), while engagement with self-managed mHealth support was high during the intervention (83%) but declined post-intervention (38%). A larger proportion of females (77%) demonstrated high adherence to the intervention compared to males (23%, $P = .043$). High adherence (80%) during the intervention was associated with maintained physical activity between baseline and the 6-months follow-up (odds ratio: 5.50, $P = .015$), while high engagement (80%) during post-intervention was associated with

maintained physical activity between the 6- and 12 month follow-up (odds ratio: 4.12, $P = .043$).

Conclusions: Supervised mHealth support was well received with high adherence, while modules for self-management of physical activity faced challenges in engaging the participants. Future research should focus on co-creating self-managed mHealth support with individuals post-stroke or TIA to better understand and address their needs of support for long-term engagement in physical activity. Clinical Trial: ClinicalTrials: NCT0511195

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Original Manuscript

Original Paper

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Keywords: digital interventions;digital health;mobile health;mobile applications;secondary prevention;exercise;engagement;adherence

Abstract

Background

Regular physical activity is a crucial and an important modifiable lifestyle factor reducing the risk of recurrent incidents after stroke or transient ischemic attack (TIA). Mobile Health (mHealth) has emerged as a promising approach for providing long-term support for physical activity. However, little is known about how individuals post-stroke or TIA adhere to and engage with mHealth interventions.

Objective

This study aimed to: (1) describe adherence to supervised sessions in an mHealth intervention targeting physical activity, (2) describe engagement with self-managed mHealth support for physical activity during and after the intervention, (3) compare characteristics of participants with high and low adherence and engagement, and (4) examine whether high adherence and engagement were associated with maintained physical activity after having completed the intervention and at a 12-month follow-up.

Methods

In this study, a secondary analysis of data from the experimental arm of a feasibility randomized

controlled trial was conducted. The experimental group received a 6-month mHealth version of the i-REBOUND intervention, which included supervised mHealth support for physical activity and behavior change, followed by a 6-month post-intervention period with access to self-managed mHealth support. Adherence outcomes included attendance at supervised exercise and counseling sessions, while engagement outcomes measured weekly interactions with self-managed mHealth support during and after the intervention. Participants' level of physical activity (steps per day) was measured using accelerometers at baseline, and at 6- and 12 months post-baseline. Logistic regression analysis examined the associations between high adherence and engagement during the intervention and post-intervention period and maintained physical activity (i.e. >7000 steps/day) across the 12-month study period.

Results

Of the 57 participants enrolled (67% female, average age 71), 96% had mild stroke symptoms, and 51 (89%) completed the intervention. Adherence to supervised mHealth support was high (supervised exercise sessions: 79%, counseling: 98%), while engagement with self-managed mHealth support was high during the intervention (83%) but declined post-intervention (38%). A larger proportion of females (77%) demonstrated high adherence to the intervention compared to males (23%, $P = .043$). High adherence ($\geq 80\%$) during the intervention was associated with maintained physical activity between baseline and the 6-months follow-up (odds ratio: 5.50, $P = .015$), while high engagement ($\geq 80\%$) during post-intervention was associated with maintained physical activity between the 6- and 12 month follow-up (odds ratio: 4.12, $P = .043$).

Conclusion

Supervised mHealth support was well received with high adherence, while modules for self-management of physical activity faced challenges in engaging the participants. Future research should focus on co-creating self-managed mHealth support with individuals post-stroke or TIA to better understand and address their needs of support for long-term engagement in physical activity.

Trial Registration: ClinicalTrials: NCT05111195

Introduction

Stroke affects 15 million people annually and is the third leading cause of death and disability in the world [1]. A previous stroke or transient ischemic attack (TIA) increases the risk of a recurrent stroke, often with more severe health consequences [2]. Physical activity is an important modifiable lifestyle factor that contributes to a risk reduction of recurrent stroke and long-term disability for up to five years after a mild stroke or TIA [3]. Despite the crucial role of physical activity in secondary prevention [2], access to long-term support for physical activity after a stroke or TIA remains limited [4, 5]. Many post-stroke individuals fail to meet recommended physical activity levels, spend extended periods sedentary [6], and often require therapist-led support to maintain long-term engagement in physical activity.

Interventions combining onsite supervised physical exercise with support for physical activity through behavior change techniques appear to be particularly effective in improving cardiovascular health (e.g. systolic blood pressure) [7]. However, barriers such as lack of access to professional support, long travel times, and inadequate public transportation limit people post-stroke or TIA from attending on-site physical activity services [8, 9]. Mobile health (mHealth), i.e. healthcare delivered via mobile devices, is a promising intervention modality for promoting physical activity post-stroke [10], offering a flexible solution with the potential to support long-term physical activity. In the context of secondary stroke prevention, mHealth provides an underutilized opportunity to enhance access to physical activity support and reduce the risk of secondary complications after stroke or TIA [10, 11].

The health outcomes of digital interventions, such as mHealth, are influenced by the individuals' adherence to (i.e., the extent to which the participant followed the intervention as designed) and engagement with the intervention [12-14]. Engagement is a multifaceted concept involving both *what* users are engaged with (i.e. the targeted health behavior and the digital intervention) and *how* they engage with the digital intervention [15, 16]. In terms of *how*, Perski et al [17] conceptualize engagement as having both behavioral and experiential dimensions. The behavioral dimension refers to the extent of active interaction with the intervention, while the experiential dimension encompasses subjective experiences such as feelings and interest [17]. A recent scoping review suggested higher adherence to mHealth interventions among males, older individuals, and those with secondary education [13]. Limited research has explored adherence to and engagement with mHealth interventions in individuals post-stroke or TIA [10], and the factors influencing these behaviors remain largely unknown. A better understanding of adherence and engagement can inform future development of mHealth interventions to promote and maintain physical activity post-stroke or TIA. This study builds on *i-REBOUND- let's get moving*, a telehealth intervention developed in Australia to support home-based exercise and the promotion and maintenance of physical activity in people post-stroke or TIA [18]. To improve reach, *i-REBOUND* was developed into a fully digital mHealth intervention [19], which was found to be safe, acceptable, and accessible for people post-stroke or TIA across Sweden [20]. The mHealth version of the *i-REBOUND* intervention provides 6 months of supervised support for physical activity and behavior change, followed by a 6-month post-intervention period with access to self-managed mHealth support. To further understand the uptake of the intervention among people post-stroke or TIA, this study sought to examine adherence and engagement patterns and their association to maintained physical activity after the intervention. Specific aims were to (1) describe adherence to supervised mHealth support during the intervention, (2) describe engagement with the self-managed mHealth support for physical activity during intervention and post-intervention, (3) compare the characteristics of participants with high and low levels of adherence and engagement in the mHealth intervention, (4) examine whether high adherence and engagement were associated with maintained physical activity between baseline and the 6-month follow-up, and between the 6- and 12-month follow-up.

Methods

Study design

The present study was a preplanned secondary analysis of data from the experimental arm of a feasibility randomized controlled trial (ClinicalTrials: NCT0511195). The trial included people post-stroke or TIA randomized into an experimental group receiving the mHealth version of the i-REBOUND intervention or a control group receiving mHealth consultations via videoconferencing [19, 20]. The analysis focused on participants' adherence to and engagement with the mHealth intervention and was therefore limited to the experimental arm. The data was collected between September 2021 and December 2023.

Ethical considerations

The study was approved by the Swedish Ethical Review Authority (dnr 2020–05062 and 2021-03622). Written informed consent was provided by participants prior to data collection. All data were anonymized to ensure participant confidentiality.

Participants

Participants were recruited through advertisements at collaborating clinics, social media, patient organizations, and the webpage of Karolinska Institutet. Inclusion criteria were (1) clinical diagnosis of stroke or TIA 3 months to 10 years prior to study enrollment, (2) living at home, (3) being able to walk a short distance indoors with or without a walking device, (4) being able to use a smartphone including e-signature identification with/without the help of a relative/carer and (5) having access to a stable internet connection. Exclusion criteria were (1) already meeting the recommended physical activity levels of at least 150 min per week of moderate physical activity or at least 75 min per week of vigorous-intensity physical activity, (2) severe health conditions compromising engagement in the intervention or, (3) enrolled in a concomitant clinical trial or participating in rehabilitation (e.g. aerobic exercises) at the time point of recruitment.

Intervention – the mHealth version of the i-REBOUND intervention

The mHealth intervention provided support for physical activity and behavior change to people post-stroke or TIA across 48 weeks divided into an intervention and post-intervention period (Figure 1). The intervention was delivered via the STAAR app (Stroke Treatment through Active and Accessible Rehabilitation), available on iOS and Android devices. Two physical therapists with ≥ 5 years' experience in stroke rehabilitation delivered the intervention through a web-based digital clinic connected to the app. Video calls were used for supervised sessions and written communication was enabled through chat.

Supervised mHealth support

During the first week, the mHealth intervention was introduced in 2 sessions with the physical therapist, including a medical history review, discussions about resources for physical activity and home exercises, and a practice exercise session. Phase 1 of the intervention (weeks 2-12) offered 2 supervised exercise sessions per week, and phase 2 (weeks 13-24) offered 1 session. The supervised 30-minute exercise sessions aimed to reach physical activity at moderate intensity (i.e. Borg Rating of Perceived Exercise Exertion Scale ≥ 12 [21]) and were delivered individually or in groups based on participants' physical capacity.

Support for behavior change consisted of individual monthly counseling sessions with the physical therapist. These sessions included discussions on goals, self-management strategies, and barriers and facilitators to physical activity. In addition to the supervised exercise sessions, the participants were encouraged to engage in any physical activity of their choice. The final counseling session during the

last week of the intervention period focused on developing an individualized self-management plan and setting goals for the post-intervention period, supporting maintenance of exercise routines and engagement in physical activity.

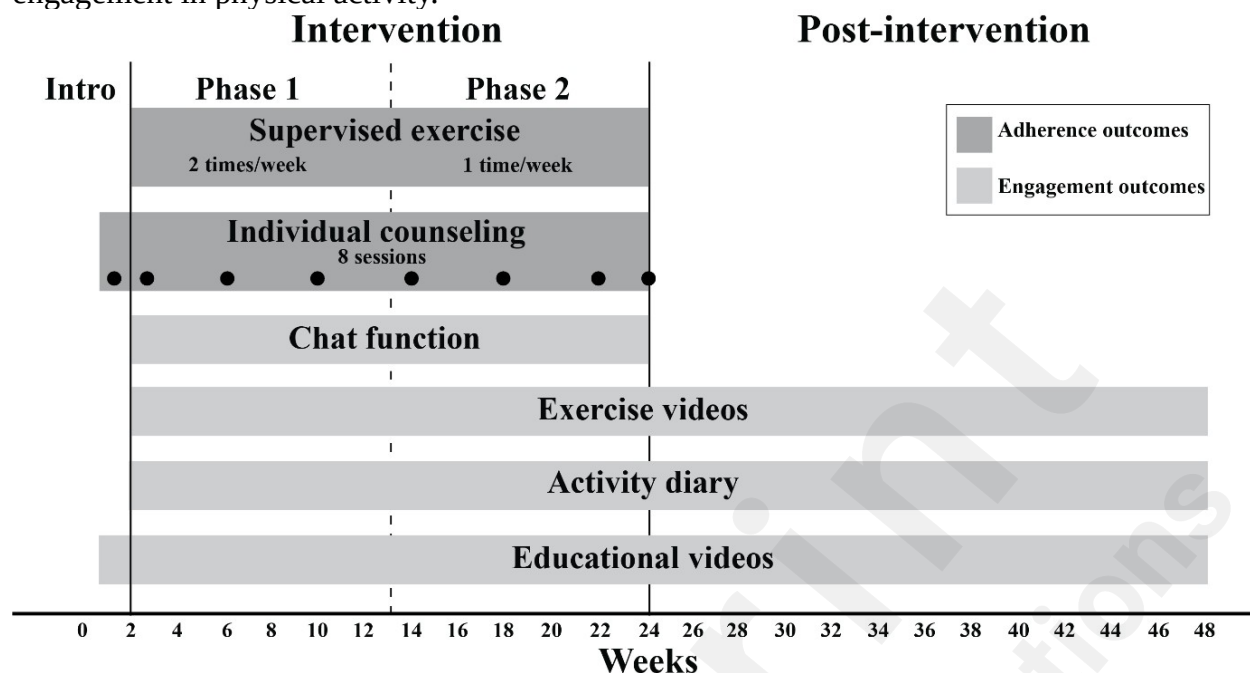


Figure 1. Illustration of the mHealth intervention and post-intervention across the 48-week study period.

Self-managed mHealth support

Educational videos on physical activity and exercise recommendations, individually prescribed exercises videos, and an activity diary were available throughout the intervention and post-intervention period as behavioral change techniques to support the promotion of physical activity. Individual exercises, with pre-recorded instructional videos for strength and/or aerobic training, were prescribed by the physical therapist based on the needs and preferences of the participant. The digital activity diary encouraged self-management by enabling participants to self-monitor their physical activity. Participants selected activities to monitor, such as outdoor walking, and designated days to perform them, marking each activity as 'performed' or 'not performed' in the diary. During post-intervention, the study participants had access to self-managed mHealth support, but no physical therapist contact was offered.

Baseline assessment

Baseline data collection included demographics (age, sex, level of education, employment status, stroke/TIA diagnosis, and living situation) and assessment of level of stroke-disability according to Modified Rankin Scale; ranging from 0-5, where 0 indicates no disability and 5 indicates severe disability [22].

Digital questionnaires were administered via the STAAR app to assess functioning. Self-efficacy for exercise was assessed by the 9-item Exercise Self-Efficacy Scale [23]. For each item, participants indicate their confidence to execute the behavior on a 100-point percentage scale divided into 10-point increments, ranging from 0% (not at all confident) to 100% (highly confident). Fatigue was assessed by the Fatigue Severity Scale 9-item version scored on a 7-point Likert scale, ranging from 1 ('disagree') to 7 ('fully agree'), with the median score of the 9 items used for analysis [24]. Levels of depression, anxiety and stress were assessed by the Depression, Anxiety, and Stress Scale 21 [25]. Each of the 21 items are rated on a 4-point Likert scale ranging from 0 ('did not apply to me at all') to 3 ('applied to me very much, or most of the time'), 7 items each pertaining to depression, anxiety

and stress. Scores for the subscales were calculated by summing the scores of each domain. Self-perceived impact of stroke was assessed using the 8 subscales (strength, memory, emotion, communication, activities of daily living/instrumental activities of daily living, mobility, hand function, social and participation) of the Stroke Impact Scale [26]. The score ranges from 0-100, higher scores indicate a lower perceived impact. Recovery after stroke was assessed with a visual analogue scale, in which participants were asked to score their global perceived stroke recovery from 0 ('no recovery') to 100 ('complete recovery') [26].

Outcome measures

Data collection included physical therapist documentation of adherence to supervised sessions during intervention phases 1-2 and user logs tracking engagement with self-managed mHealth support throughout the study period. Physical activity was measured with an accelerometer at baseline, and at follow-ups 6- and 12-months post-baseline.

Adherence measures

Adherence to supervised exercise and individual counseling sessions during the intervention was documented in the digital clinic by the physical therapist. Individual adherence rates in percentage were calculated by dividing exercise sessions attended by the total sessions offered in phase 1 (n=22) and phase 2 (n=12). The same approach was applied to calculate adherence to the counseling sessions offered (n=8). Based on their adherence to supervised exercise participants were categorized into high adherence ($\geq 80\%$) and low adherence ($< 80\%$) groups [20].

Engagement measures

Participants' weekly engagement with the app was assessed during the intervention and post-intervention, with an 'active week' defined as at least one interaction with the chat function (only intervention period), prescribed exercises, or activity diary. Overall engagement was then calculated as the percentage of active weeks over the 48-week study period, excluding the introductory week. Based on this metric, participants were categorized into high engagement ($\geq 80\%$) and low engagement ($< 80\%$) groups. Non-use attrition, defined as when participants stopped engaging with the activity diary and prescribed exercises videos for at least 4 consecutive weeks post-intervention, was calculated as number of weeks to attrition.

Participants were categorized by activity diary use as low (≤ 19 weeks), sporadic (20–39 weeks), or frequent (≥ 40 weeks) engagers and by engagement with prescribed exercises as limited (≤ 5 sessions), sporadic (6–19 sessions), or frequent (≥ 20 sessions) engagers. Engagement with educational videos across the entire study period was calculated as the number of viewed videos divided by the total number available (n=8).

Physical activity measures

Physical activity was measured using the activPAL accelerometer (PAL Technologies Ltd) at baseline, and at 6- and 12- months post-baseline [27]. The activPAL device demonstrates reliability and validity in measuring step count [28] and is recommended for assessing physical activity after a stroke [29]. Participants received the monitor by mail with instructions to wear it on their non-affected or dominant leg (as applicable) for 7 consecutive days (24 hours/day) before returning it via prepaid post. Participants with at least 3 days of physical activity data, each containing a minimum of 10 hours of data, were included in the analysis [30]. The outcome was the number of steps per day. As no minimal clinically important difference in steps has been established for the stroke population, we used ≥ 7000 steps/day as a criterion for optimal cardiovascular risk reduction [31]. Changes in physical activity between baseline and the 6-month follow-up, and between the 6- and 12-month follow-up, were grouped into 4 categories:

- 1) Unchanged—low physical activity (<7000 steps/day at baseline and 6-month follow-up, <7000 steps/day at 6-month and 12-month follow-up)
 - 2) Declined physical activity (≥ 7000 steps/day at baseline and ≤ 7000 at 6-month follow-up, >7000 steps/day at 6-month follow-up and ≤ 7000 at 12-month follow-up)
 - 3) Unchanged—active (≥ 7000 steps/day at baseline and 6-month follow-up, ≥ 7000 steps/day at 6-month and 12-month follow-up)
 - 4) Improved physical activity (<7000 steps/day at baseline and ≥ 7000 at 6 months follow-up, <7000 steps/day at 6 months follow-up and ≥ 7000 at 12 months follow up).
- Participants in categories 3 and 4 were classified as having maintained their level of physical activity.

Data analysis

The IBM SPSS Statistics (v. 24.0) software was used for statistical analyses. Baseline characteristics and descriptive statistics for aims 1-3 were calculated and presented as mean (standard deviation (SD)), median (interquartile range (IQR)), and frequencies (percentage).

For the first and second aim, descriptive statistics described the adherence and engagement in the mHealth intervention across the study period. Participants who completed the introductory week and began intervention phase 1 were included in the analysis, with data analyzed up to the dropout week for those who discontinued.

For the third aim, between-group differences regarding demographic characteristics between the sub-groups with high and low adherence, and high and low engagement, were analyzed using Mann Whitney U test for continuous variables and Chi-square test for binary variables.

For the fourth aim, logistic regression analysis was used to examine the associations between high adherence during the intervention, high engagement during the intervention and post-intervention periods, and maintained physical activity levels (categories 3 and 4, as described earlier) from baseline to the 6-month follow-up and from the 6-month to the 12-month follow-up. The α level was set at $P \leq .05$ for all analysis.

Results

Characteristics of participants

Of the 57 participants enrolled (38 females), 51 (89%) completed the intervention (Figure 2). The mean age of the participants completing the intervention was 71 years (SD: 8) and the median time since stroke or TIA was 2.4 years (IQR: 1.3). Thirty-four (67%) of the participants were female, 27 (53%) had a university degree, 8 (16%) were employed, and 47 (93%) reported no or mild post-stroke or TIA symptoms (i.e. Modified Ranking 0-1) (Table 1).

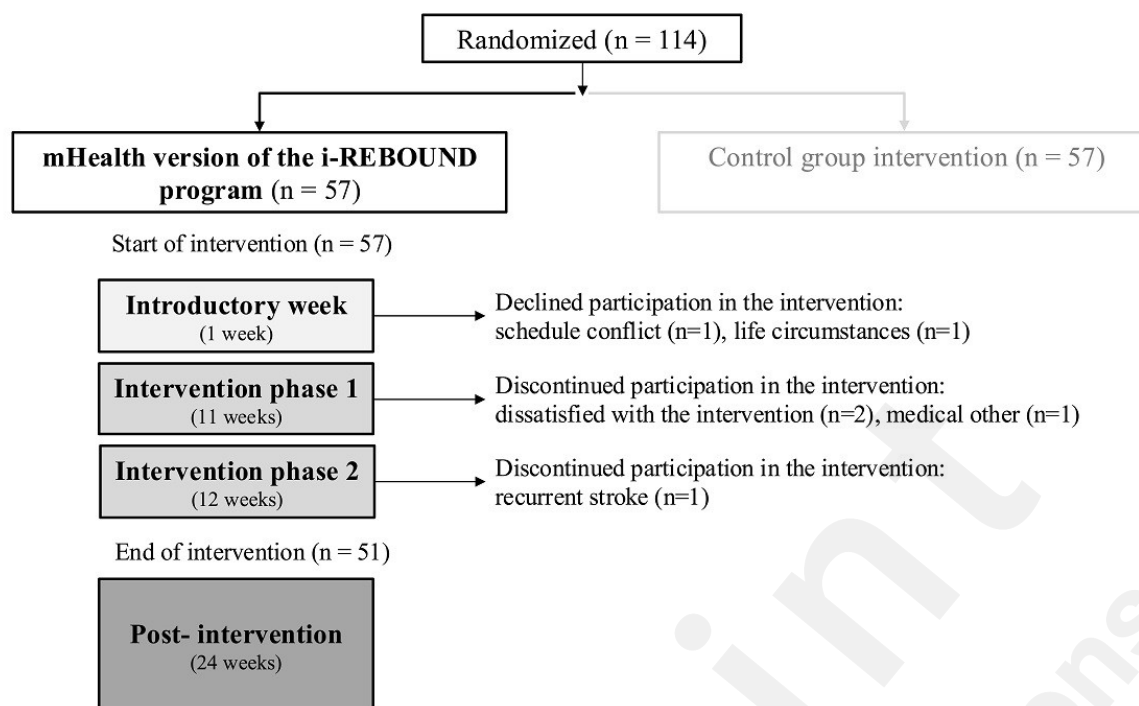


Figure 2. Participant flow chart.

	Completed intervention (n=51)	Discontinued (n=6)	All (n=57)
Age, mean (SD ^a)	71 (8)	70 (12)	71 (9)
Gender, female, n (%)	34 (67)	4 (67)	38 (67)
University degree, n (%)	27 (53)	4 (67)	31 (54)
Employed, n (%)	8 (16)	1 (17)	9 (16)
Stroke/TIA ^c , n (%)	36 (71)/15 (29)	4 (67)/2 (33)	40 (70)/17 (30)
Years since stroke, median (IQR ^b)	2.4 (1.3)	2.4 (3.5)	2.4 (3.7)
Use walking aid, n (%)	16 (31)	2 (33)	18 (32)
Living with someone, n (%)	34 (67)	2 (33)	36 (63)
Modified Ranking Scale, n (%)			
No symptoms	10 (20)	-	10 (18)
No significant symptoms	37 (73)	6 (100)	43 (75)
Slight disability	3(6)	-	3 (5)
Moderate disability	1(2)	-	1 (2)
Depression, Anxiety, and Stress Scale (0-42), median (IQR)			
Depression	4 (8)	5 (10)	4 (8)
Anxiety	2 (6)	3 (7)	2 (6)
Stress	8 (6)	13 (19)	8 (7)
Stroke impact scale (0-100), median (IQR)			
Strength	75 (31)	81 (20)	81 (31)
Memory	91 (13)	89 (32)	91 (16)
Emotion	53 (8)	53 (16)	53 (8)
Communication	96 (11)	96 (13)	96 (11)
ADL/iADL ^d	94 (15)	93 (12)	94 (15)
Mobility	88 (20)	89 (12)	88 (20)
Hand function	95 (35)	85 (30)	90 (30)
Social participation	81 (36)	72 (22)	78 (81)
Recovery	77 (30)	58 (39)	77 (35)
Self-efficacy for exercise (0-90), median (IQR)	68 (25)	58 (51)	66 (27)
Fatigue severity scale (1-7), median (IQR)	4 (2)	4 (3)	4 (2)
Physical activity ≥ 7000 steps/day, n (%)	24 (47)	1 (17)	25 (44)

Table 1. Baseline demographic and clinical characteristics of participants who completed the intervention versus those who discontinued, and both groups pooled.

^aSD: standard deviation

^bIQR: interquartile range

^cTIA: transient ischemic attack

^dADL/iADL: activities of daily living/instrumental activities of daily living

Adherence to supervised mHealth support

The mean adherence to supervised exercise across the intervention period was 79% (min-max: 29-100%) (Figure 3), with 911 of 1151 sessions attended in phase 1 and 489 of 618 sessions attended in phase 2. The mean adherence rate to individual counseling sessions across the intervention was 97% (min-max: 50-100%) and among those who completed the intervention, 82% (n=42) attended all counseling sessions.

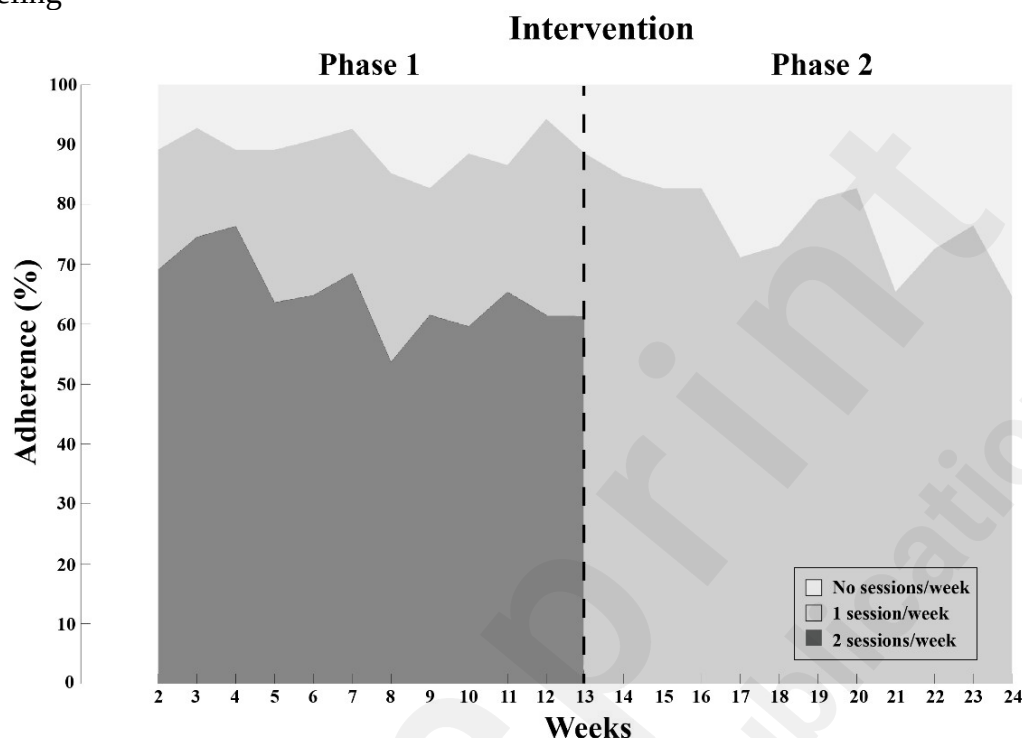


Figure 3. Weekly adherence to supervised exercise during intervention phases 1-2.

Engagement with self-managed mHealth support

The average weekly engagement with self-managed mHealth support across the study period was 60% (min-max: 18–94%), with higher engagement during the intervention phase (84%; min-max: 69–94%) compared to the post-intervention period (38%; min-max: 18–63%) (Figure 4). The majority of participants (n=37, 73%) discontinued using the app during the post-intervention period, with an average time to non-use attrition of 5 weeks (min-max, 1-19).

Engagement with the chat function and activity diary were the most common types of engagement (Figure 5). The average weekly engagement with the chat function was 63% in phase 1, decreasing to 50% in phase 2 (Figure 5A). On average, participants sent 1.6 weekly chat messages during the intervention. Forty-three participants (78%) utilized the activity diary to some extent across the study period (Figure 5C), with the most frequently monitored activities being outdoor walking (28%), aerobic exercise (13%) and unspecified physical exercise (12%). Among participants using the activity diary, 14 (28%) demonstrated low usage (≤ 19 weeks), 17 (40%) sporadic usage (20–39 weeks), and 12 (33%) frequent usage (≥ 40 weeks). Fifty participants (91%) were prescribed individual exercises, and among those, 33 (66%) had limited engagement (≤ 5 sessions), 12 (24%) sporadic engagement (6–19 sessions), and 5 (10%) frequent engagement (≥ 20 sessions). The mean engagement with educational videos was 67% (min-max: 0-100%), with each participant viewing 5 out of 8 videos on average, and 29 participants (53%) watching all the content.

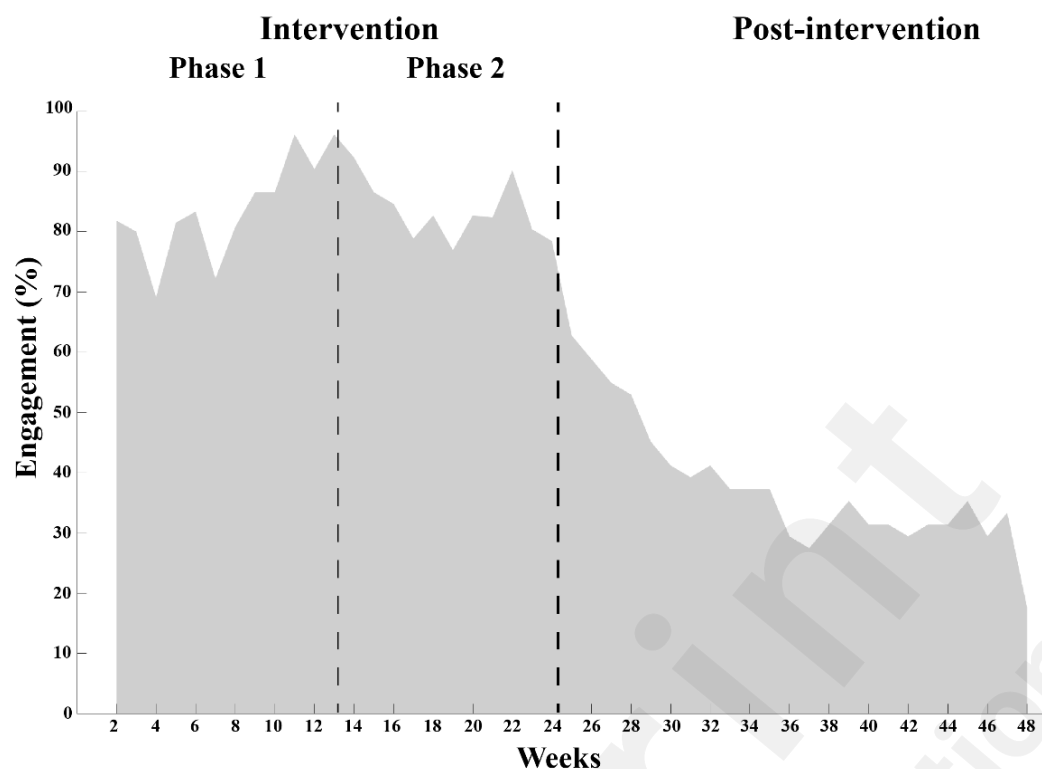


Figure 4. Weekly level of engagement during the intervention and post-intervention period.

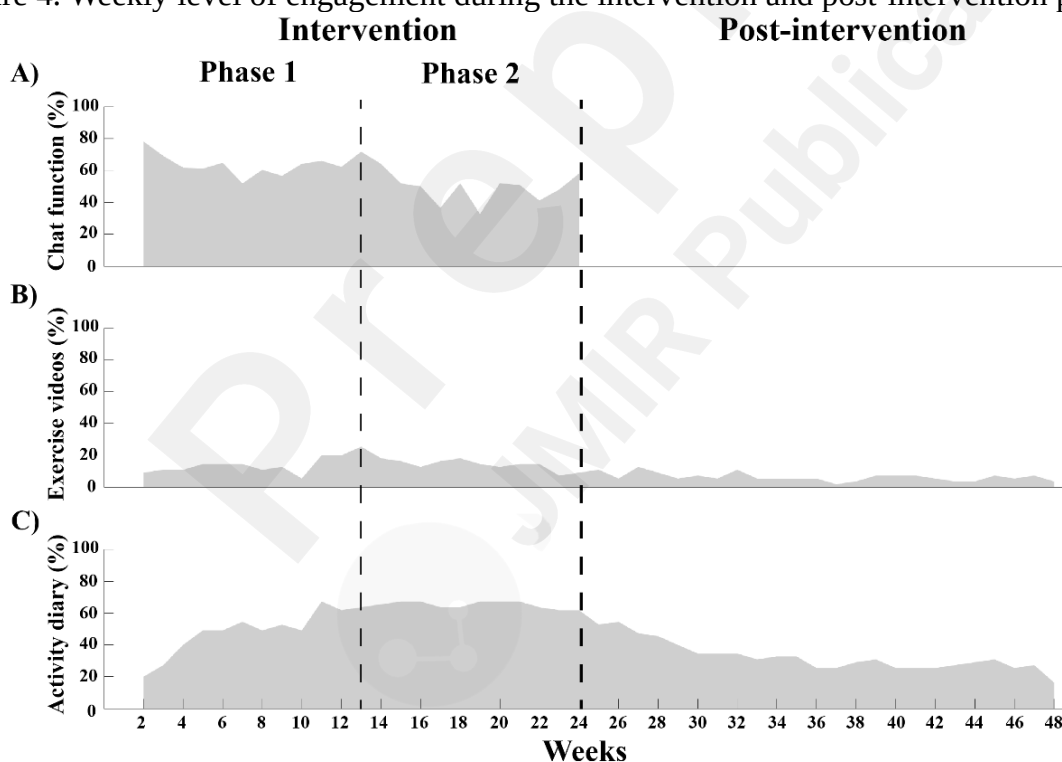


Figure 5. Weekly engagement in the chat function (A), exercise videos (B), and activity diary (C) during the intervention and post-intervention period.

Comparison of characteristics of users with different levels of adherence and engagement

Of the 51 participants completing the intervention, 31 (61%) had high adherence (i.e. $\geq 80\%$) and 15 (30%) had high engagement (i.e. $\geq 80\%$). Most personal and contextual factors, as well as clinical

and functional measures, showed no significant differences between participants with high versus low adherence or high versus low engagement in the mHealth intervention (Table 2). A higher proportion of females (77%) demonstrated high adherence to the intervention compared to males (23%, $P = .043$).

Table 2. Comparison between four user groups.

Variable	High adherence (n=31)	Low adherence (n=20)	P value	High engagement t (n=15)	Low engagement t (n=36)	P value
Age (years), median (IQR ^a)	72 (10)	71 (13)	.368	72 (13)	72 (10)	.764
Gender, female, n (%)	24 (77)	10 (50)	.043	9 (60)	25 (69)	.514
University degree, n (%)	16 (52)	11 (55)	.813	7 (47)	20 (55)	.562
Employed, n (%)	5 (16)	3 (16)	.914	1 (7)	7 (19)	.253
Stroke diagnosis, n (%)	22 (71)	14 (70)	.941	9 (60)	27 (75)	.284
Years since stroke, median (IQR)	2 (3.8)	2.5 (4.1)	.985	3.0 (6.4)	2.4 (3.6)	.528
Use walking aid, n (%)	9 (29)	7 (35)	.654	5 (33)	11 (31)	.846
Depression, Anxiety, and Stress Scale (0-42), median (IQR)						
Depression	4 (8)	4 (10)	.389	4 (10)	4 (8)	.098
Anxiety	2 (4)	3 (6)	.209	2 (6)	4 (4)	.834
Stress	8 (8)	7 (6)	.888	4 (8)	8 (6)	.727
Stroke Impact Scale, (0-100), median (IQR)						
Strength	75 (31)	81 (69)	.953	88 (25)	75 (34)	.138
Memory	91 (13)	91 (69)	.727	94 (22)	88 (13)	.148
Emotion	53 (8)	51 (8)	.495	56 (3)	51 (8)	.141
Communication	96 (11)	95 (36)	.541	96 (11)	95 (10)	.620
ADL/iADL ^b	94 (17)	96 (54)	.520	98 (17)	93 (17)	.112
Mobility	85 (20)	89 (48)	.704	98 (23)	85 (18)	.147
Hand function	95 (30)	90 (50)	.601	95 (30)	90 (39)	.392
Social participation	81 (28)	81 (64)	.492	86 (33)	76 (35)	.237
Recovery	79 (26)	75 (39)	.271	81 (60)	76 (29)	.230
Self-efficacy for exercise (0-90), median (IQR)	68 (27)	65 (26)	.692	68 (28)	68 (25)	.796
Fatigue severity scale (1-7), median (IQR)	4 (2)	4 (2)	.908	3 (3)	4 (2)	.185

^aIQR: interquartile range

^bADL/iADL: activities of daily living/instrumental activities of daily living

Factors associated with maintained physical activity

Valid physical activity data were available for 45 participants (88%) at 6 months and 42 participants (82%) at 12 months among those who completed the intervention. Twenty-four participants (53%) maintained their physical activity between baseline and the 6-month follow-up, whereas 19 (45%) maintained their physical activity between the 6- and 12-month follow-ups (Table 3). High adherence during the intervention was associated with maintained physical activity between baseline and the 6 months follow-up (Odds ratio (OR): 5.50, 95% CI: 1.39-21.71, $P = .015$), and high engagement during the post-intervention was associated with maintained physical activity between 6 and 12 months (OR: 4.27, 95% CI: 1.05-17.42, $P = .043$). High engagement during the intervention was not

associated with maintained physical activity between baseline and the 6-month follow-up (OR: 3.50, 95% CI: 0.77–15.88, $P = .104$), nor was high adherence during the intervention associated with maintained physical activity between the 6- and 12-month follow-ups (OR: 2.15, 95% CI: 0.58–8.00, $P = .252$).

Table 3. Study participants demonstrating ≥ 7000 steps/day at 6- and 12-months follow-up, as well as a classification of the change between baseline and the follow-ups.

	Classification of change ^a	
	Baseline to 6-months follow-up (n=45)	6- to 12-months follow-up (n=42)
Unchanged - low physical activity	16 (36%)	16 (38%)
Declined physical activity	5 (11%)	7 (17%)
Unchanged – physically active	17 (38%)	17 (40%)
Improved physical activity	7 (15%)	2 (5%)

^a Unchanged—low physical activity (i.e., <7000 steps/day at baseline and 6-month follow-up, <7000 steps/day at 6-month and 12-month follow-up), declined physical activity (ie, >7000 steps/day at baseline and ≤ 7000 at 6-month follow-up, >7000 steps/day at 6-month follow-up and ≤ 7000 at 12-month follow-up), unchanged—active (ie, ≥ 7000 steps/day at baseline and 6-month follow-up, ≥ 7000 steps/day at 6-month and 12-month follow-up), and improved physical activity (ie, <7000 steps/day at baseline and ≥ 7000 at 6 months follow-up, <7000 steps/day at 6 months follow-up and ≥ 7000 at 12 months follow-up).

Discussion

This study investigated adherence and engagement during and 6 months after an mHealth intervention for people post-stroke or TIA. Adherence to supervised sessions remained high ($>75\%$) across the intervention and more females adhered to the supervised exercise than males. Engagement with self-managed mHealth support was initially high but decreased post-intervention. High adherence during the intervention was associated with maintained physical activity between baseline and the 6-month follow-up, while high post-intervention engagement was associated with maintained physical activity between the 6- and 12-month follow-ups.

Adherence to supervised exercise during the intervention averaged 79%, which is comparable to adherence rates in non-digital [32] and digital interventions for people post-stroke or TIA [18, 33]. Adherence to counseling sessions (97%) was higher compared to a previous study showing decreasing adherence to long-term non-digital physical activity support in people post-stroke [34]. The current study's digital format provided an accessible and flexible solution which may have contributed to the high adherence rates. Low engagement within physical activity apps is a well-known challenge in mHealth interventions [35], yet our findings showed high engagement with self-managed support modules during the intervention, particularly the chat function and activity diary. Engagement post-intervention decreased to 38%. Similar patterns of declining engagement have been observed in unsupervised mHealth interventions for people with chronic conditions [36].

Several possible factors could explain the levels of adherence and engagement observed in this study. High adherence is common during supervised phases of exercise programs [37] and the weekly physical therapist interaction during the intervention likely influenced the adherence positively. While the supervised sessions followed a structured schedule, engagement with the self-managed mHealth support was optional, guided by preference of participants, and not explicitly formulated as a goal of the intervention. A recent review suggests that clear guidance on the frequency and type of mHealth engagement can promote maintained participant engagement [36]. Further, lack of therapist-contact during post-intervention may have contributed to the decreasing engagement patterns, as such support has been shown to enhance app engagement [17, 38]. Personalized app content commonly benefits app engagement [35]. However, despite individually prescribed exercises

and access to an activity diary with self-selected activities, only 10% and 33%, respectively, frequently engaged with these modules in the present study. Engaging mHealth features, such as prompts, gamification, and regular content updates, have been shown to significantly enhance app engagement [17, 35, 38]. These elements were not incorporated into the current intervention; however, integrating them in future development could be a valuable strategy to encourage maintained engagement among individuals post-stroke or TIA. We believe that refinement of the mHealth version of the i-REBOUND intervention should be co-created with people post-stroke or TIA and target multiple domains, including technology, intervention design, and the establishment of clear expectations for adherence and engagement [39].

In line with a meta-analysis of digital physical activity interventions in adults [14], our results suggest that adherence during the intervention and engagement post-intervention is important for maintaining physical activity after the intervention period. Contrasting previous findings, this study found no significant differences in high adherence or engagement between sub-groups, such as age or education level, which has previously shown to influence mHealth intervention adherence [13]. However, our results showed that females adhered to supervised sessions more than males, potentially because females tend to be more proactive and engaged in health-related issues [40]. The results from this study support that adherence to and engagement with an mHealth intervention might be important factors influencing the intervention's impact on maintained engagement in physical activity.

Methodological considerations

Participants were mostly female, highly educated, and with mild stroke symptoms, which limits the generalizability of the findings to other stroke or TIA populations [41]. The 7,000 steps/day cut-off for physical activity, while clinically relevant for optimal cardiovascular risk reduction [31], is a crude measure for detecting change over time. Furthermore, participants in the sample exhibited a notably high level of physical activity at baseline, exceeding the average daily step count of 4,078 for individuals with stroke [6]. User logs yielded an in-depth examination of the participants' mHealth engagement behavior but could not sufficiently capture the multifaceted nature of engagement. Therefore, for a more comprehensive understanding, exploration of participants' subjective experiences of engagement is necessary. A strength was the 48-week study period, which allowed for a thorough investigation of changes in adherence and engagement patterns over time. However, adherence and engagement levels >80% were considered 'high', for more substantiated levels, future studies should determine adequate levels for effective mHealth engagement and adherence and set a predefined benchmark [36].

Conclusion

Supervised mHealth support was well received with high adherence, while modules for self-management of physical activity faced challenges in engaging the participants. Associations were found between high adherence during the intervention and physical activity maintenance immediately after the intervention, whereas high engagement post-intervention was associated with physical activity maintenance at 12-month follow-up. However, factors associated with high and low adherence and engagement remain uncertain and need further investigation. Future research should focus on co-creating self-managed mHealth support with individuals post-stroke or TIA to better understand and address their needs of support for long-term engagement in physical activity.

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Authors' Contributions

All authors conceptualized the study. DMC, SH, LB and HL contributed to the investigation. LB and HL conducted the data management. HL and DMC carried out the analyses. LB and HL prepared the figures. HL wrote the initial draft, and all authors contributed to the critical review and revision of the final manuscript.

Conflicts of Interest

The authors declare no conflict of interest.

Abbreviations

TIA: transient ischemic attack

mHealth: mobile health

SD: standard deviation

IQR: interquartile range

OR: Odds ratio

Data availability

The data set used in this article is not readily available due to the risk of compromising research participants' privacy. Requests to access data should be directed to the Research Data Office at Karolinska Institutet (rdo@ki.se).

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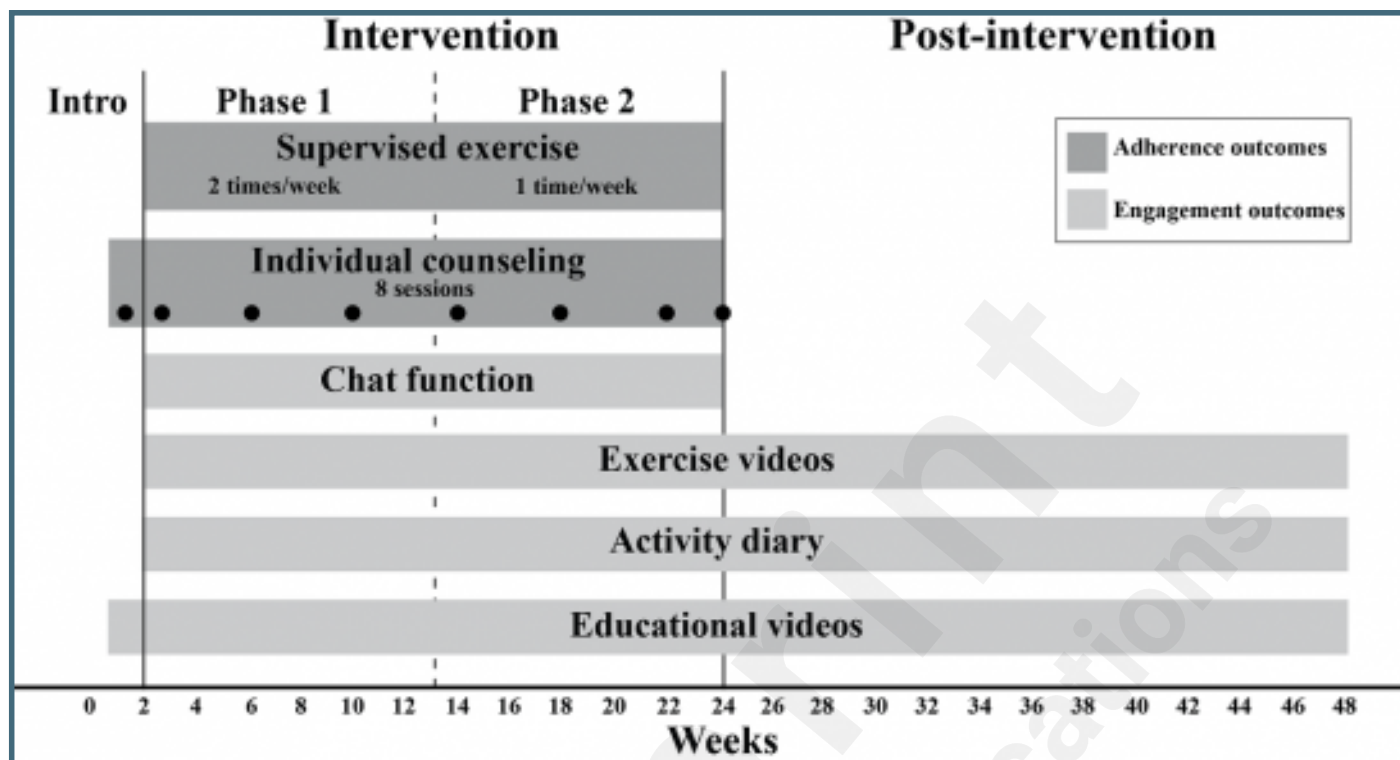
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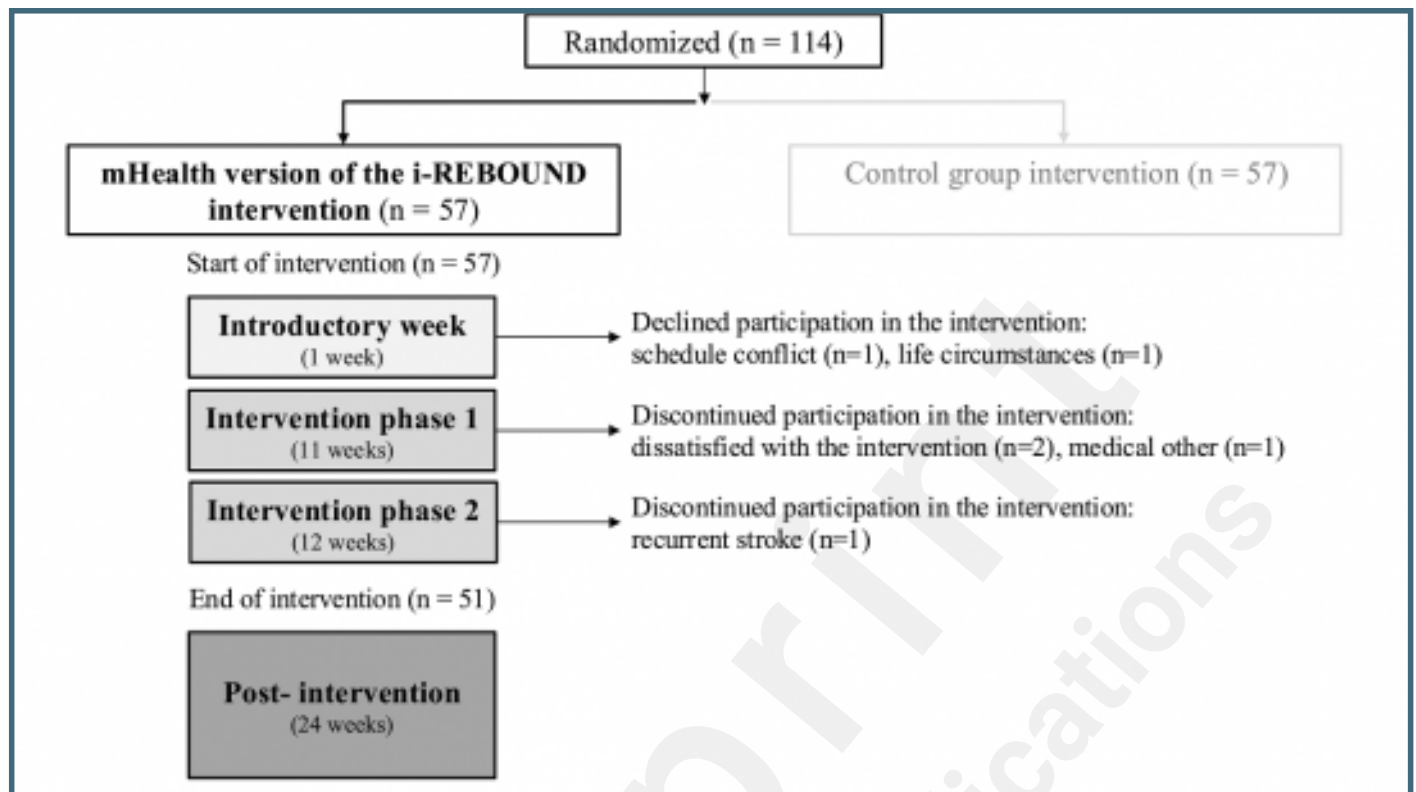
Supplementary Files

Figures

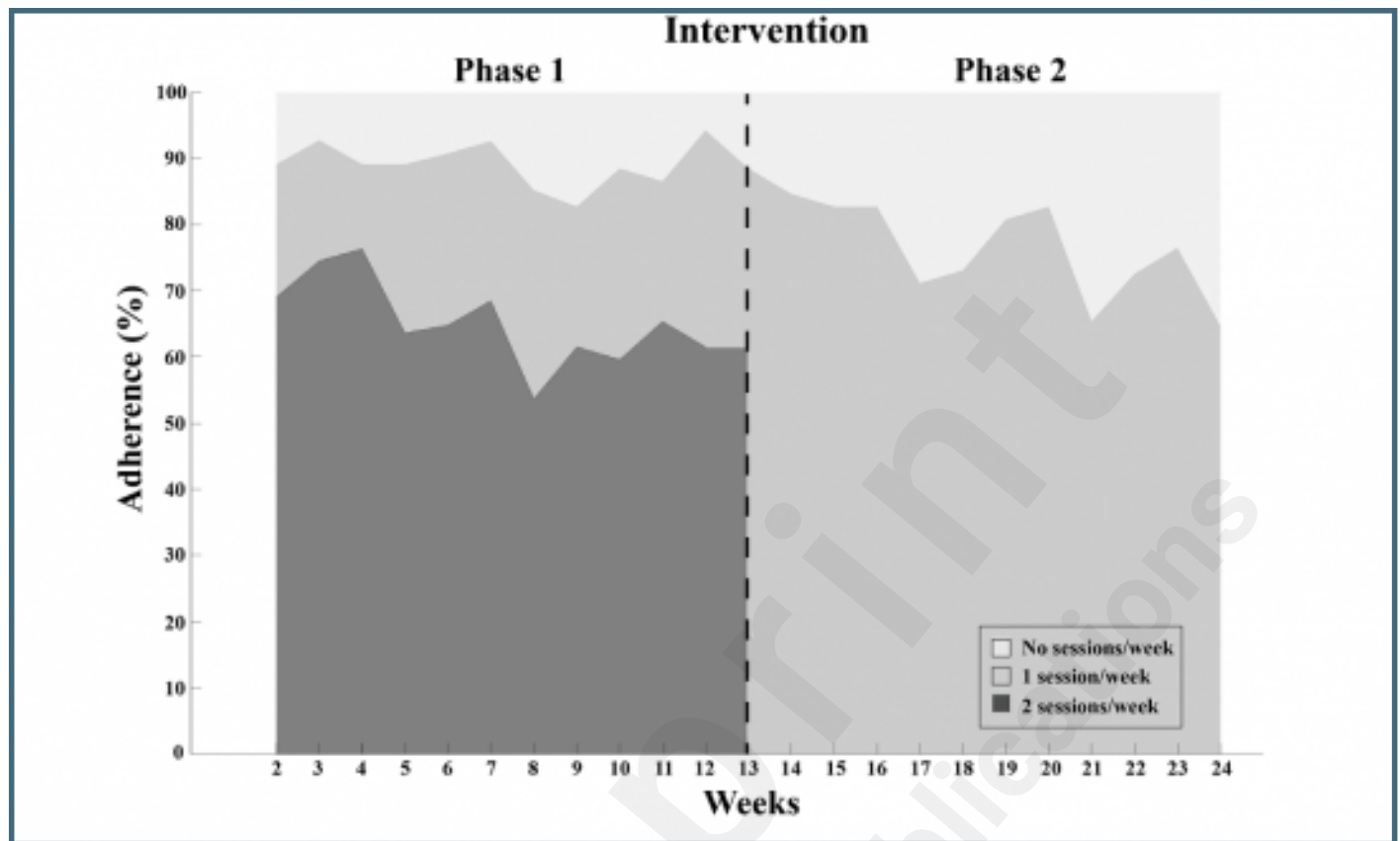
Illustration of the mHealth intervention and post-intervention across the 48-week study period.



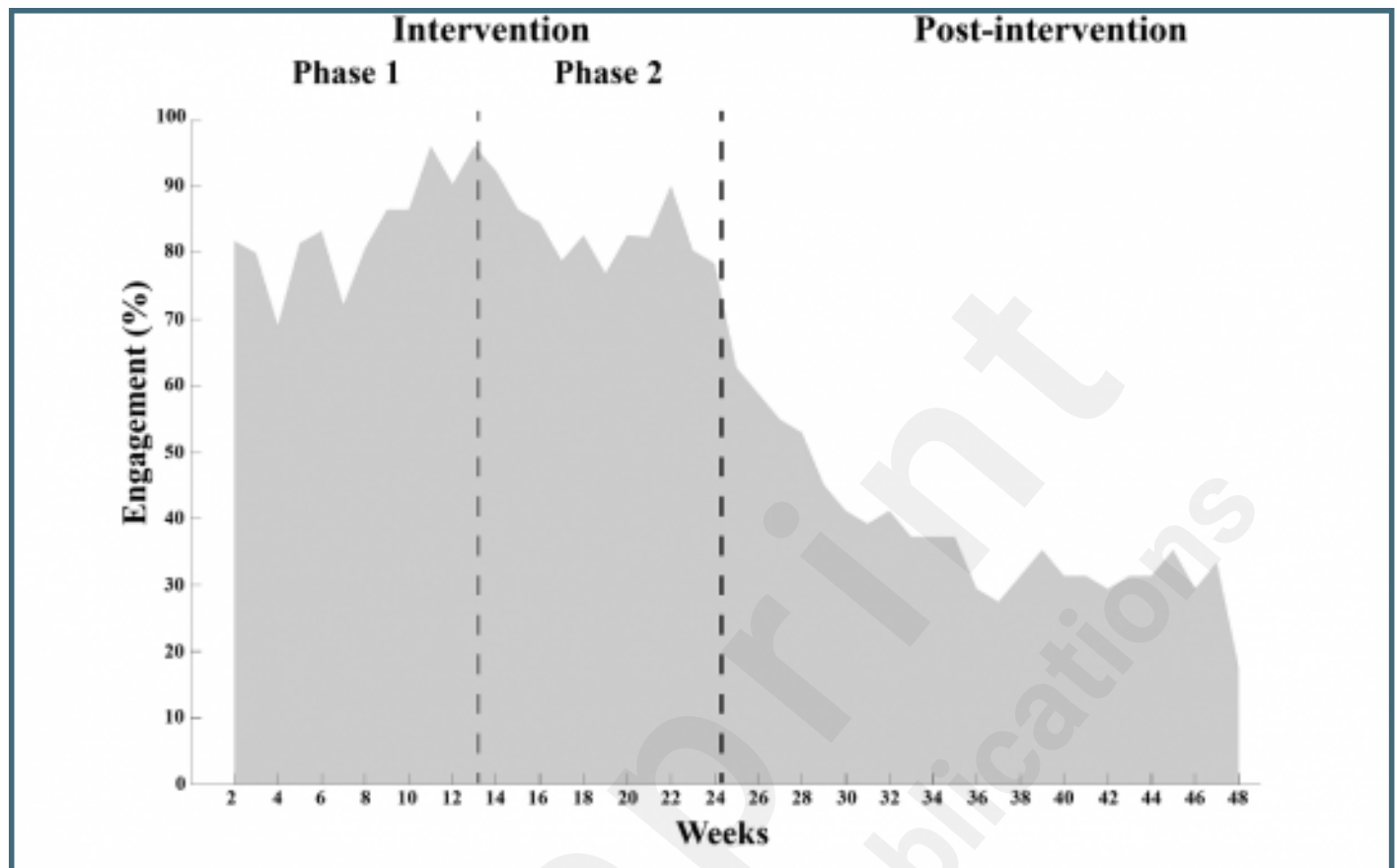
Participant flow chart.



Weekly adherence to supervised exercise during intervention phases 1-2.



Weekly level of engagement during the intervention and post-intervention period.



Weekly engagement in the chat function (A), exercise videos (B), and activity diary (C) during the intervention and post-intervention period.

