Increasing physical activity in stroke survivors using STARFISH, an interactive mobile phone application: a pilot study

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Abstract

Background: Following stroke, people are generally less active and more sedentary which can worsen outcomes. Mobile phone applications (apps) can support change in health behaviours. We developed STARFISH, a mobile phone app-based intervention, which incorporates evidence-based behaviour change techniques (feedback, self-monitoring and social support), in which users' physical activity is visualised by fish swimming.

Objective: To evaluate the potential effectiveness of STARFISH in stroke survivors.

Method: Twenty three people with stroke (12 women; age: 56.0 ± 10.0 years, time since stroke: 4.2 ± 4.0 years) from support groups in Glasgow completed the study. Participants were sequentially allocated in a 2:1 ratio to intervention (n=15) or control (n=8) groups. The intervention group followed the STARFISH programme for six weeks; the control group received usual care. Outcome measures included physical activity, sedentary time, heart rate, blood pressure, body mass index, Fatigue Severity Scale, Instrumental Activity of Daily Living Scale, Ten Metre Walk Test, Stroke Specific Quality of Life Scale, Psychological General Well-Being Index.

Results: The average daily step count increased by 39.3% (4158 to 5791 steps/day) in the intervention group and reduced by 20.2% (3694 to 2947 steps/day) in the control group (p=0.005 for group-time interaction). Similar patterns of data and group-time interaction were seen for walking time (p=0.002) and fatigue (p= 0.003). There were no significant group-time interactions for other outcome measures.

Conclusion: Use of STARFISH has the potential to improve physical activity and health outcomes in people after stroke and longer term intervention trials are warranted.

Introduction

Stroke survivors generally spend less time physically active and more time sedentary than their age-matched healthy counterparts. [1-3] A recent systematic review reported that stroke survivors took less than half the number of steps per day as matched, healthy controls.[4] Our work, published since this review, demonstrated similarly that community dwelling stroke survivors took, on average, 48% of the steps of age, gender and body mass index matched controls and furthermore that sedentary time (including sleep) was significantly higher in stroke survivors (20.4hours/day) compared to controls (17.5 hours/day).[5]

Physical inactivity following a stroke is associated with reduced muscle strength and cardiovascular fitness, decreased ability to perform activities of daily living and a heightened risk of recurrent stroke and cardiovascular disease.[6, 7] Barriers to undertaking physical activity following stroke include the severity of the residual impairment following stroke, co-morbities, fatigue, motivational issues, lack of family support and social isolation. [6, 8]

Walking is an effective, popular and sustainable form of physical activity, which requires no special equipment, can be incorporated into everyday life [9] and is an acceptable form of activity in those most physically inactive.[10] However it is recognised that novel methods of supporting physical activity and exercise programmes follwing stroke should be developed. [6, 11]

Mobile devices, such as smartphones, are effective platforms for supporting changes in health behaviours, including physical activity. [12, 13] They can provide real-time feedback to the user, allow individualised content and facilitate social support .[12] The ubiquitous nature of mobile devices potentially provides an opportunity to use the devices to improve the health of the population in general and more specifically those following stroke. [14]

In a recent systematic review Burke et al reported on 14 studies which investigated mobile health technology for increasing physical activity following stroke [14]. Nine of the 14 studies used the internet as the main technology platform leading the authors to highlight that research to date has focussed on SMS (Short Message Service) and the internet despite advances in mobile technology.

Few studies, even in the general literature, have investigated the use of mobile phone applications (apps) on increasing physical activity. [15, 16] These apps have used metaphors, such as a garden of flowers [15] or virtual fish pets [16] to visually represent individuals physical activity. However, these apps required the user to carry an additional device, such as a pedometer, to monitor physical activity. The use of an integrated mobile phone app to increase physical activity after stroke has not been investigated.

STARFISH, a smart-phone based app, was designed by our group, as a behavioural change intervention to encourage the user to become more physically active.[17] In STARFISH, which uses the metaphor of a fish tank, virtual groups of four people, receive real time feedback on their own physical activity and that of each member of the group. This approach facilitates social support, and individual and group rewards provide additional motivation.

It is important that smart phone apps, which have the intention of improving health and wellbeing, are rigorously evaluated [14] and to that effect the aim of this study was to investigate the potential effectiveness of STARFISH in improving levels of physical activity, sedentary time, walking speed, and markers of health and wellbeing in people following stroke

Methods

Ethical approval for the study was received by the West of Scotland Research Ethics Service (Reference 12/WS/309) and all subjects gave written informed consent.

A convenience sample of stroke survivors was recruited from local stroke support groups. To be included participants had to; have had a single unilateral stroke, be able to walk independently with or without using an aid or orthosis, be discharged from rehabilitation and be able to comprehend instruction (based on the researcher's clinical judgement).

As this was a pilot study the sample size was based on participant availability with a recruitment goal of 24 participants. Twenty four participants were recruited and assigned, in a 2:1 ratio, to intervention (n=16) or control group (n=8). The first eight participants were recruited to the intervention group (which formed two STARFISH groups), the next four to the control group, then eight to the intervention, and the final four to the control group.

The STARFISH app

In the STARFISH app, each person in the group is represented by coloured fish within a fish tank, which the participant can see on their mobile phone display. When the participant is active their fish swims and blows bubbles which they, and other participants, can see. Individualised step goals were set for each person. In week one the daily step count target was the mean number of steps per day recorded on the phone during the baseline period (see below) plus 10%. At the end of each week, if individuals achieved their step count target on five of seven days, their target for the following week was increased by 5%. This update was indicated to the user by an exclamation mark attached to their fish. If the target was not reached, it remained unchanged for the following week. These targets were based on pragmatic decisions in terms of the potential ability of the participants.

Individual and group ‘rewards’ for achieving goals were provided. As the participant reached their target number of steps, their fish’s fins and tail grew. If all four members reached their step count target on at least five days of the week then the group was rewarded by another sea creature being added to their fish tank e.g. sea horse or crab (Figure 1).

Figure 1 Near Here

We used a participatory co-design approach, involving four stroke survivors, to adapt the existing STARFISH software to ensure that STARFISH was fit for purpose for people with stroke. A number of changes were made to the STARFISH app as part of the co-design sessions; the colour scheme of the screen was changed to make the font easier to read, text and tick boxes were enlarged and feedback on the personal daily goal (previously displayed as a percentage of the individuals daily step target) was changed to a progress bar display.

Intervention

The intervention group were given a mobile phone (Samsung Galaxy SIII) with the STARFISH app, and asked to carry the phone for one week during which the fish were not visible however step count baseline activity data were collected. Participants were advised to keep the phone in their pocket or to use the pouch to attach it to their belt approximately at the midline above the greater trochanter. After the first week the intervention group returned to the Clinical Research Facility (CRF) where the STARFISH app was activated on their phones. The app was explained and demonstrated to them and an instruction booklet given. Participants were encouraged to try the different features of the app and to ask questions. This session (not including baseline assessment) lasted approximately 30 minutes. Participants then used the app for six weeks and were given the contact number of the researcher should they have any problems.

At week 3, each group of participants in the intervention arm attended the CRF to discuss their progress.

The control group received usual care, which did not involve any active rehabilitation, only appointments with health care professionals as required. At the end of the trial the control group were given the opportunity to follow the STARFISH programme for six weeks; these data were not included in the analysis.

Outcome measures

Although the accelerometers within the phone provided real time step counts a validated method of assessing physical activity was used as the outcome measure. To determine baseline levels of physical activity and sedentary time all participants were provided with an ActivPAL™ activity monitor (PAL Technologies, Glasgow, Scotland) to wear for seven days. The activity monitor was attached to the unaffected leg.[18] The measure of physical activity was the number of steps per day averaged over the data collection period. We also calculated sedentary time (time spent sitting/lying and including sleep time), upright time (time spent standing or walking) and walking time (time walking with a cadence of greater than 20 steps/min). Both groups returned to the CRF at the end of the seven day period for collection of baseline data; height, weight, resting heart rate and a mean of three readings of blood pressure.

Participants completed a series of self-administered questionnaires. The Fatigue Severity Scale (FSS) is a self-reported questionnaire that evaluates the impact of fatigue. The FSS consists of nine statements which the participant responds to on a seven point scale ranging from strongly disagree to strongly agree. The total score is averaged to give a final score of 1 to 7 where lower scores indicate less fatigue. [19] The FSS is valid for use in stroke survivors. [20]

The Instrumental Activities of Daily Living Scale (IADL) contains eight items to assess complex activities of daily living necessary for functioning in community settings. The IADL scores range from 0 to 8; the higher the score, the greater the person's abilities.[(21)] The IADL has reported high inter- and intra-observer coefficients of reliability and test-retest reliability.[(21)]

The Stroke Specific Quality of Life Scale (SS-QOL) is a self-report questionnaire consisting of 49 items in the 12 domains of energy, family roles, language, mobility, mood, personality, self-care, social roles, thinking, upper extremity (UE) function, vision, and work/productivity. Total scores range from 49-245; higher scores indicate better quality of life.[(22)] The Scale has excellent reliability and acceptable validity in stroke. [(23)]

The Psychological General Well-Being Index (PGWBI) is a measure of subjective well-being and consists of 22 items such as anxiety, positive well-being, self-control, depression, general health and vitality. Scores range from 0 to 110 and higher scores suggest better well-being.[(24)] Although the psychometric properties have not been established in stroke specifically it is well used and validated in other clinical conditions.[(25)]

Participants also performed The Ten Meter Walking Test (10 MWT).[16] The time taken to walk 10 metres was recorded and converted to gait speed and an average of three trials was recorded. The reliability and validity of the 10MWT are well established and acceptable in stroke. [(26)]

Following the six week intervention or control period participants returned to the CRF for final measures. In week 5, an ActivPAL™ activity monitor was sent by post to each individual to wear for 7 days before bringing it to their final assessment.

Data analysis

Baseline variables were compared using two sample *t*-tests. Two factor repeated measures Analysis of Variance (ANOVA) (Group and Time) with a Greenhouse-Geisser correction factor was performed for each outcome measure. Partial eta square results were interpreted as; small effects partial $\eta^2>0.02$, medium effects partial $\eta^2>0.13$ and large effects partial $\eta^2>0.26$. [27]

Statistical analysis was performed using IBM SPSS version 22. The power calculation for a future fully powered trial was estimated using nQuery v7. Data are presented as means and standard deviations and significance was accepted at $p < 0.05$.

Results

Twenty four people were recruited for the study; 16 in the intervention group and 8 in the control group. One person in the intervention group had another stroke during the seven day baseline physical activity monitoring period. This adverse event was reported following required procedures and deemed not to be related to the study. Thus data are reported for 15 people in the intervention group.

Using gait speed to classify ambulation [28], in the intervention group 5 participants were classified as household ambulation (<0.4m/s), 7 as limited community ambulation (0.4-0.8m/s) and 3 as full community ambulation (>0.8m/s). In comparison, 4 of the controls were classified as household ambulation, 1 as limited community and 1 as full community ambulation.

At baseline there was no significant difference between intervention and control groups in terms of age (p=0.870), time since stroke (p=0.638) (Table 1) or mean steps/day at baseline (p=0.951).

Insert Table 1 Near Here

In terms of the primary outcome measure, the mean number of steps/day increased by 39.3% (1,633 steps/day) relative to baseline in the intervention group. In the control group the mean number of steps/day reduced by 20.2% (747 steps/day) (Table 2) however one participant reduced their steps/day by 50% which may have skewed the results. Steps/day increased in 13 of the 15 participants in the intervention group but only 2 of 8 in the control group. Statistical analysis demonstrated a significant group/time interaction effect (p=0.005) and a large effect (partial $\eta^2 = 0.314$). Average walking time increased, on average, by 20 mins per day in the intervention and reduced by 14 mins per day in the control group. Analysis demonstrated a significant group/time interaction (p=0.002) and a large effect (partial $\eta^2 = 0.381$).

Insert Table 2 Near Here

Average daily sedentary time reduced in both groups; 4.8% (55 mins) in the intervention group and 2.9% (34 mins) in the control group, but there was no significant group/time interaction (p= 0.705).

This pilot study achieved, for the mean steps/day variable, an interaction observed power of 84% though a group effect power of only 25%. The data, however, suggests that a fully randomised controlled study would require 58 participants in each group to detect, with 80% power, a 30% difference in change in steps/day between intervention and control groups, at a 5% level of significance.

In terms of secondary outcome measures, fatigue reduced in the intervention group and increased in the control group (Table 3). Statistical analysis showed a significant group effect (p=0.031, partial η^2 = 0.203) and group/time interaction effect and a large effect (p=0.003, partial η^2 = 0.349). Thus the intervention also appeared to have a positive effect on fatigue.

Table 3 Near Here

Systolic blood pressure, gait speed (10MWT) and quality of life (SS-QOL) demonstrated significant time effect (p= 0.001, p=0.022, p=0.002 respectively) with medium to moderate effects over time (partial η^2 = 0.390, 0.225 and 0.375 respectively). For these measures there was no significant group or interaction effect (Table 3).

There were no significant results from the other outcome measures; BMI, DBP, resting HR, PGWBI.

Discussion

Using the STARFISH app for six weeks led to a significant increase in physical activity, as measured by mean number of steps/day, in community living stroke survivors (39.3%). This confirms the findings of a recent meta-analysis which reported that mobile devices are an effective means to support increases in physical activity. [12] The intervention also had a positive effect on the average walking time.

Cross-sectional studies demonstrate that levels of physical activity are reduced following stroke. [1, 29] Indeed the baseline steps/day of all participants was low, on average 3997 steps/day. Previous studies have mainly examined task specific gait training from a rehabilitation care paradigm such that gait parameters, functional ability or falls have been the primary outcome measures rather than physical activity [10]: this is the first study to evaluate a community-based programme following stroke with physical activity (steps/day) as the primary outcome measure.

This is also the first intervention study to include sedentary behaviour as an outcome measure in studies of physical activity and exercise in stroke however the results were not statistically significant. STARFISH is designed to increase physical activity, rather than to reduce sedentary behaviour, which may require different design features. However as sedentary time is a risk factor for cardiovascular disease independent of levels of physical activity [30] physical activity studies should measure both physical activity and sedentary time.

The intervention had a positive and statistically significant effect on fatigue. Post stroke fatigue affects up to 72% of stroke survivors, [31] affects physical and psychological function and is a predictor of mortality following stroke. [32] De-conditioning, physical impairment, depression, sleep disorders, drug side effects may predispose individuals to post-stroke fatigue. [33, 34] The mechanisms by which physical activity might reduce post stroke fatigue is not clear but may include activation of the pre-frontal circuits, insula and anterior cingulate cortex which improves attention and reduces fatigue, [35] reversal of de-conditioning, [36] increase in cerebral blood flow through stimulation of the sympathetic nervous system [37] and alternations in neurotransmitters. [38] Physical activity may also increase individual's self-efficacy and in doing so reduce their fatigue. [33] Future studies of STARFISH, and other physical activity interventions in stroke, should aim to examine the mechanisms involved.

Interventions which include behaviour change techniques associated with control theory (goal setting, planning, monitoring and feedback) are more effective at increasing physical activity than interventions which do not include these techniques. [39, 40] We have mapped the behaviour change techniques within STARFISH to the taxonomy of behaviour change techniques proposed by Michie et al [41] the results of which demonstrated that STARFISH includes the behaviour change techniques of goal setting, planning, monitoring and feedback as well as rewards and social facilitation. [17] The relative contribution of each of the techniques to the effectiveness of STARFISH is not known, however STARFISH is one of the first physical activity interventions in stroke that uses behaviour change techniques of known effectiveness.

The options for stroke survivors to engage in physical activity programmes are limited, with the main barriers to engagement being the costs associated and the transport requirements. [42] Although there are a number of commercially available products for monitoring physical activity which interface with the user's smartphone (e.g. Fitbit, Jawbone) there is little data available on the accuracy of these devices or the evidence for their effectiveness in clinical populations [14]. Furthermore social interaction and community participation are often adversely affected following stroke [43] and the most common motivator of engagement in physical activity programmes is reportedly meeting other stroke survivors. [6] The STARFISH intervention involves groups of people working together to achieve shared goals and the social/group aspects, although virtual, is one of the strengths and novel features of STARFISH compared to other commercial devices. The STARFISH app may therefore be a feasible physical activity option for stroke survivors as it addresses the identified barriers; is relatively low cost, requires no regular transport and is undertaken with other stroke survivors.

Novel and innovative methods to support stroke survivors to become more physically active are required. [6, 10] The use of mobile phone apps within healthcare is rapidly increasing although there are few studies showing the effects of apps on the health of users.[44] Technology based programmes are reportedly a challenge to implement as the technology is not deemed suitable or appropriate for stroke survivors who may lack confidence in their use.[6] The younger cohort of stroke survivors in this study maybe more familiar with, and accepting of, mobile technology than older stroke survivors however the original STARFISH app was adapted using co-production with stroke survivors to ensure some of these challenges were addressed and the app was fit for purpose for the clinical population.

This study has a number of limitations and areas for future consideration. Participants were relatively young for a cohort of stroke survivors and recruited from local support groups and thus may not be representative of community based stroke survivors, limiting the generalisabilityof the findings. Further study would be required on older stroke survivors and those in the more acute stage after stroke. Formal validation of the accelerometer within the mobile phone in measuring steps in those with hemiplegic gait is also required.

Perhaps due to the recruitment method the sample was relatively heterogeneous in terms of physical activity (as demonstrated by the large standard deviations within the results). In addition, participants were not randomised to the groups so two of the four intervention groups knew each other beforehand as they attended the same support group. It would be interesting to evaluate the specific influence of the group relationships in terms of the potential effectiveness of the STARFISH intervention. The intervention group also had one more visit to the CRF, compared to the control group which may have been an additional motivator.

The assessor was not blind to the group allocation, although many of the measures were objective and thus not strongly influenced by assessor bias. The duration of the intervention was only six weeks and longer interventions are required to facilitate long term, sustainable, behaviour change.

The current STARFISH app only measures step counts and other forms of physical activity are not logged. Furthermore although there was a moderate correlation between the step count data from the phone accelerometers and the activPAL (r=0.67), at slower walking speeds the reliability of accelerometers in detecting steps is reduced. Sedentary time also includes sleep time and future studies should record participant's sleep times to allow it to be distinguished from sedentary time. Higher intensity physical activity e.g. walking at higher cadence may improve cardiovascular health more than walking at self-selected speed (REF). The current STARFISH app focuses on increasing the number of steps/day, however further development of the app may be considered to incorporate design features to encourage increasing the intensity of the activity and/or reducing sedentary time to confer maximal health benefit to stroke survivors.

Conclusion

The results of this pilot study indicate that a six-week intervention using the STARFISH app, can increase steps/day, walking time and reduce fatigue in community dwelling stroke survivors.

The effectiveness of the STARFISH app over a longer intervention period requires to be investigated in a fully powered randomised controlled trial. However given the relatively low cost and high penetration of mobile phones STARFISH may offer a relatively cheap, fun method of encouraging community based physical activity not only in those with stroke but also potentially in other chronic conditions.

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The authors declare no conflicts of interest.

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Table 1. General characteristics of both groups (n=23*).

		Intervention (n=15)	Control (n=8)	p value
Sex	Male	**7**	4	1.000[1]
	Female	8	4	
Mean Age (years) (±SD)		56.3 (8.7)	55.3 (12.6)	0.870[2]
Mean time since stroke (years) (±SD)		3.8 (2.5)	4.9 (6.1)	0.638[2]
Side of the body affected by stroke	Left	8	3	0.667[1]
	Right	7	5	
Mobility aids	Independent	8	5	0.257[3]
	Walking aid	7	3	
	- Walking stick	4	3	
	- Elbow crutch(s)	3	0	

* 23 participants as one participant had a severe adverse effect not related to the study

[1] Fisher's Exact test, [2] Two independent sample t-test, [3] Chi-square test

Table 2 Summary (mean and SD) of physical activity/sedentary behaviour, before (baseline) and after the intervention (Week 6) and ANOVA results

	Intervention Group (n=15)		Control group (n=8)		Group Effect	Time Effect	Group/Time Interaction
	Baseline	Week 6	Baseline	Week 6			
Step count (steps/day)	4158 (2550)	5791 (2952)	3694 (3764)	2947 (2399)	0.186	0.261	0.005*
Sedentary time† (hrs)	19.48 (1.81)	18.54 (2.16)	19.94 (1.78)	19.36 (2.76)	0.423	0.127	0.705
Upright time (hrs)	3.70 (2.00)	4.89 (1.92)	3.36 (1.91)	3.82 (3.15)	0.408	0.108	0.467
Walking time‡ (hrs)	0.98 (0.48)	1.32 (0.58)	0.95 (0.75)	0.71 (0.46)	0.185	0.562	0.002*

†Sedentary time includes sleep time, ‡walking time = upright time minus physical activity at cadence <20steps/min * denotes significant result at p<0.05

Table 3 Summary (mean and SD) of outcome measures, before (baseline) and after the intervention (Week 6) and ANOVA results

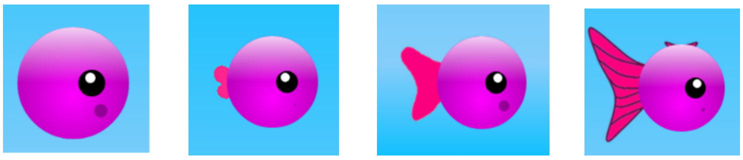
	Intervention Group (n=15)		Control group (n=8)		Group Effect	Time Effect	Group/Time Interaction
	Baseline	Week 6	Baseline	Week 6			
BMI (kg/m^2)	24.1 (3.5)	24.1 (3.5)	24.8 (1.8)	24.9 (2.1)	0.599	0.761	0.570
SBP (mmHg)	144.3 (16.6)	134.1 (15.7)	138.9 (24.0)	134.5 (16.1)	0.740	0.001*	0.155
DBP (mmHg)	81.9 (11.4)	80.1 (10.3)	77.6 (5.4)	77.5 (5.0)	0.380	0.483	0.541
HR (bpm)	77.1 16.8)	75.9 (14.9)	72.5 (12.5)	71.6 (10.6)	0.486	0.505	0.916
10MWT (m/s)	0.36 (0.19)	0.42 (0.18)	0.37 (0.26)	0.41 (0.19)	0.866	0.022*	0.967
SSQoL	171.3 (36.3)	185.4 (35.4)	169.0 (50.1)	176.8 (55.5)	0.768	0.002*	0.313
IADL	5.3 (1.9)	5.3 (1.4)	4.8 (2.3)	5.5 (1.6)	0.853	0.090	0.090
PGWBI	76.7	79.8	79.4	82.6	0.705	0.103	0.961

	(17.7)	(15.0)	(14.8)	(19.8)			
FSS	3.6	3.1	4.1	5.2	0.031*	0.179	0.003*
	(1.4)	(1.4)	(1.4)	(1.6)			

SD= Standard deviation BMI=Body Mass Index, SBP=Systolic Blood Pressure, DBP=Diastolic Blood Pressure, HR=Resting Heart Rate, bpm=beats per minute, 10MWT=Ten Meter Walking test, SSQoL=Stroke Specific Quality of Life Scale, IADL= Instrumental Activities of Daily Living Scale, PGWBI= Psychological General Well-Being Index, FSS= Fatigue Severity Scale. * denotes significant result at $p<0.05$

Figure 1a) Change in visualisation of fish as users reach their individualised step target

b) Examples of sea creatures who are added to the fish tank if the group reach 80% of their weekly target a)



b)