Web based home hazard modification app for falls prevention: the views of those at risk of falling and their carers

Holliday N, Ward G, Walker-Clarke A, Barker R.

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Title: Web-based home-hazard modification app for falls prevention

Sub-title: the views of those at risk of falling and their carers

Nikki Holliday, Gillian Ward, Aimee Walker-Clarke, Rachael Molitor

Abstract

Purpose: The purpose of the study was to assess the usability and acceptability of FallCheck, a web-app that allows users to complete home-hazard assessments within their own home, with a group of people at risk of falling and their carers.

Approach: This mixed method study used an online survey followed by semi-structured telephone interviews to collect both qualitative and quantitative data. A Think-Aloud study was used to test usability of the web-app through structured tasks.

Findings: Findings showed that FallCheck was easy to use, with few usability issues. The web-app was deemed appropriate to use by people at risk of falling (young or old), or by carers if appropriate. The depth of knowledge provision and breadth of content was acceptable, and many participants reported subsequently making changes to their home environment to reduce their risk of falling. Overall, the majority of participants reported feelings of improved confidence and safety, with an increased awareness of fall risks, and a reduction in fear of falling at home.

Conclusion: FallCheck has good acceptability and usability with people at risk of falling and their carers and has the potential to improve access to home-hazard assessment, and affect behavioural change regarding fall risk hazards and behaviour.

Originality/value: This paper describes successful use of an app that may be helpful in identifying home-hazards and making changes to reduce risk of falls, particularly in the absence of occupational therapy intervention, and has the potential for integration into falls care pathways.

Key words: home hazard assessment, mobile apps, occupational therapy, falls, falling, behaviour change, mixed methodology research

Introduction

Annually, an estimated 646,000 individuals die from falls globally, with adults aged over 65 having the greatest number of fatal falls, and 37.3 million falls being severe enough to need medical attention (World Health Organisation 2018). Younger adults with intellectual and physical disabilities are also at risk of falling (Morgan and McGinley, 2013; Finlayson, Morrison and Jackson et al, 2010). The World Health Organisation (2018) recommends that fall prevention strategies emphasize education, training, creating safer environments, prioritizing fall-related research and establishing effective policies to reduce risk. This includes home assessment and environmental modification for those known to be at risk; strategies also supported by the United Kingdom (UK) and other countries (Elliot and Leland 2018, Maggi et al 2018, Stark et al 2017, Pighills et al 2016; NICE 2013).

With regards creating safer environments, gaps in access to home-hazard assessment and intervention have been highlighted – only 65% of hip fracture patients and 19% of non-hip fracture patients receive home-hazard assessment by an occupational therapist and less than half of these take place in situ (Royal College of Physicians 2010). Although evidence suggests that occupational therapist led home-hazard interventions are effective (Pighills et al 2016, Pighills

2011, Costello and Edelstein 2010), the scale and significance of fall-related problems intensified by reduced health and care provision suggests that new, innovative approaches to delivering effective multifactorial interventions must be explored. A number of apps to support those at risk of falling have been reported in the literature, and include apps to determine falls risk via connected shoe insoles (Harte, Quinlan & Glynn et al, 2017), and those that include questionnaires and balance tests (Rasche, Mertens, Bröhl, et al, 2017). However, it has been reported that falls apps that tend to focus on intrinsic risk factors for falling (such as balance and gait), and often neglect extrinsic risk factors, such as environmental hazards (Hamm, Money, Atwal et al, 2016; Rajagoplan, Litvan & Jung, 2017). Where extrinsic factors are considered, many apps still require clinician input to provide advice or interpret results. For, for example, Hamm et al (2019) reported an app which allowed carers to conduct assessments for assistive technologies to improve home safety, and two papers described the use of technology to allow clinicians to conduct safety and hazard assessments remotely via video (Romero, Lee, Simic et al, 2018) and robotic technology (Du, Jagtap & Padir et al, 2016). Whilst these papers reported good usability and acceptability from participants, these apps still require the involvement of a clinician, which leaves such services out of reach for those who do not meet the relevant support. service criteria. Money, Atwal & Boyce et al (2019) described a serious game that educates users on how to detect and fix environmental hazards in the home. Again, this app received positive acceptability and usability feedback from participants, however the advice on how to reduce extrinsic fall risks was limited and did not signpost users to further support, for example advice on assistive technologies that can help.

FallCheck, developed at Coventry University from a sound evidence-base to support home-hazard modification as a component within a multifactorial intervention, is a web-app that

supports identification of home-hazards and directs end-users towards self-management strategies to reduce fall risk at home, including the purchasing of assistive technologies where appropriate. The web-app guides the user through falls risks that may be present in each room of their home, allowing relevant hazards to be added to a personalised 'Checklist', and provides advice on how to reduce or remove these hazards, or signposts to products/services that may help. FallCheck is suitable for any web-enabled device and can be downloaded from www.coventry.ac.uk/fallcheck. Testing of a beta-version of FallCheck by health and social care professionals found good acceptability for use in practice or as a digital self-assessment tool by people at risk of falls, which may support environmental and behavioural change to reduce fall risk at home (Ward, Walker-Clarke and Holliday, 2017).

Reducing falls with behaviour change interventions

Implementing evidence-based occupational therapy, including home hazard modification, often depends on successful behaviour change interventions to enable people to change daily living habits (Lord, Menz & Sherrington, 2006). This requires appropriate methods for characterising interventions and linking them to analysis of the targeted behaviour, in this case, the end-user making changes to their home environment or adopting safer methods of carrying out activities of daily living. Behavioural change models may provide indications of how and why FallCheck could result in behavioural change. For example, the COM-B Model of Health Behaviour (Michie, van Stralen, & West, 2011) suggests behavioural change most likely occurs when one or more components of behaviour are altered. These are: capability (psychological or physical ability to enact behaviour); opportunity (reflective and automatic mechanisms that activate or inhibit behaviour) and motivation (physical and social environment that enables behaviour). A behavioural analysis of why falls occur might suggest the following as shown in Table 1 below:

Table 1: Behavioural analysis of falls using the COM-B model

Using the COM-B model to reflect on the components of FallCheck, the researchers suggest that the web-app could influence all three components of behaviour change:

- the psychological ability; by educating users in the awareness of hazards in the home that are associated with falling AND by providing information on methods to reduce fall risk;

- physical and social opportunity: by offering the opportunity to easily assess presence of fall risks without professional intervention AND providing links to consumer resource sites

- reflective motivation; allowing the user to evaluate and plan their own personalised strategies for reducing fall risk within the home.

For successful behaviour change supported by technology, the technology must also be accepted, so as well as the required components described above, the FallCheck app must be perceived as useful and easy to use by the intended user as per the Technology Acceptance Model (Davis 1989). Ward et al's (2017) study reported the iterative development process and evaluation of FallCheck with health and social care professionals, however the perceived usability and ease of use of a system by the intended end-user is an important influence on user engagement (O'Brien and Toms 2010; Davis, 1989). Usability is defined in ISO standard 9241 (2010, Part 210 p. 3) as the "extent to which a system, product or service can be used by specified users to achieve specified goals with effectiveness, efficiency and satisfaction in a specified context of use" and commonly includes the evaluation of acceptability in terms of ease of use, usefulness, ease of learning and satisfaction. The aim of this study was therefore to evaluate perceived usability and acceptability of FallCheck with a group of people and their carers worried about falling and it's

potential to support behavioural changes and environmental modifications to reduce the risk of falls at home.

Method

This sequential explanatory mixed-method study (Creswell, Plano, Gutmann et al, 2003) used an online survey followed by semi-structured telephone interviews, and a 'Think-Aloud' usability study (Lewis and Rieman, 1994). Mixed methodology is recommended for the evaluation of digital health interventions as it allows collection of data to explore a process and outcome-oriented evaluation (Johnson, Onwuegbuzie, Turner, 2007). Use of mixed methods also afford collection of critical information regarding how people engage and interact with the intervention, including whether or not behaviour is affected offline (Yardley, Spring, Riper et al, 2016).

Ethical approval for the study was given by Coventry University Ethics Committee (reference P42787). Informed consent was obtained from all participants who were assured of their rights of anonymity, confidentiality and that they were free to withdraw from the study without giving a reason.

Participants and recruitment

Inclusion criteria for taking part in the study were: adult over 18 years (to include those younger people who may be at risk of falls) and either a person worried about falling at home or a carer/family member of a person at risk of falling, access to an electronic device with internet access (i.e. smartphone, tablet or PC), and able to give consent to take part in the study. Participants were recruited through Age UK Coventry, Coventry Older Voices, and Parkinson's UK. Carers of those at risk of falling were also recruited through Coventry University staff and

student networks. Gatekeepers sent an invitation email out to appropriate contacts, and those who were interested in taking part were asked to contact the researchers. Potential participants were then provided with a Participant Information Sheet, and given the opportunity to ask the researchers any questions. Participants were also provided with a digital link to provide their consent to take part. The recruitment process and numbers are shown in Figure 1. Participants had the option to take part in the two-week trial or the Think-Aloud study. Of the final two-week trial participants, twenty-two were adults at risk of falling, and eleven were carers of those at risk of falling. Carers were ages 19-76 years, with a mean age of 50, whilst those at risk of falling had an age range of 54-87 years, with a mean age of 70. Regarding the Think-Aloud study seven participants were recruited, three being carers (age range 27 – 39, mean age 32), and four people at risk of falling (age range 55 – 87, mean age 73). Fewer participants chose to take part in the Think-Aloud study and the authors reflected this may be due to the requirement to attend the session at a University location, which may have been difficult for some people at risk of falls.

Figure 1: Recruitment of participants

Data Collection

For the trial, participants were asked to use FallCheck over a two-week period, at least once or more, after which, the researcher sent a link to the survey (hosted via Online Surveys – Jisc, 2018). The survey was adapted from the 30-point USE Questionnaire, developed to assess Usefulness, Satisfaction and Ease of Use of consumer interfaces – metrics of user experience associated with acquisition and use decisions, and usability (Lund, 2001; ISO 9241, 2010) and used in a previous evaluation of the web-app with health and social care professionals (Ward et al 2017). Participants were asked to rate their agreement with statements in a Likert style questionnaire, from ‘Strongly Disagree’ to ‘Strongly Agree’ (Likert, 1932).

Once the questionnaire had been completed, researchers contacted participants to arrange a suitable time and date for a telephone interview. A semi-structured interview schedule was used to guide the interview and lasted between 30-60 minutes. Questions covered areas exploring ease of use, usefulness ease of learning and satisfaction, and changes made following use of the app. Participants were reminded up to three times to complete their questionnaire or provide a date for the telephone interview where necessary. After this, they were considered as drop-outs from the study.

The Think-Aloud evaluation allowed in-depth exploration of the usability of FallCheck incorporating a cognitive walk-through methodology (Lewis and Rieman, 1994; Neilsen and Mack, 1994; Beer, Anodenko and Sears, 1997). Participants were asked to 'Think-Aloud' whilst completing tasks related to functionality, usability, intentions and problem-solving to identify problem areas within FallCheck to then enable formulation of priorities to enhance usability and ease of use (Nielsen and Mack, 1994; Nicol and Gomoll, 1990; O'Brien and Toms, 2010).

Data analysis

Quantitative survey data were analysed using descriptive statistics, in Microsoft Excel. Percentages for participants strongly agreeing or agreeing with the statement as per their response on the Likert scale questionnaires were combined to give an overall figure of positive agreement of acceptability for that item. More than 60% overall agreement (i.e. the majority of participants agreed) was considered acceptable for each item by the researchers (Ward et al, 2017). Qualitative data from the telephone interviews were transcribed verbatim and analysed using thematic analysis (Green and Thorogood, 2014). A collaborative analysis approach was taken (Flick 2014) where researchers (NH and GW) read, re-read, classified and collated data

into categories that were then organised into overarching themes. Where the two initial coders could not agree on categories and themes, a third researcher (RM) was approached to consider consensus. For the Think-Aloud data, usability metrics such as timed responses were gathered, as well as qualitative data as participants talked aloud their thoughts whilst progressing through using FallCheck (Lewis and Rieman, 1994; Jordan, 1998).

Results

Trial results

Survey results are shown in full in Table 2, and are discussed alongside the qualitative thematic results, to place the quantitative results in context.

Table 2: Results of the online survey

Six themes were identified from the thematic analysis of the telephone interviews: (1) End user suitability, (2) Appearance and design, (3) Ease of use, (4) Provision of knowledge regarding home-hazard modification, (5) Behaviour change, (6) Effects on confidence and fear of falling.

End-user suitability

Survey results suggested that FallCheck is suited to the target population. All carers (100.00%) and 86.36% of those at risk of falling agreed that FallCheck would help to identify fall risks in the home, and that it meets the needs of those at risk of falling (64.63% carers, 59.09% at risk). The same proportion (36.36%) of carers and of those at risk of falls stated that they would keep FallCheck on their device, with over a third (36.36%) being unsure of whether they would keep it. This may be because once they had completed the home-hazard modification assessment and made changes they would not need to use FallCheck again unless their circumstances changed.

Finally, most participants (84.84% overall, 90.91% of carers, 81.82% of those at risk) stated they would recommend FallCheck to someone at risk of falling.

FallCheck was regarded as appropriate for use with older people, however it was acknowledged that not all older people would have access to internet-enabled devices, or if they do have access, the confidence or ability to use, a particular concern for those living with reduced cognitive ability or restricted dexterity:

> *"…Perhaps [it wouldn't be suitable for the] very elderly or [someone who] doesn't have the dexterity" (Risk of Falling Participant 3)*

In such cases, FallCheck could be used with the support of a carer or relative. Indeed, carer participants felt that FallCheck was suitable for use by those caring for people at risk of falls, by providing them with information to assess for hazards, to reduce associated fall risk. They discussed how FallCheck was a useful tool to begin a conversation with their loved ones regarding changes at home to reduce fall risk:

> *"…[I'd go] …through it with her… Rather than me going in and saying 'nan – I'm going to sort your house out', I'd say …you've been falling, let's look at this… that's a hazard there isn't it? … It just kind of supports your case." (Carer Participant 4)*

Although falls are often associated with older people (typically 65 years plus), our study attracted interest from younger older people with physical disabilities, with the youngest participant being 54 years old. Indeed, participants highlighted that FallCheck may have a broader appeal, for example to younger people with health conditions which might make them

prone to falls, or health and social care professionals, but that the content and appearance may need to differ for these audiences:

> *"…If it were to be adapted for young people with physical disabilities, the visuals …wouldn't be age-appropriate… I think there would be much more emphasis on technology and the whole environment is totally different from the environment of an older person." (Risk of Falling Participant 3)*

> *"…[it could] be used by physios and domiciliary care workers …people who regularly work with people who are potentially likely to fall …it could be part of the discharge plan…" (Risk of Falling Participant 2)*

The personalised nature of FallCheck was considered well-suited to the audience. Participants described how the checklist allowed them to navigate the house and decide whether something was personally relevant, and then add it to the checklist to be able to return to the information later. This was contrasted to non-digital formats such as leaflets, which may contain irrelevant information.

> *"If you get a leaflet, or a brochure or something, quite a lot of it isn't particularly relevant to you, so you have to wade through the information." (Carer Participant 6)*

FallCheck in its current form may not be suitable for those with limited English language use, or those who are non-verbal communicators, and could be adapted to increase suitability for this group of people:

"…A lot of the carers are not English, a lot of them don't understand English properly …the language is a barrier." (Carer Participant 3)

Appearance and design

Overall, participants liked the appearance of FallCheck, finding it aesthetically pleasing, relevant, age-appropriate, and "clutter-free", allowing ease of navigation, and with clear photos. One participant appreciated that the design did not appear to look like it was from a medical or statutory provider, which made FallCheck feel more accessible:

"It doesn't look scary and it doesn't look medical… It doesn't look like a social services assessment or something… It's friendly." (Carer Participant 4)

Some of the carers commented that the photographs were dated, although it was recognised that this would not matter if the main target user group was older people. Discussion of the future development of FallCheck included the need for an easily discoverable accessibility tool for people with vision problems to adjust the font size. This was also a problem highlighted in the Think-Aloud study, whereby participants attempted to use the 'pinch and zoom' method to enlarge the text, however found that this method did not work. It was also felt that the menu option to increase the font size was not easy to find:

"I found it by accident …You can change the text size which is obviously good from an accessibility point of view, but that it might be worth having at the very beginning just to say 'If this text is a bit small, click here'…" (Carer Participant 4)

Ease of use

Overall, FallCheck was considered easy to use, with few inconsistencies or usability issues. Most participants strongly agreed that FallCheck is user friendly (90.91% of carers, 81.82% of those at risk), and that they could complete tasks in the fewest possible steps (90.91% carers, 81.82% at risk). The 'checklist' feature was well-received, with many people noting the benefits of being able to personalise the hazards particular to their situation The majority of participants felt that instructions were easy to follow (carers – 100.00%, at risk – 90.91%), and they were able to remember how to use it at a later time (carers – 100.00%, risk – 90.91%). One participant suggested the addition of a 'links checklist' to allow users to go through solutions requiring the user to select external links. Some participants also suggested the ability to add custom entries to the checklist, in case they had identified a hazard unique to their situation. Participants also suggested that the checklist could be further improved by adding an export feature, which would allow users to save or print their checklist and the related advice, for future reference:

> *"…If you could create the checklist, and then maybe export it, like e-mail it or something to yourself, or someone else…" (Carer Participant 6)*

With regards ease of navigation, participants found it easy to navigate through the menu structure to complete the checklist, even those who did not perceive themselves to be digitally literate. Participants praised the simple menu structure, including the 'always-accessible' side-bar, allowing easy navigation to other areas of FallCheck:

> *"For me, and I'm not totally good with technology, I found the look was, it was quite easy to follow… the clarity and preciseness of it was good." (Risk of Falling Participant 15)*

Navigating through the menus room-by-room was particularly easy for participants who were using a tablet. This seemed to a balance between a device that allows larger text, whilst still being a mobile device that could physically be taken from room-to-room whilst in use, and that this may be more difficult on a smartphone due to reduced screen and text size. Some participants experienced problems when selecting external links that opened up a new browser tab, with some participants being unsure of how to navigate back to FallCheck:

> *"I found it a lot simpler on the iPad, I think it would have been more difficult on my iPhone because I need [larger] … text." (Risk of Falling Participant 15)*

> *"…I'd been on a link that led me to another link… getting back to that original [FallCheck]. So I am not quite sure how it would be better navigated." (Risk of Falling Participant 19)*

Provision of knowledge/information regarding Home-hazard Modification

The majority felt that the information provided comprehensive, practical advice, and raised awareness of products and solutions that they had not previously known about. They felt that included content was relevant, including indicators of fall risks that had previously not been considered:

> *"I thought it prompted the [things] that I possibly wouldn't have thought of, like the marks on the walls..." (Carer Participant 2)*

It was suggested that breadth of content could be increased to include further information on the garden (e.g. garden shed/garage), and the area immediately outside of the home, (e.g. doorsteps that might require a handrail). Further suggestions included provision of advice on what to do in

the event of an actual fall, and inclusion of information on person-based fall risks (e.g. lack of exercise or clothing). Participants appreciated the external links to consumer and information sites, although there were concerns about the lack of stock and pricing options on some links. Participants appreciated reassurance that the developers were not receiving commission on the products users are signposted to:

> *"The [Name of Site] site I thought was fantastic… That took me straight to all those different aids for the elderly which is fantastic… I found the additional information about who to contact, where to go, that was really useful." (Carer Participant 11)*

> *"I thought actually that's quite a good thing to say to reassure people that you are not just trying to sell them stuff." (Carer Participant 4)*

Behaviour change

In response to using FallCheck, 40.00% of interviewed trial participants reported making a hazard modification, either by purchasing products, contacting services, or via 'quick fixes', such as fixing down rugs.

> *"We put …new lights at the back and front of the house… I have a pair of slippers which I can't walk in properly because they're too big for me, so we've said 'to hell with the expense, we'll get a new pair of slippers that fit me.'" (Risk of Falling Participant 8)*

Some had not yet made any changes to the environment since using FallCheck, although 13.33% stated that they intended to make changes in the near future. Those who did not intend to make

changes (46.67%) included those who had not identified any home hazards via the app. Others suggested resistance to change as a reason, for example carers reported difficulties in making changes, either because the person at risk of falling was reluctant to pay for changes, or simply that many older people enjoy their home environment and independence and did not want to make changes:

> *"If I think particularly about my mum, there's a real resistance there to asking for support, she needs support but she's of the generation that was built out of steel and she's not going to be told by anybody what to do." (Carer Participant 3)*

Effects on confidence and fear of falling

Many participants reported that after using FallCheck, they felt more aware of their environment with improved knowledge on how to help themselves, therefore feeling safer at home, reporting a reduced fear of falling (for themselves or others). No participants reported an increase in fear of falling. Participants whose fear of falling remained unchanged expressed that they still had concerns about falling outside of the home. Alternatively, time elapsed since use may be a factor in this study; for example, one carer suggested that her relative was yet to take on the advice given by FallCheck so it too soon to see a reduction in fear of falling. Others reported increased confidence after using the app, suggesting this came from knowing how they could reduce their risk of falling, and knowing where to get further advice and help. However, confidence was not increased for all participants, for example, one participant stated that he remained unconfident following use of FallCheck because his balance problems meant that he was likely to fall even with home-hazard modifications.

"Very much so. I'm much more aware of it, the app made me think of things I didn't think of and that gave me confidence so I can now… I know where all the hazards are." (Risk of Falling Participant 8)

Think-Aloud Study Results

Table 3 displays the results of the Think-Aloud study. For each task, the table indicates whether or not the participant successfully completed the task, and how long it took them to complete. All participants brought their own devices to use in the study, except for Participant 2 who was provided with a laptop. Overall, participants were able to complete the majority of tasks, however there was between-person variation on how long participants took to complete tasks, and this seemed to be related to each individual participants' experience with using technology. The task which took the longest to complete was Task 1 – downloading FallCheck to the device, and the researchers observed that this was because some of the participants were slower at typing in the web-address, rather than being unable to understand the instructions. Throughout the tasks all participants using a tablet or smartphone devices attempted to use to 'pinch' method to zoom into the display, however at this time FallCheck did not have this functionality. Participant 1 had difficulty locating the 'menu' icon during Task 4 (identifying the main content), as she had significant visual impairment (and brought her own magnifying glass to assist with the tasks). This visual impairment meant that Participant 1 took longer to complete some tasks than the other participants, particularly for finding and navigating to particular areas in FallCheck. One participant experienced difficulty on Task 8, as she was confused as to why the 'back' button would not navigate back to the previous menu. Participants 3 and 5 were confused by the external links, as it was not immediately apparent to them that links opened a new tab. Both

attempted to use the back button to return to FallCheck, but once they realised that the back button would not bring them back to FallCheck, they were able to successfully reorient back.

Table 3: Results of the Think-Aloud study

Discussion

The utilization of pragmatic, applied mixed methods in an iterative manner (Yardley, Spring & Riper, 2016; Ward, Walker-Clarke & Holliday, 2017) has led to the development of a web-app that is easy to use by the target audience, with few usability problems, that has potential to be accepted by the target audience and change behaviours to reduce fall risk. FallCheck was considered appropriate to use by people at risk of falling or their carers. The provision of knowledge regarding home-hazard identification and modification, as well as depth and breadth of content was deemed acceptable, although participants suggested that advice could be extended to cover areas immediately outside of the home whilst still being within FallCheck's remit. Overall, most participants reported increased feelings of confidence and safety, with an increase in awareness of fall risks, coupled with a reduction in fear of falling in the home.

The results provided the project team with clear, actionable suggestions for improvement of FallCheck which when implemented will further improve the usability and acceptability of FallCheck. These changes are detailed in Table 4, and the development team have already begun to implement changes.

Table 4: Changes to the FallCheck app to improve usability and acceptability

Following use of FallCheck, 40.00% of interviewed participants demonstrated behavioural change by making changes within their home environment, or contacting external services for

support regarding reducing the risk of falling (with a further 13.33% indicating intent towards behavioural change). Some participants were resistant to making changes, and there was concern that where the changes were instigated by a carer the physical changes in the home may not endure. These results indicate that FallCheck has the potential to invoke behaviour change which may lead to reduction in fall risk in the home environment. As outlined by the COM-B Model of Health Behaviour (Michie et al, 2011) this would be achieved by improving (1) *psychological ability* by providing users with an educational awareness of risks and hazards around the home and by providing information and methods on how to reduce these risks, (2) *physical and social opportunity* by offering the opportunity to easily assess the safety of their home with the need for professional resource and intervention, as well as providing links to consumer resource sites, (3) *reflective motivation* by allowing the user to evaluate and plan their own personalized strategies for reducing fall risk in the home. The positive results regarding ease of use and perceived usefulness will also serve to maximise any chances of behavioural change, as the technology is more likely to be accepted and ultimately used by the target users (Davis, 1989).

The potential impact of FallCheck is likely to be significant. All participants felt that the web-app was a suitable digital tool to use, and with cohort effects meaning that increasing numbers of older people are downloading and using health apps, and populations expecting mobile health to play a larger role in managing health in the future (Kuerbis, Mulliken and Muench et al, 2017; Nauta, 2017; Economist Intelligence Unit, 2012, cited in PriceWaterHouseCoopers, 2014), the concept of using an app to manage fall-risk may become increasingly normalised. Further, with gaps in access to home-hazard assessment and intervention, FallCheck has the potential to bridge this access gap and thus offer a service improvement by offering those not eligible for state-supported home-hazard assessment by an occupational therapist.

Limitations of the study

The limitations of this study are that the sample were self-selecting and aware that the study required use of a web-app, therefore may represent older people at risk of falling (and their carers) with a higher level of digital literacy and appetite for health-app use than is found in the general population. It is also not known how many times each participant used FallCheck over the two-week trial period, therefore there may be differences in time spent using FallCheck which may have influenced the results. The trial only followed behavioural change and intention following a short two-week period, and thus was not able to detect changes outside of this short time period. Finally, as reported in Ward et al (2017), whilst the USE evaluation tool (Lund, 2001) lacks evidence of psychometric properties, the researchers considered it appropriate for assessment of usability and it has allowed the researchers to gain information regarding the usability of FallCheck which has led to distinct changes being made that have a high likelihood of improving usability further.

Next steps will require a larger scale trial of the updated version of FallCheck to further validate the web-app following the changes, and also to provide evidence as to whether using FallCheck promotes behaviour change, and provides a service quality improvement regarding the physical health and wellbeing of people at risk of falling (e.g. reduced falls, increased feelings of safety and confidence, and improved quality of life), and whether these changes are maintained over time, and continue in line with increasing fall-risk (e.g. is the user able to recognize when re-engagement with FallCheck may be necessary). To affect behaviour change on a larger scale, it is likely that FallCheck will need to be embedded into care pathways in order to reach those who would benefit most from home-hazard modification, therefore future research should explore the practicalities of integrating FallCheck into care pathways, and whether there would be any

barriers, such as digital literacy of staff, and subsequent change management strategies to facilitate integration. The participants in the present study are likely to be more motivated to prevent falls than the general fall-risk population, therefore it would be pertinent to explore reasons for lack of engagement amongst populations who are not likely to engage with FallCheck as engagement is a precondition for effectiveness of digital behaviour change interventions (Yardley, Spring, Riper, et al 2016).

In conclusion, the FallCheck web-app, developed from a sound evidence base, has potential to add a quality improvement to the management of falls as it supports self-management, is tailored to individual users, and offers an intergenerational and wider public health and information approach to falls management. It encourages behavioural change via the identification of home-hazards and directs users to self-management strategies to reduce fall risks arising from the identified hazards. FallCheck is acceptable to both people at risk of falling, and their carers, and has scope to be suitable for other users, although further research would be required to ascertain suitability with young adults, and further changes may be needed to appeal to much younger groups. With reduced access to home-hazard modifications supported by an occupational therapist or other health professional, FallCheck may be a useful digital behaviour change intervention to support people at risk of falling in the absence of (or in addition to) face to face support.

Declaration of authorship

All authors made substantial contributions to the conception or design of the work (NH/GW/AWC); the acquisition, analysis, or interpretation of data for the work

(NH/GW/AWC/RM) and were involved in drafting the work or revising it critically for important intellectual content (NH/GW/AWC/RM); and final approval of the version to be published (NH/GW/AWC/RM); and have agreed to be accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved.

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