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Use of Information Technology for Falls Detection and Prevention in the Elderly

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Abstract This research aims to clarify the arguments in the body of knowledge on IT use in fall prevention among the elderly, synthesize ideas to assist in the delivery of healthcare to prevent falls in older people and further add to the available body of knowledge. An extensive literature search was carried out and the information retrieved from the literature was synthesised into paragraphs using themes to structure the types of information technology used for falls prevention. The different modalities of IT used in falls prevention at the different places of care for each category were explored and inferences were drawn from the structured themes which summarized the major findings. The research found that there is potential ground for a wider use of the forms of IT used in falls prevention in the elderly in various settings and outlined the factors involved in this usage. With further refinements in larger studies, many of these forms of IT would be better explored and acceptance is likely guaranteed provided they are accessible and affordable. The need for IT use in fall prevention in the elderly is unavoidable with the trend in technology and the associated convenience. More work is needed to further define the effects of IT in falls prevention using larger prospective studies that will be more generalizable.

Keywords Information technology · Falls prevention · Elderly · Active ageing

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Introduction

Information Technology (IT) has been put to several uses, creating speed, comfort and efficiency in service delivery in its various applications. It has served several functions all through its evolution and its use in healthcare is increasingly being linked to advances in the field of medicine. This can be exemplified by the higher quality of health care delivery in more technologically advanced countries when compared to the developing world (Tomasi et al. 2004). Information technology includes any part of the hardware or software used to store, retrieve, and manipulate information (Alexandrou 2011) and it has helped patients and healthcare workers to communicate faster and monitor treatment processes with ease (ADHA 2003). Particularly important is the use of various forms of IT in delivering healthcare to the aged. For many aged care service providers, the use of information technology offers many benefits in terms of efficiency, resident care and safety (ADHA 2008).

Falls are the leading cause of injury-related deaths in the ageing population (Weber et al. 2008). Approximately 51 % of residents in long-term care facilities fall at least once each year with ten percent to 25 % of these falls resulting in serious injuries (Scott et al. 2003) while 30–40 % of community dwelling older adults have been estimated to fall each year (Moyer 2012; Rao 2005). Also, an analysis of research on preventing falls in older people showed that falls place a financial burden on the individual and the community (ADHA 2004). It was estimated that falls in those aged above 65 costs the NHS £4,600,000 each day (Age UK 2010).

Significant gaps exist in research on effective falls prevention and few studies exist that demonstrate the successful translation of evidence to practice (Scott et al. 2007). Further research is justified to clarify the impact of IT strategies to optimise care for people with tendencies to fall (Gillespie et al. 2009). There is a need to explore the benefits of information technology in preventing falls in the elderly (Leitch et al. 2010), and it is important to identify methods for improving uptake and ongoing participation by older people in recommended fall prevention actions (ADHA 2004). Scott et al. (2003) in their published review on best practices in falls prevention also recommended further research on falls prevention interventions and their effect on different sub-populations of seniors.

Potentially, IT strategies aimed at optimising care and preventing falls in the elderly offer significant contribution to effectiveness of health services. While a preliminary search revealed that a review on the use of information technology for falls prevention in the elderly has not been published, this study explored the different ways information technology is being used and its benefits in falls prevention in the elderly. This study is a contribution to understanding the benefits of IT use in falls prevention in the elderly.

This review is theoretical in nature and is intended to adopt a textual approach to elucidate contentious areas in the body of knowledge on the use of information technology for fall prevention in the elderly and also provide new conceptual insights into such knowledge. This research summarized and critically analyse current knowledge generated by basic science as the foundation of future scientific and clinical advancement because an understanding of the current state of knowledge is a prerequisite for further studies. It also aimed to clarify and perform a critical analysis on the

arguments in the body of knowledge on IT use in falls prevention among the elderly, offer ideas to assist in the delivery of healthcare to prevent falls in older people and further add to the available body of knowledge. This is because a sound theoretical base is considered vital to the design of complex interventions and in explaining likely mechanisms for success (Wilson and Petticrew 2008).

Methodology

Search Strategy

A number of databases were used in the search for relevant academic published articles including BMJ, Oxford Journals, Sage journals, PubMed, Scopus, Embase, Cochrane, Sumsearch, Uptodate, Web of Science, Medscape, MD Consult, Ovid MEDLINE, Cinahl, African HealthLine, MagNet, Asian Journal of Social Sciences, Google scholar and Web of Knowledge. Bibliographies cited within references, Internet Evidence Based Medicine Resources and text book sources were also used. Searches for grey literature on the topic area were conducted using Google. Articles for this review were drawn from peer-reviewed journals, conference papers, consumer studies, health professional studies, research by recognised independent institutions as well as systematic and narrative reviews of the various related topics.

A broad range of databases were chosen because studies on this title might be referenced in non-academic databases.

Search Terms

The terms used for search purposes were: elderly, health, internet, falls prevention, use of information technology, online health information, e-health and aged care.

Exclusion/Inclusion Criteria

The literature review focused on research published from 2002 to November 2012. This time interval was chosen because of the bulk of the published materials on the topic and because studies earlier than 2002 would give references that may no longer be relevant to the current technology. The study therefore excluded research works published before 2002. Studies from any country, exploring the use of information technology in preventing falls among the aged and dealing with the research question were included. The studies included were only those that have been carried out on patients aged 65 and above who are classified as 'elderly' by the World Health Organization (WHO 2001, 2008). Papers that are not relevant to the topic or that are duplicates of other articles were excluded. The search was also limited to studies published in English because it is the commonest language used in international conferences and seminars worldwide (Moher et al. 2003) and yielded adequate literature for this review. This language limit also reduced the complications, time and resource consumption that may arise from interpretation of other languages and as well reduced information that might be hard to compare (CRD 2009). A diagrammatical illustration of the exclusion process is rendered in Fig. 1.

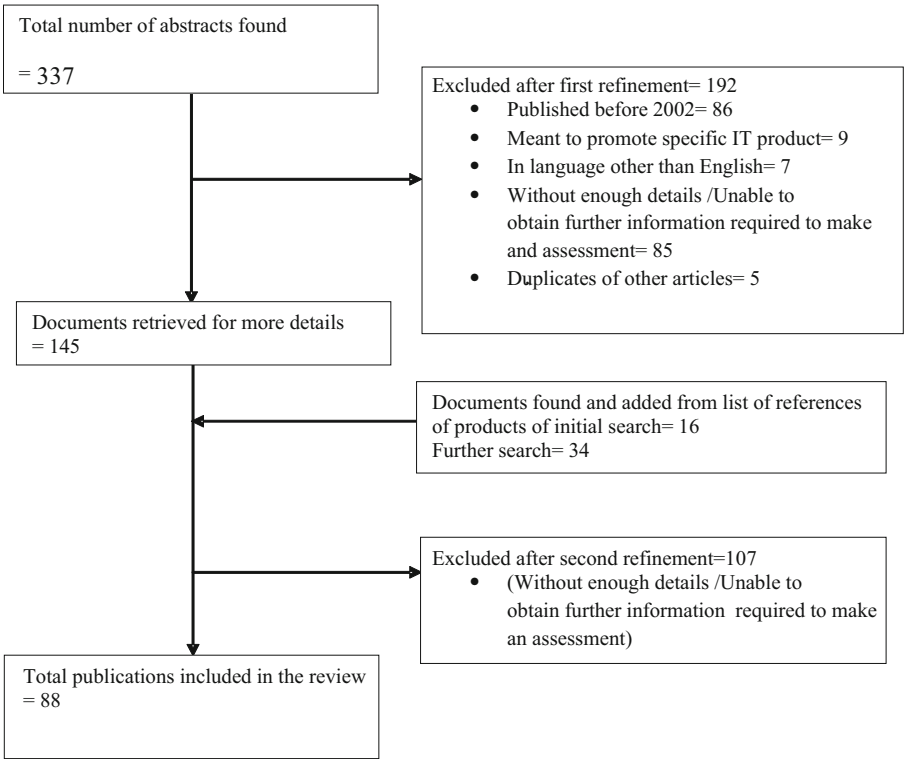

Fig. 1 Diagram showing path of document selection

Search Results

This search strategy yielded 337 articles and these were examined in order to assess their suitability. In total, 88 articles met the criteria for this review after eliminating duplicates.

Citations located by the search were sifted through and a first decision was made based on titles and, where available, abstracts. These were assessed against the outlined inclusion and exclusion criteria, and the research question. An article that did not meet the inclusion criteria was rejected. Rejected articles that were clearly not relevant were recorded as irrelevant studies while those that addressed the topic of interest but failed on one or more inclusion criteria were noted as such. For studies that appeared to meet the inclusion criteria, or in cases when a definite decision could not be made based on the title and/or abstract alone, the full paper was obtained for a full assessment against the inclusion criteria.

Narrative Synthesis

The information retrieved from the literature was synthesised into comprehensive paragraphs using a narrative approach (Popay et al. 2006). Themes were used to structure the types of information technology used for falls prevention and categorise them under some likely places of falls of the elderly: falls at home, falls in a nursing

home or hospital. These described the different modalities of IT use in falls prevention at the different places of care.

The different methods and types of IT use in falls prevention for each category were explored. The literature was interpreted along with the quality assessment of the papers. This assessment was done with a narrative overview rating scale which was obtained from the clinical update of Green et al. (2006).

Literature Review—Preventing Falls at Home

There are several IT methods and tools that have been tested or used in falls prevention while maintaining the ability of the elderly to grow old at home (ageing in place) and they are discussed in the following paragraphs.

The Telephone in Falls Prevention

The use of telephones as a form of IT in falls prevention has been explored in several ways. A fall risk model constructed by Stalenhoef et al. (2002) using telephone calls for follow-up helped to monitor risk prone elderly patients in their homes and information about fall determinants were gathered. This model facilitated the prediction and prevention of falls and is an easily accessible means of IT for use in preventing falls, as telephones are available to most individuals and are easy to use. An evaluation carried out by Dai et al. (2010) on the use of Android phones as a platform for detecting falls also revealed a high level of fall detection performance. This result is similar to that obtained from the Telecare program to improve care for falls at a Veterans Affairs healthcare facility described by Miake-Lye et al. (2011). The Telecare program used a nurse advice telephone line to identify patients' risk factors for falls and to triage patients to appropriate services. Although only 35 out of the 113 patients considered for inclusion participated during the lifespan of the project, medical record review showed that the system enhanced usual medical care with respect to home safety counselling and helped veterans maintain a higher level of safety. A modification of this system had been used in Thailand by Assantachai et al. (2002) who recruited 1,043 elderly subjects living in the urban area around a hospital for a study with 585 of them allocated to the study group and 458 subjects to the control group. A leaflet containing information on important risk factors of falls within their community was enclosed with a follow-up postcard in the study group only. All respondents received a postcard asking about any falls which had occurred over the previous 2 months on six occasions and a telephone call if the postcards were not returned to the team. The percentage of elderly who kept in contact was 92.5, 90.6, 89.3, 89.2, 86.2 and 85.45 % for the first to final follow-up respectively. After 1 year of longitudinal study, the overall incidence of falls was 6.6 % in the study group and 10.1 % in the control group. This modification is a cost-effective method of preventing falls as leaflets can be easily supplied to patients and followed up with phone calls. Illiterate patients however may find it difficult to read from leaflets and benefit from this programme. This can be solved by having the leaflets translated to the local dialects of the patients and the healthcare worker or literate relative of the patient may also read and explain the contents of the leaflets.

A difficulty that users of telephones for falls prevention may face is the fluctuation in network signals that may arise especially in severe weather conditions and this may prove to be a significant disadvantage in periods of need. Also, elderly residents of areas not reached by telephone networks especially in rural communities of developing nations may not be served by such technology. However, it is expected that telephones would be easy to use and beneficial to the elderly provided that telecommunication companies and service providers can maintain good network service to as many areas as possible.

Smart Home Technology and Wireless Sensor Network

It has been observed that many people prefer to grow old at home (Cheek et al. 2005). Smart home technology facilities would aid ageing-in-place by assisting patients with emergency assistance, fall prevention/detection, reminder systems, medication administration and assistance for those with hearing, visual or cognitive impairments. The benefits of this technology include continuous monitoring and improved psychosocial effects to make ageing-in-place a reality.

A wireless sensor network (WSN) can be used in smart homes monitoring and it consists of spatially distributed autonomous sensors to monitor physical or environmental conditions, such as temperature, sound, pressure, etc. and to cooperatively pass their data through the network to a main location (Surie et al. 2008). The WSN is built of "nodes" connected to a sensor with each node typically having several parts: a radio transceiver with an internal antenna or connection to an external antenna; a microcontroller; an electronic circuit for interfacing with the sensors; and an energy source, usually a battery (Debnath et al. 2012) (Figs. 2 and 3).

Tyrer et al. (2006) explored the use of sensors to monitor the activities of the elderly and prevent falls while they live in their homes by measuring motion, footfalls, sleep and restlessness through sensors and sensing mats, all connected wirelessly to a computer. This study focused on offering the elderly 'ageing in place' and allowing them to have control over their privacy and treatment while providing substantive improvement in quality of life. Measurements of motion, footfalls and sleep patterns with the sensor network are a substitute for some monitoring functions of a caregiver and would relieve the burden of patient care. Workload on caregivers and functional decline of patients would be reduced as data collected are continually used to implement interventional programmes. Also, the wireless models presented by Fernandez-Luque

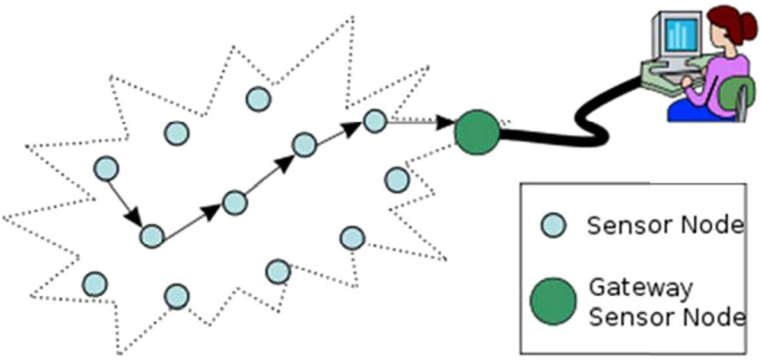

Fig. 2 A simple wireless sensor network (VTT 2013)

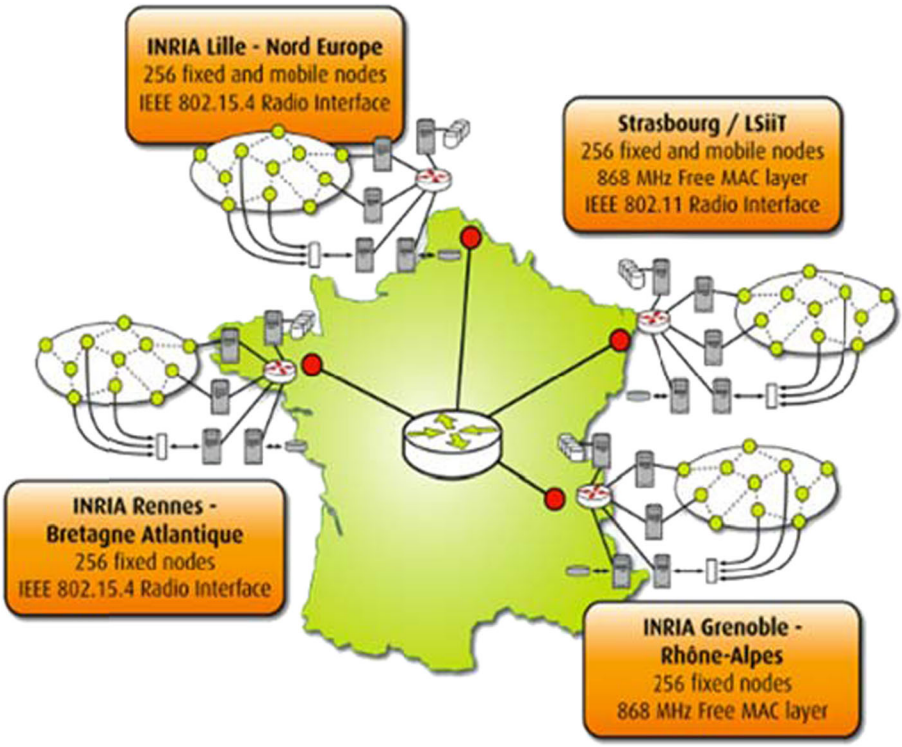

Fig. 3 A multi-hop network (SensLAB 2013)

et al. (2010a, b) for detecting falls in the elderly were based on nodes that hopped radio messages to a base station where they were passed to a personal computer. These systems assist the user without the need to wear a device, a contrast to the modified fall detection sensor device created by Eklund et al. (2005) which has to be placed on the user's hip like a waist belt. Although this device provides continuous and instantaneous data corresponding to the changes in the user's body and it facilitates the safety, security, and continuous and accurate supervision of a constant care environment, the user must remember to wear it. When the subject moves around at night-time, such as making a trip from the bedroom to the toilet, it is unlikely that they would remember or even feel an inclination to wear such a device. Ariani et al. (2010) investigated the potential usefulness of an unobtrusive fall detection system, based on the use of passive infrared sensors (PIRs) and pressure mats (PMs) that detected falls automatically by recognizing unusual activity sequences in the home environment (Table 1).

Table 1 Sensitivity, specificity and accuracy of a sensor based algorithm (Ariani et al. 2010)

Sensitivity (the ability of the system to detect actual falls when they occur)	100 %
Specificity (ability of the system to detect a 'no fall' situation when the subject has not fallen)	66.67 %
Accuracy	90.91 %

The system reduced the 'long-lie' scenario (inability to get up from the floor after a fall, followed by lying on the floor for 60 min, or more) after a fall

The specificity of this system is relatively low and false positives could be high such that falls alarm are triggered when falls have not occurred. This could be improved by using algorithms with higher differentiating capacities. Since patients do not need to wear any device, it would help prevent falls in frail geriatrics patients and those suffering from dementia. However, the cost and availability of WSNs are major concerns of this technology (Cheek et al. 2005). It would be useful for further research studies to be carried out on WSNs to explore cheaper components so as to make feasible its applicability in low income households. Sensors can be improved to cost less and weigh less with batteries lasting longer. It is important to consider the cost and sustainability when selecting WSN for use as long as reasonable quality and function are not compromised.

Artificially Intelligent Camera-Based System

A method to detect falls with a multiple camera system without any wearable device was proposed by Auvinet et al. (2008). The system used image analysis to localise people and reconstruct their 3D shape and position while cameras shared a large common field of view and detected fall positions. Experimental results obtained with 14 different fall scenarios and 14 normal daily activities showed a 100 % fall detection efficiency. Similarly, Wang et al. (2010) conducted experiments using inexpensive webcams for extracting body sway parameters from a three-dimensional reconstruction. Subjects stood and swayed in the anterior–posterior direction and then in the lateral directions with two different frequencies. On computer software, the images taken from the cameras are used to construct a three-dimensional representation of the markers, noting the position of the subject. The development of this technology provides potential capability of measuring body sway in daily living environment for elderly people, and can be used as part of a balance, stability and fall risk assessment tool. Swaying can be captured and assessed for fall risks in elderly patients for whom interventions can be designed to prevent falls. A Camera based systems is particularly important for an elderly person who has suffered a fall because such may lie on the ground for a long period of time before proper healthcare would arrive, a major risk factor, particularly for the elderly living alone. The system is automatically activated and reliable for prompt detection of falls, injury limitation and prevention of possible subsequent falls.

Digital Video Disc (DVD) and Game-Based Measures

Technology created for informative entertainment and recreation like the DVD and game consoles can be utilised as a tool in falls prevention. Yamada et al. (2011a) carried out a randomized control trial to evaluate the effectiveness of a DVD-based dual-task (DT) stepping exercise to improve the DT walking capability in elderly people. Dual tasking (DT), or engaging in two activities at the same time, is common in daily living. With advancing age, the addition of walking to activities of daily living involving DT can create difficulties that lead to complex multi-task situations, thus increasing the risk of falling. If DT is improved, it helps the subject to concentrate and have greater control on his surroundings thus reducing the incidence of falls (Silsupadol et al. 2006) (Table 2).

In another study, Yamada et al. (2011b) carried out a game-based assessment with the purpose of examining whether the Wii Fit program can be used for fall risk

Table 2 DVD-based DT exercise trial (Yamada et al. 2011a)

	DT group	Control group
Prescribed activity	20 min of group training twice a week using an exercise DVD that included a 15-min basic exercise and a 5-min DT exercise	Nil exercise programme
	(Dual task involved verbal task and quick stepping)	
Duration	24 weeks	24 weeks
Clusters	4	4
Sample size (n)	48	45

The median relative adherence to the study was 87.5 % in the DVD group and the outcome measurements, including the DT walking capability among participants in the DVD group were significantly improved ($p<0.05$)

assessment in healthy, community-dwelling older adults. The 45 elderly women who were included in the trial were aged 65 years or older and community-dwelling. A peripheral Wii Balance Board is available with the Nintendo Wii video game console. It is a wireless device that can be powered for up to 60 h with four AA batteries and communicates via Bluetooth with the Wii console. It has four pressure sensors situated at each corner from which enough information is available to obtain calibrated readings on changes in user's standing posture. The Wii Fit program requires the distribution of attention to a motor task and the monitor (cognitive task). Thus, it is assumed that the Wii Fit program includes a constituent of DT.

Websites

The internet is a vital tool for delivering health promotion and prevention strategies. Internet-based health prevention aims not only to reach a wider population more efficiently, but also to sustain effective communication between patients and the healthcare professionals that take care of them. In addition, the Internet gives unlimited possibilities for finding health information and offers access to knowledge and empowerment (Alpay et al. 2004). The internet is also a system that the elderly can use themselves if they have access to simplified information, websites and technology. A survey of 500 elderly people (65 and above) living in Lisbon, Portugal revealed 72 % owned a mobile phone, 13 % used computers, and ten percent used the Internet. The same survey revealed the elderly were willing to learn how to use computers and the internet if properly guided. Programmes can be targeted at training the aged on how to use computers and health care providers can put information on the web which can be read and utilised.

Websites have been developed to target the elderly population for effective prevention of falls. For example, the NHS has websites that can be accessed by older persons for information on healthcare (Brzezinski 2009) and the Dutch 'SeniorGezond' website is also focused on the elderly population in the domain of fall prevention (Alpay et al. 2007a). Nyman and Yardley (2009) accessed the usability and acceptability of a website that provides older people with tailored advice to help motivate them to undertake physical activities that prevent falls. Views on the website from interviews

with 16 older people and 26 sheltered housing wardens were analysed thematically. The website was well received with only one usability difficulty with the action plan calendar. The older people selected balance training activities out of interest or enjoyment, and the wardens were motivated to promote the website to their residents. Studies like this would help website developers to improve on areas of need. According to Tinetti (2003), it is important to consider putting several aspects of falls prevention into broadcast/website with well integrated message of healthcare teaching for elderly citizens taking medications that can make them more susceptible to falls. The doctors prescribing these drugs and the patients using them need to be informed about the risks of falls associated with them as well as the precautions to follow to avoid falls.

A disadvantage in relying on the internet for falls prevention was investigated by Whitehead et al. (2012) who stated that "websites have fallen short of their potential to provide accessible, evidence-based information on the risks of falls and their prevention" despite noting that increasing numbers of older people are accessing the internet for health-related information. Forty-two websites were identified using popular search engines and were assessed using evidence-based guidelines and codes of conduct on coverage of falls-related information, credibility and senior friendliness. Overall, scores were poor for coverage of falls information and credibility, although they were higher for senior friendliness. Few of the websites had been recently updated and none provided individually-tailored advice.

Another disadvantage in solely relying on the website in falls prevention unlike other forms technology described is that it is dependent on the patient being able to access it. Elderly citizens that are not computer literate or have some limitations in using a computer may not be able to utilise it. Even seniors who are computer literate may find navigation difficult on a website. They may also have problems in evaluating health information, assessing good quality information and understanding the information retrieved (Alpay et al. 2007b) Generally though, it still remains advantageous and could positively complement other forms of information technology in falls prevention especially as many patients are more involved and take an active role in deciding about and planning their care (Evans et al. 2003). There is an increased awareness amongst the elderly population that although they may have health problems, they can take action to live healthy. As the ageing population is rising and health costs become more expensive, health professionals and policy makers are often stimulating this attitude and the need for more prevention and self-management. Appropriate information organised in a meaningful way should be made available to the elderly. Websites intended for falls prevention should be made simple, easy to access and preferably equipped with a navigation guide for the elderly population. The information given should be two-way with the healthcare giver supplying information on falls prevention and also getting information on website usability from the users.

In-Patient Settings—Hospitals and Nursing Homes

In-patient falls are relatively common and are widely recognized as causing significant patient morbidity and increased costs of care (Bates et al. 2003). Risk of falls increases markedly with age (Dykes et al. 2010) and hospitalization further increases risk of the unfamiliar environment, illnesses, and treatments. Various ideas are being offered that

would provide the appropriate level of care in nursing homes and hospital settings in a more efficient manner by taking advantage of current technologies.

Cameras

Cameras can be used to monitor elderly in-patients so as to prevent falls. Oggier et al. (2003) developed a toolbox for the automatic monitoring of elderly residents in a nursing home (or in the natural home environment) that monitors patients' activity patterns and the changes associated with such patterns rather than monitoring vital signs or other biomedical parameters. The information on activity is derived from visual information using image processing algorithms while the visual information is acquired using 3D camera technology. The system is highly accurate and can monitor patients and detect various falls positions. By incorporating this technology into the unobtrusive fall detection system (WSN) described by Ariani et al. (2010), the specificity of that system could be improved since the cameras are meant to record whatever is in their view and the likelihood of misinterpreting a standing position for a fall is low. Using cameras in a falls detection system has an added advantage of automatically monitoring people without the need for victims to initiate a call for help. Studies based on a similar principle of automation have been carried out by Belshaw et al. (2011) who used a frame that classifies positions of the subject into fall and no-fall positions and sends signals to the computer if the fall position is detected. The patient does not need to remember to wear a device because the system is an automatic emergency response type which has a wide field of view that can capture activities in a single large room, is able to operate effectively under moderate lighting changes and is able to handle multiple active movements as well as fall postures on the floor. The technology could be improved and explored for a wider scope of use in falls prevention in older person's nursing homes.

Accelerometers and Sensors

Sensor-based IT devices are also useful in the nursing home environment for preventing falls in the elderly. A device capable of automatically detecting a fall with loss of consciousness (FLoC) and activate an alarm by means of an accelerometer sensor was designed and tested by Quagliarella et al. (2008). Of all the 400 trials performed by 20 participants (10 young and 10 elderly adults), all FLoC cases were correctly detected using this method thereby supporting its usefulness in preventing falls. The algorithm used relied on the recognition of the effects of three events characterizing a FLoC: impact of the body against the ground, lying down and immobility. Likewise, other studies have shown the applicability of accelerometry to detect persons with a high fall risk. Marschollek et al. (2008) provided a simple unsupervised method to assess the fall risk of elderly persons as measured by reference clinical fall risk assessment scores. Parameters computed by analysis on accelerometer data recorded in a clinical setting were used, and they were evaluated using simple logistic regression (statistical process for estimating the relationships among variables which helps one understand how the typical value of the dependent variable changes when any one of the independent variables is varied) with reference to three clinical reference scores. The overall prediction accuracy of the models ranged from 65.5 to

89.1 %, with sensitivity and specificity between 78.5–99 % and 15.4–60.4 %, respectively. These results showed that a simple method can be used to detect persons with a high fall risk with a fair to good predictive accuracy when tested against common clinical reference scores. The specificity is low and the number of false positive results would be high. Further modifications and studies are indicated to improve the specificity of falls detection using this device. Such modifications have been done on other technologies for falls prevention. Brown (2005) developed and conducted a research on a rectangular sensor board which was designed to monitor continuous acceleration on a sensor device placed on the waist while the values registered by this device is used to monitor falls in the elderly. The idea was a modification on the wrist version of the sensor device which was dropped and tried on other body parts because of the unpredictability of a user's motor response in the case of a fall and inaccuracy of a wrist sensor's falls detection capabilities as the arm continuously moves (Eklund et al. 2005). The waist was then concluded as the most stable position to monitor movement using the sensor board after several tests were conducted with it in various positions such as the chest, the neck, and the waist. Marschollek et al. (2011) also conducted a study with 119 geriatric inpatients wearing an accelerometer on the waist and results obtained suggest that accelerometer data may be used to predict falls in an unsupervised setting and the parameters used for prediction are measurable with an unobtrusive sensor device during normal activities of daily living. Such reliable automated fall detection can increase confidence in people with fear of falling, promote active safe living for older adults, and reduce complications from falls.

As many of the falls detection systems use accelerometers attached to the torso, Sim et al. (2011) went further to place accelerometers on shoes to detect falls in the elderly. The shoes were preferred to make the device easy to carry as it was perceived that the elderly would feel uncomfortable when banding a sensor on the chest every day. Also, Noury (2002) had previously given a proposition of a fall sensor principle integrated in a garment. Various positions for the sensor have been favoured by different researchers with reasonable and scientific explanations. Regardless of the sensor site, the system should be designed with convenience, effectiveness and affordability in mind.

Electronic Walkway

An electronic walkway system was designed to measure gait parameters to predict short-term fall risk in nursing home residents with dementia in a prospective cohort study conducted by Sterke et al. (2012). Measurements were collected every 3 months over a 15 month period from 57 ambulatory nursing home residents with moderate to severe dementia, with each measurement being a baseline for the subsequent measurement. The predictive validity of the walkway system, the GAIT Rite® walkway system (a portable computer based electronic roll-up walkway with an overall dimension of $823 \times 90 \times 0.6$ cm connected to a personal computer with application software for calculation of temporal and spatial parameters of gait) was expressed in terms of sensitivity and specificity while logistic regression analysis was conducted to examine the association between these parameters and falls occurrence within each 3 months for which measurements were collected. The best predictive values were a velocity of 68 m/s (with a sensitivity of 82 % and a specificity of 52 %) and a mean stride length of 85 cm (with a sensitivity of 86 % and a specificity of 52 %). It was found that gait parameters as

measured with the electronic walkway system can be used for the prediction of short-term fall risk in nursing home residents with moderate to severe dementia. This would in turn help prevent falls among such residents. However, the sample size of 57 ambulatory patients used in the research by Sterke et al. (2012) was relatively small and studies with larger sample sizes will help to increase the precision of their findings and as well increase the applicability of seemingly positive findings to a larger population.

Bed-Exit Alarm System

Bed alarm systems are built to detect a person making attempt to get out of bed thereby making it easy for the caregiver to monitor them closely and prevent unguided movements that could lead to falls. Major identified requirements for an optimized bed-exit alarm system were usability, wide range usage, low costs, hygiene factors, integration into nursing beds and nurse call systems and an adequate alarm/false alarm ratio with early alarm trigger functionality (Yuki 2002). On the basis of the criteria mentioned above, Hilbe et al. (2010) developed an integrated bed-exit alarm system and collected data regarding preliminary sensitivity and specificity for alarm set-off. Both the preliminary sensitivity (96.0 %) and the specificity (95.5 %) of the trigger level indicate a satisfactory alarm/false alarm ratio. In general, it was observed that bed-exit alarm systems with extended features could play a major role in ambient assisted living technologies. However, besides the theoretical evaluation, it is necessary to perform more tests and to gather more data about the effect of bed alarm system on fall rates and resulting injuries. This system may also need to be adequately evaluated for applicability to the restless, light weighted individuals, uncooperative patients, incontinent and confused patients. Other new technologies make use of adjustable sensor pads fixed with an alarm system that connects to the nurse call system to alert staff when at-risk patients attempt to exit the bed unaided. The sensor pads and alarm systems that have been used in pilot studies were fixed to beds or chairs in patients' rooms (Poe et al. 2005). This may however be abused as the staff may feel that when patients were placed on beds or chairs with activated fall alarms, the periodic checks that they would ordinarily need to carry out in lying-in wards may not be necessary. This may create a problem for patients who require these checks for their safety. Such patients as are comatose, completely paralyzed, or completely immobilized need basic safety interventions and it is important to define situations in which the use of alarm systems and sensor pads would still require close monitoring and frequent periodic checks. Overall, alarm systems that notifies the caregiver when a patient attempts to leave the bed or chair are better preventive measures than those that alerts when the patient has fallen. This is not to say that the latter has no place in the care of elderly patients. For example, Li et al. (2010) developed an acoustic fall detection system, FADE, which automatically detects a fall and reports it to the caregiver, thereby giving the patient a chance to be urgently attended to. Alerting the caregiver after a fall may help limit injuries and their impacts.

Fall Prevention Software

Software can integrate existing communication patterns into a health information technology application for falls prevention. Dykes et al. (2010) designed a falls

prevention toolkit (FPTK) software which produced bed posters composed of brief text with an accompanying icon, patient education handouts, and plans of care, all communicating patient-specific alerts to key stakeholders. Cluster randomized study was conducted from January 1, 2009 through June 30, 2009, comparing patient fall rates in four urban US hospitals (Table 3).

These results supported earlier findings by Browne et al. (2004) on using information technology to redesign a fall prevention program for adult in-patients using a computerized information system for which the tool (ADAPT Fall Tool) provided an accurate assessment of the fall risk of each patient. Indicators embedded into routine assessment documentation for each patient and tailored interventions for specific patient risks helped to significantly reduce fall risks. Furthermore, fall risk information gathered can easily be integrated into the geriatric patient care plan.

Data Mining

Data mining is the process of finding correlations or patterns among dozens of fields in large relational databases that includes data preparation, selection, cleansing, incorporating prior knowledge on data sets and interpreting accurate solutions from the observed results (Frand 2009). The process entails analyzing data from different perspectives and summarizing it into useful information. A widely used technique in data mining is the knowledge discovery in database (KDD) process (Fig. 4) which generates models that can predict the likelihood of falls among the elderly who reside in long-term care facilities.

Volrathongchia et al. (2005) incorporated a data mining technique termed Likelihood Basis Pursuit into the KDD process, applied it to a dataset and were able to correctly identify which of the variables in this data set were associated with falls . Falls can be predicted and mitigated using this model.

Factors Affecting Use of Information Technology for Falls Prevention in the Elderly

Advances in information communications technology and related computational power are providing a wide array of systems and related services to support the health, safety

Table 3 Result from use of fall prevention tool kit (Dykes et al. 2010)

Parameters	Intervention (falls prevention programme using FPTK)	Control (usual care)
Number of hospital units	4	4
Number of patients	5,160	5,104
Number of falls (p=0.02)	67	87
Site adjusted fall rates (95 % confidence interval)	3.15 per 1,000 patient-days (2.54–3.90)	4.18 per 1,000 patient-days (3.45–5.06)

The software was found to be particularly effective with patients aged 65 years or older (adjusted rate difference, 2.08 [95 % CI, 0.61–3.56] per 1,000 patient-days; P=0.003)

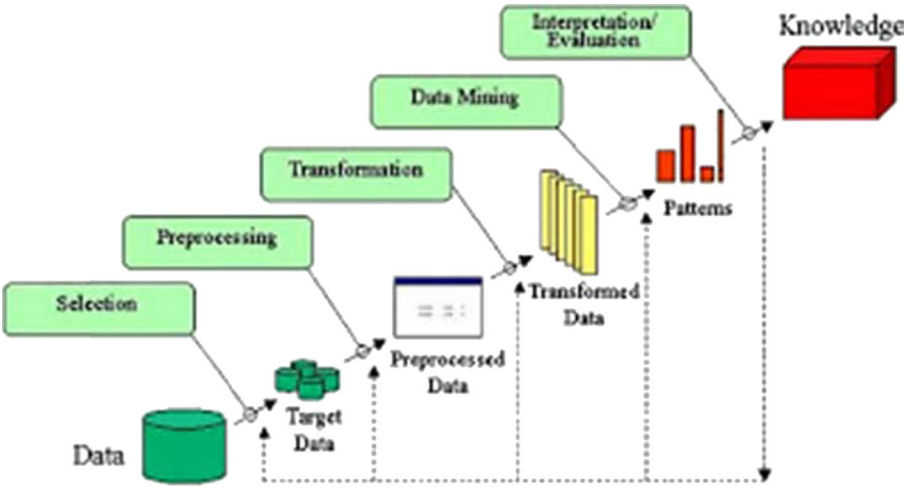

Fig. 4 Knowledge discovery in database (Techopedia 2013)

and independence of older adults. While these technologies offer significant benefits to older people and their families, they are also transforming older adults into lead adopters of a new lifestyle of being monitored, managed, and, at times, motivated, to maintain their health and wellness. Healthy ageing advocates have expressed support for technological advancements along with a variety of factors that included usability, reliability, trust, privacy, stigma, accessibility and affordability (Coughlin et al. 2007) (Table 4).

The design of a falls prevention systems and the position or site of the device influenced the patient's choice of one. Gövercin et al. (2010) conducted focus group discussions with older adults and their relatives to guide the development of assistive devices for fall detection and prevention in the home and to include these requirements in a user-centred development process. A semi-structured interview format based on an interview guide was used to conduct three focus group discussions with 22 participants. The average age was 75 years in the first group, 68 years in the second group and 50 years in the third group (relatives). Participants widely considered a fall prediction system to be as important as a fall detection system. Although the ambient, unobtrusive character of the optical sensor system was appreciated, wearable inertial sensors were

Table 4 Comparison of the trial results of some IT methods used in falls prevention

	Sensitivity (%)	Specificity (%)	Proportion of falls detected (%)
Smart home technology	100	66.67	
Artificially intelligent camera based system	Not available	Not available	100
Accelerators and sensors	Not available	Not available	100
Electronic walkway	86	52	
Bed exit alarm	96	95.5	

preferred because of their wide range of use, which provides higher levels of security. Security and mobility were two major reasons for people at risk of falling to buy a wearable and/or optical fall prediction and fall detection device. The participants also preferred design specifications that include a wearable, non-stigmatising sensor at the user's wrist, with an emergency option in case of falling. The study helped to sample the opinion of the potential user of IT devices and would solve the problem that may arise with user acceptance (one of the major problems in the development of information and communication technologies for older adults).

Highly educated people were more in favour of a programme via Internet compared with their lower educated counterparts. However, when diverse formats of effective programmes are made available, uptake and adherence may be increased (Debnath et al. 2012). Nyman and Yardley (2009) noted that while a minority of older people use the Internet, some older people underestimated how much activity was enough to improve balance, and others perceived themselves as too old for the activities. Also, some verbal persuasion or physical cueing may be necessary in as many as 80.7 % of older persons before participating in IT based studies aimed at falls prevention Sterke et al. (2012). However, according to Whitehead et al. (2012), increasing numbers of older people are accessing the internet for health-related information, including information on falls risk and prevention and evaluated English-language websites offering falls-related advice to members of the public. It has been deduced that older persons' attitude to technology is healthy and they will try helpful approaches to protect themselves from falling. Studies aimed at determining the attitudes, concerns and impressions of the elderly and health care staff to IT use in health care yielded results that showed the elderly support the use of IT for falls prevention (Tyrer et al. 2006). IT reduces the workload on caregivers, fostering communication between residents and family, and giving the elderly independence.

Awareness of the general population about IT available for falls prevention and the effectiveness of an IT system will also aid its acceptability by potential users (Skelton et al. 2004). A multifaceted program that utilized multiple personalized interventions was more effective in reducing the falls rate of frail (those with complex medical and psychosocial problems) nursing home residents (Theodos 2003). This kind of programme will more easily be accepted by such residents and their families because of its scientifically proven effectiveness.

Also, methods used in keeping health records may indirectly assist in ensuring complete data on falls in the elderly are kept for proper decision making. For example, e-coding of causes of death on fall death rates in the elderly helps to adequately identify all fall related death rates, thereby accounting for actual fall mortality burden in the elderly. Each unit increase in the median number of cause of death codes was associated with a 10 % increase in the number of falls (Maresh et al. 2012). This can assist policy makers as well as caregivers to direct fall prevention strategies appropriately against specific fall risks.

The cost of falls detection and falls prevention technology is a very important determinant of access to such. In communities where the government is absolutely responsible for the healthcare of seniors, direct costs are not really borne by the patients. The important task would be to convince decision makers to subscribe to IT for falls prevention in the elderly. They will also need to employ well trained personnel for proper application of the gadgets and tools. However, where payment

for healthcare is mainly out-of-pocket, it is only those that can afford them that will benefit from such technology.

Conclusion and Future Work

Introduction

In a general perspective of IT use, this research set out to add to understanding its applications to falls prevention in its several forms alongside a concern about the relevance and appropriateness of such uses. The study also examined the factors that influenced the acceptance and use of IT in falls prevention and the effectiveness of the different devices and methods.

Overview of the Research

Fall events constitute an important factor in terms of mortality, morbidity and costs in the ageing population and these events have a high incidence especially in the elderly. Falls in the elderly remain a leading cause of deaths due to injury and a major cost to the health system despite being often preventable. The research aimed at clarifying the claims and arguments in the body of knowledge on IT use in preventing falls among the elderly, synthesizing ideas to assist in the delivery of healthcare to prevent falls in older people using IT and further adding to the available body of knowledge as a basis for the design of complex interventions and in explaining likely mechanisms for success. Several IT methods aimed at optimising care and preventing falls in the elderly offer significant contributions to effectiveness of health services. These methods and IT equipments like cameras, telephones, sensors and software are essential in falls prevention while maintaining the ability of the elderly to grow old at home.

Limitations and Difficulties

The initial hindrance that was encountered with the research was as a result of difficulty to access the full text versions of certain important and needed abstracts. Those not available through Athens were accessed through research gate and by contacting authors personally. Authors contacted in all cases responded and shared full versions of their papers. Restriction of the search to electronic database might have led to publication bias as this approach is unlikely to identify studies that have not been published in peer review journals, studies that have been published in non-electronic journals or grey literature. The effect of this was reduced as much as possible by accessing the National Technical Information Service (NTIS), the Health Management Information Consortium (HMIC), the conference of papers Index and some non-electronic journals. Although a systematic review would be preferable, a narrative approach was used so as to fully interpret collected evidence and also because studies on IT use in fall prevention in older persons might be too diverse to combine in a meta-analysis (CRD 2009). Since meta-analysis was not carried out, the evidence based precision that is associated with combining the data and results of several studies might have been avoided. Nevertheless, the review led to an interesting and potentially useful

focus on the capacity of researchers to carry out larger prospective studies on the use of IT for falls prevention among older persons. This review also demonstrates the relevance of a narrative approach in pooling literature for knowledge base and basis for policy making. A narrative review is an essential part of a knowledge management system which helps to pull many pieces of information together into a readable format and summarise primary research findings which would be laborious to pick and read from several published articles (Cipriani and Geddes 2003).

Potential Application of Learning from this Study

Certain Information Technologies are still untested in a larger population but have the potential in reducing risks of falling. The cost of applying some of these technologies for falls prevention seems to be high but cannot be compared to the huge cost of treatment for injuries resulting from falls. IT initiatives need to be further explored and managed with a focus on equally effective and cheaper alternatives that can be implemented in low resource environments. This study suggests that this issue should be a concern for all stakeholders including healthcare providers, governments and IT firms without leaving out elderly citizens.

For healthcare organisations and their IT departments, there is a need to understand flexible IT use without limiting the freedom and comfort of geriatric patients. Healthcare workers need to be orientated on the feasibility and simplicity of these technologies in preventing falls. For the elderly, there is need to sensitize them on the applicability and simplicity of using IT in preventing falls. For IT firms and companies the successes and limitations identified in this study should act as a pointer to areas requiring further research.

Applications and Recommendation

Many of the researches described were carried out on small sample populations (sample size was 20–119 for most) while only two had sample sizes of above 1,000 (n=1,043 and 10,264) in community based studies. There is a need to explore the feasibility of applying the technologies to larger prospective studies. It would be useful to build on the findings of this research by testing them in larger populations and in healthcare settings. Generally, it is expected that telephone-based systems would be cheaper and easy to use and beneficial to the elderly provided that telecommunication companies and service providers can maintain good network service to as many areas as possible.

Eliciting the views of IT departments of healthcare institutions, research institutes and other stakeholders in IT firms would serve to strengthen the findings. Research that compares cost-effectiveness and safety practices in relation to IT initiatives for falls prevention would potentially highlight approaches that are easily acceptable by most. Research into the relative benefits of different approaches to planning and implementation of falls prevention programmes for the elderly in home and institutional settings could give rise to practical tools and guidance for IT developers, users and managers of such processes.

Research that helps to articulate changes and challenges in assumptions, structures and roles, and identifies useful strategies to support implementation and use of IT in

elderly falls prevention will make a contribution to the effective deployment of recent advances in information communication technology.

Conclusion and Future Work

From the discussions in this review, there is evidence that the need for IT use in falls prevention in the elderly is unavoidable with the trend in technology development and the convenience IT brings with the added advantage of preventing fall episodes and their associated costs. More work is needed to get the true picture of the effect of IT in falls prevention using larger prospective studies. Besides, this review has not made a classification for falls in the elderly occurring in shopping malls, places of worship and on streets. There are many places where falls can occur but the home, nursing homes and healthcare facilities are regular places where the aged stay or visit. The potential adaptation of successful IT use in these regular places to other sites where falls could occur can be studied. The wearable sensors, camera based systems and the ubiquitous monitoring systems or their modifications could be used in any of these places. The feasibility of incorporating falls prevention strategies using IT into primary health care should also be explored. Further studies, using larger sample sizes and appropriate technology should be considered. The need to provide affordable, safe and effective service to elderly patients through best practice will be the ultimate drive for the general use of various cost-effective IT forms in falls prevention.

Conflict of Interest Atoyebi Oladele Ademola, Stewart Antony and Sampson June declare that they have no conflict of interest.

Informed Consent As there is no person or personal data appearing in the paper, there is no one from whom a permission should be obtained in order to publish personal data.

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