



## Methodological Review

## Fall prevention intervention technologies: A conceptual framework and survey of the state of the art

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## ARTICLE INFO

## Article history:

Received 16 October 2015

Revised 14 December 2015

Accepted 20 December 2015

Available online 7 January 2016

## Keywords:

Falls prevention

Technology-based interventions

Conceptual framework

Collaborative care

Healthcare

Self-care

## ABSTRACT

In recent years, an ever increasing range of technology-based applications have been developed with the goal of assisting in the delivery of more effective and efficient fall prevention interventions. Whilst there have been a number of studies that have surveyed technologies for a particular sub-domain of fall prevention, there is no existing research which surveys the full spectrum of falls prevention interventions and characterises the range of technologies that have augmented this landscape. This study presents a conceptual framework and survey of the state of the art of technology-based fall prevention systems which is derived from a systematic template analysis of studies presented in contemporary research literature. The framework proposes four broad categories of fall prevention intervention system: Pre-fall prevention; Post-fall prevention; Fall injury prevention; Cross-fall prevention. Other categories include, Application type, Technology deployment platform, Information sources, Deployment environment, User interface type, and Collaborative function. After presenting the conceptual framework, a detailed survey of the state of the art is presented as a function of the proposed framework. A number of research challenges emerge as a result of surveying the research literature, which include a need for: new systems that focus on overcoming extrinsic falls risk factors; systems that support the environmental risk assessment process; systems that enable patients and practitioners to develop more collaborative relationships and engage in shared decision making during falls risk assessment and prevention activities. In response to these challenges, recommendations and future research directions are proposed to overcome each respective challenge.

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## 1. Introduction

Falls prevention within the home environment has been a topic of research for over 30 years [1] and is recognised as an important health issue within the United Kingdom (UK), Europe, North America and Australia [2]. The frequency of falls increases with age, often as a result of physical, functional, and cognitive impairments which are likely to emerge as a result of advanced ageing [3]. Consequently, it is estimated that 30% of older adults aged 65 and over fall at least once a year [4]. One in five falls result in bone fractures and the need for specialist medical attention [5]. Fall related fractures may cause disabilities and in some extreme cases premature death among older adults, which has a significant impact on

demand for health and social care services resulting in a cost of £1.8 billion per year to the National Health Service (NHS) in the UK [6].

Falls prevention activities are carried out across a range of health disciplines including occupational therapy, physiotherapy, general practice, nursing, geriatric, gerontology health and social care [7–9]. There is evidence in the falls prevention research literature which suggests that in excess of 50% of potential falls relating to older adults are avoided as a result of ongoing falls prevention interventions [10]. There is a range of clinically established prevention interventions that target fall related risk factors [1]. A number of recent meta analyses, and systematic reviews considered a comprehensive range of falls prevention intervention studies for preventing falls in community-dwelling older people [11–15]. Fig. 1 presents a diagrammatic summary of the key categories of intervention that are considered in these reviews and serves as a high-level overview of the key areas in which falls prevention research has been undertaken in recent years.

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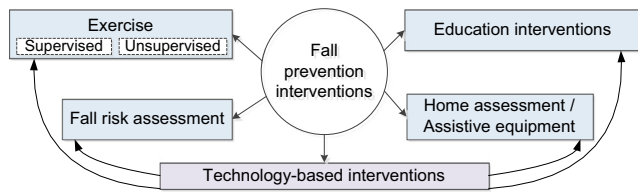


Fig. 1. Overview of falls prevention interventions.

In recent years, one popular approach to falls prevention has been to explore ways of targeting the restoration of muscle strength and balance for prevention of fall risks [16,17]. Exercise interventions are becoming an increasingly popular approach to falls prevention and there is an extensive body of evidence suggesting that these interventions can be effective in reducing falls and the risk of falling [18]. There are many issues, however, with regards to adherence and acceptance of the range of existing *exercise* interventions. *Supervised* one-to-one interventions with the patient and the practitioner are resource intensive in terms of cost and time, whilst supervised group exercise interventions require older adults to be able to travel to the location of exercise classes. Furthermore, there are many issues with regards to adherence and acceptance of existing *unsupervised* home-based exercise interventions, partly due to the lack of interactivity and personalisation that the paper-based exercise interventions typically use in these settings [19]. As such, 3D technology and games are increasingly being seen as a potential means of improving adherence by providing patients with more tailored and interactive exercise programs to engage with [20,21].

*Fall risk assessment* is an approach used to assess a number of risk factors, specifically mobility issues and physiological factors that include muscle strength and balance, stability, posture and gait reaction time. There are many tests (e.g. Berg balance scale, Timed Up and Go, Turn 180° test) that have been developed to screen older people for fall risks in the community or in a clinical setting [22]. These tests are widely known with research evidence that supports their effective use in predicting fall risks to uncover issues that may lead to falls. Older adults who are exposed to fall risks such as gait and balance abnormalities, admitted into hospital for medical attention as a result of falling are at high risk of falling. Consequently, they are offered a multifactorial fall risk assessment that is administered by clinicians in a clinical setting, or within a specialist fall service. Such assessments are a part of multifactorial risk assessment or a singular assessment. It is crucial that older adults who are at high risk of falling are identified using the fall risk assessment tests so that targeted falls prevention interventions can be prescribed. Conducting such assessments has included high cost equipment in specialist fall services. However, 3D technology and games have shown promise as a low cost solution to augment traditional fall risk assessments and to account for low adherence rates of self-assessment of fall risks done at home [23].

*Education interventions* are developed to increase knowledge about falls prevention and educate patients regarding their risk of falling and falls prevention strategies based on the available evidence-based literature. This type of intervention, as a single component, is often part of a multifactorial falls prevention programme, which leads to positive outcomes such as behavioural change, decreased fear of falling and increased mobility. Education interventions typically take the form of fact sheets with evidence-based materials. These inform their readers about the preventive measures to reduce falls, or checklist to help to identify fall hazards in the home and to take preventive measures such as change of behavioural patterns. In addition, patients are also offered information regarding where they can seek help and assistance in case of a

fall to avoid long lie syndrome. As such, there is little research evidence of education interventions as a single component intervention that reduces the risk and rate of falls [11].

*Home assessments* are carried out and *assistive equipment* is prescribed to reduce falls within the home environment. Typically, home assessments involve clinicians visiting the older adult's home to assess the suitability of the home environment in relation to the mobility of the patient. Clinicians then propose adaptations, often via the installation of assistive equipment, in order to facilitate independent living and to mitigate any potential fall risks, which could arise during performing activities of daily living (ADLs). Accordingly, reviews in the falls literature have revealed that home assessments and adaptations as a single intervention do not, in general, significantly reduce the risk of falling. They do, however, have some positive effect for those who are at higher risk of falling [8,11]. Furthermore, identifying environmental risks and adapting the living environment accordingly may reduce fall risks among older adults significantly [24]. By definition, assistive equipment are systems or specialist devices prescribed by clinicians, that provide functional support to older adults to help with mobility, which would otherwise been proven difficult to do and maximises independent living and reduces falls. Assistive equipment includes grab rails, walking frames, hoists, raised toilet seats, stair rails, raised chairs and beds within the patient's home [25–30]. Notwithstanding the benefits of the assistive equipment provision, there are issues which often persist with the use of equipment as it is not always adopted successfully. Consequently, research evidence indicates that more than 50% of home modifications and equipment are rejected [31–33]. As a result, there has been an increase in functional decline, leaving older adults vulnerable to the risk of falling. Equipment abandonment is often associated with a number of factors such as lack of knowledge about the equipment's use, involving the users in the decision making process, their attitude towards the equipment, and a lack of fit of the equipment between service users and their environment [32,34–36].

*Technology-based interventions* have been deployed in a wide range of falls prevention contexts and include diagnosing and treating fall risks [37–39], increasing adherence to interventions [40–42], detecting falls and alerting clinicians in case of falls [43–45]. Technology is also seen as having the potential to play a key role in enabling older adults to self-assess, which is in line with the personalisation agenda within the UK, giving older adults the opportunity to perform self-assessments for assistive equipment provision [46–50]. With an increasing pressure and demand on the NHS and with limited spending budgets, partly due to an unprecedented increase of life expectancy resulting in an ageing population [51], there is a need to find new ways of providing care to enable patients to provide effective self-care and further steps towards recognising patients as experts of their own care by giving them the chance to provide their own care [52]. Innovations in technology are seen as key to reducing costs and lessening the burden on the healthcare system, whilst also improving the quality and effectiveness of care provided [48], thus enabling patients to engage in the effectiveness of self-care to improve clinical outcomes. Encouraging the adoption of technology, however, has been a primary area of focus, particularly among the older population. There are contributing factors that include usability for the older adult cohort [53], exploring older users' perceptions and beliefs [54], intuitive interactions [55], and multisensory feedback [56], which play a central role in motivating older adults to engage in clinical interventions. These should be catered for if technological interventions are to be adopted by older adults. Therefore, deploying usable and effective information and communication technologies (ICT) in areas of assisted healthcare, specifically falls prevention, within the home has the potential to enable older

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