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Use of web-based medication error reporting and management systems in improving medication safety in assisted living facilities: a systematic review

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Abstract: Given the negative health outcomes of medication errors, there is the need to explore the effectiveness of web-based medication error reporting and management systems in improving medication safety. Therefore, this study critically evaluates the literature on this innovation to explore how they have proven effective in reducing the number of medication errors in assisted living facilities. A systematic review of literature following the PRISMA guidelines was used to identify and screen peer-reviewed articles that analysed the use of web-based medication error reporting systems in assisted living facilities. After screening 314 articles, seven were selected for this review. The thematic analysis suggests that the medication reminders and other notifications of the web applications improved medication adherence and led to medication error reduction. Overall, findings indicate that web-based error reporting systems are useful in improving drug safety and medication management in assisted living facilities.

Keywords: medication errors; assisted living facilities; web-based applications; safety; health technology; management systems; systematic review.

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1 Introduction

Medication errors can be very harmful and costly to patients, their families, healthcare professionals and organisations. Notwithstanding technological advances and the introduction of many innovations for medication management systems in recent years, there is still high prevalence of medication errors. Consequently, medication errors are considered a leading cause of injury and avoidable harm in many healthcare systems, with estimates showing the global costs associated with medication errors to be about US$42 billion annually (Aitken and Gorokhovich, 2012). As the discourse on patient safety continues to gain traction, reducing medication errors has become an area of interest among many stakeholders in health.

In the quest to reduce medication errors, there is a call for an increased focus on medication management systems in settings such as assisted living facilities (Stefanacci and Haimowitz, 2012). To provide context, assisted living facilities are non-medical settings that offer residential care involving food services, personal services and medication administration to frail elders or other persons with physical and mental disabilities (Ball et al., 2000). They are also known as long-term care facilities, nursing homes, skilled nursing facilities, convalescent care homes, rest homes or old people's homes.

As the number of elderly persons needing support in assisted living facilities continues to rise, there has also been a concomitant rise in the number of medication errors across many assisted living facilities (Kozak and Mithani, 2015). For instance, adverse drug events due to medication errors in assisted living facilities are estimated to occur at an incidence rate of 1.2–7.3 per 100 resident-months, with an annual cost of $7.6 billion in the US alone (Handler et al., 2008). While the statistics relating to nursing homes in the UK is scarce, a 2018 report by Economic Evaluation of Health & Care Interventions Policy Research Unit (EEPRU) of the UK Department of Health Policy Research Programme revealed that about 230 million medication errors occur in the NHS annually, resulting in up to 22,300 deaths (Elliott et al., 2018). Whereas this data suggests a high number of medication errors in hospital settings, patients in assisted living facilities are more likely to experience medication errors than patients in acute care settings, perhaps due to their higher medication use (Grissinger, 2016). This therefore necessitates the identification of innovative ways to prevent medication errors for patients living in assisted living facilities.

However, there are marked differences between the efforts made by assisted living facilities to prevent medication errors as compared to hospital settings in many health systems (Gallagher et al., 2011). A key reason to explain this is the lack of use of health information technologies in some assisted living facilities, some of which even come with inbuilt medication error detection and prevention features (Agyemang and While, 2010; Bowman, 2013). These technologies range from barcode unit dosing to computerised decision support systems, computerised physician order entry (CPOE) systems, electronic health records, and electronic prescribing systems and have been successfully used in many hospitals and other high-risk industries such as the aviation industry (Pierson et al., 2007; Bowman, 2013). A low-cost health technology that has been recommended to improve medication safety in assisted living facilities involves the use of web-based medication error reporting and management systems to identify, manage and report medication errors. However, there is a scarcity of reviews undertaken to explore the effectiveness of web-based medication error reporting and management

systems in improving medication safety in assisted living facilities. Given these issues, together with the negative health outcomes of medication errors, this research critically reviews the literature on web-based innovations to explore their effectiveness in reducing the number of medication errors in assisted living facilities.

2 Methods

2.1 Aim

This review is aimed at investigating the effectiveness of web-based medication error reporting and management systems in improving medication safety.

2.2 Eligibility criteria

The literature search was limited to peer-reviewed article published in English between 2010 to 2021 in order to capture only contemporary evidence. An overview of the criteria for inclusion and exclusion of the articles identified in this study are shown in Table 1.

Table 1 Eligibility criteria

Population/setting	• We included primary studies of patients receiving medication in assisted living facilities. Studies that were not carried out in assisted living facilities were thus excluded
Intervention	• We considered all web-based medication error reporting and management systems interventions. We excluded studies in which the intervention was not web-based and/or directly related to medication error reporting and management systems
Study design	• The studies included were primary qualitative and quantitative studies published between 2010 and 2021. The studies are also peer-reviewed and published in English language. Reviews, expert opinions, commentaries and conference presentations were excluded.
Outcome	• Our primary outcome measure was the reduction of the rate of occurrence of medication errors (wrong medication, wrong dose, wrong site or route, unordered drug, extra dose, and wrong time related to any component of dispensing). Other outcomes include the adherence to medications and users' mastery of the web applications. These outcomes are assessed either through self-reported or device assessed means.

2.3 Data sources

This systematic review of literature was conducted following the PRISMA protocol. The databases used in searching for the relevant literature for this study include: CINAHL, PubMed and Google Scholar. The literature search using the CINAHL and PubMed databases was undertaken on the 26th of March 2021, while additional searches for publications were undertaken on Google Scholar on the 1st of April 2021. These databases were used because they contain information relevant for this subject matter. The limitation of the Google Scholar results with focus on first 200 reflects the recommendation by Haddaway et al. (2015) that suggests that searches of article titles on Google Scholar should focus on the first 200 to 300 results, where moderate amounts of

literature relevant to the subject matter are contained. The keywords and the medical subject heading (MeSH) terms of the main keywords applied in the literature search are described in the following subsection.

2.4 Full search strategy used for all databases

The search terms were identified by looking at words in the titles and abstracts from two previously identified relevant studies. A preliminary search was then undertaken to inform the identification of additional search terms. The search strategy was aligned with the eligibility criteria, and was validated by testing whether the systematic search process could identify the two previously known relevant studies. The search terms used include: 'medication errors', 'drug errors', 'medication administration errors', 'drug administration errors', 'drug use error', 'errors, medication', 'high-alert drug error', 'LASA medication errors', 'look-alike drug name errors', 'look-alike sound-alike drug errors', 'look-alike sound-alike drug substitution errors', 'look-alike sound-alike medication errors', 'lookalike drug name errors', 'lookalike soundalike drug errors', 'lookalike soundalike drug substitution errors', 'lookalike soundalike medication errors', 'nursing homes', or 'care homes', or 'long-term care', or 'residential care', or 'aged care facility', 'nursing health services for the aged', 'homes for the aged', 'housing for the elderly', 'web-based interventions', 'e-health', 'internet-based interventions', 'web-based application', 'web application', 'online application' and 'internet application'. The Boolean operators 'OR' and 'AND' were used to aid the search process.

2.5 Study selection and data collection

Two researchers independently conducted reviews of citations, full-texts, and extracted data. A data extraction form was used to extract data the different studies. We collected data on the author(s) and year of publication; the study (sample size and study design), the type of intervention and outcomes (see Table 2). The outcome measures assumed for the primary outcome (reduction in the number of medication errors) in this research include wrong medication, wrong dose, wrong site or route, unordered drug, extra dose, and wrong time related to any component of dispensing. Other outcomes extracted include the adherence to medications and users' mastery of the web applications. These outcomes are assessed either through self-reported or device assessed means. The tests used in each study should have had evidence of validity and reliability for the assessment of web-based medication error reporting and management systems interventions, but studies were not excluded on this basis. No restrictions were placed on the timeframe for assessment of the outcome measures.

2.6 Quality appraisal of the included studies

The methodological quality was appraised using JBI critical appraisal tools. In line with the broader view of evidence, the JBI critical appraisal tools have proven useful to assess the methodological quality of studies from all diverse forms of evidence. They also help determine the extent to which studies address the possibility of bias in its design, conduct and analysis.

The quality was appraised independently by two review authors, who recorded any supporting information to justify their appraisal for each domain. Any discrepancy was to

be resolved by consensus between the two review authors. The overall summary of quality was determined by the number of concerns (designated as no or unclear) in any of the domains identified in each study.

2.7 Synthesis methods

The data synthesis phase assumed a narrative approach. The outcomes of the different studies were combined using a thematic analysis approach because the review was qualitative in nature. This means that this study did not measure any level of heterogeneity in the included studies, that is, it did not measure the extent to which the results of studies are consistent.

3 Results

3.1 Database search results

The first database search produced 310 studies and four additional articles were identified through citation searching. Seven studies were then selected for this review (Figure 1 shows the different steps undertaken in reaching the seven studies on a PRISMA flow diagram). The study by Hansen et al. (2010), although potentially relevant as it analysed the web-based error reporting system using statistical methods to identify areas for improvement, it was excluded because it only determined associations between medication type and possible causes retrospectively to inform quality improvement, which is not an outcome measured in this systematic review.

3.2 Study characteristics

Among the selected studies, two were randomised controlled trials (Mira et al., 2014; Goldstein et al., 2014). Four on the other hand were observational studies (Mira et al., 2015; Grindrod et al., 2014; Mertens et al., 2016; Elseviers et al., 2014), while one of the studies was a cohort study (Greene et al., 2010). Five of the studies had less than 100 participants or study subjects (Mira et al., 2014; Goldstein et al., 2014; Mira et al., 2015; Grindrod et al., 2014; Mertens et al., 2016). One study included 5,823 medication error reports (Greene et al., 2010) while another one (Elseviers et al., 2014) had 1,730 participants respectively. The data in six of the studies were from patients (Mira et al., 2014; Goldstein et al., 2014; Mira et al., 2015; Grindrod et al., 2014; Mertens et al., 2016; Elseviers et al., 2014). One study lacked clarity as to whether the data was from patients, hospital staff or families of the patient (Greene et al., 2010). The combined number of participants in all seven studies was 7,832 with a mean sample size of 1,118.857, which ranges from 24 participants to 5,823 participants. The combined mean age for all the participants in the seven studies that described the ages of the participants was 57 years, including 49.9% males and 51.1% females. For the country of origin and study setting, two of the studies were carried in Spain, specifically, in 13 nursing home centres in Alicante and Bilbao Districts and in three diabetic nursing home centres in Alicante, Elche and Elda districts respectively (Mira et al., 2014, 2015). Two of the studies were carried out in the US, i.e., in a nursing home in Summa Health System in Akron, Ohio (Goldstein et al., 2014) and in 393 nursing homes in North Carolina (Greene et al., 2010).

One study was undertaken in a nursing home in Waterloo, Ontario, Canada (Grindrod et al., 2014). Another study was carried out in a cardio-rehab centre in Aachen, Germany for people aged 60 years and above (Mertens et al., 2016), while one study was carried out in Belgium (Elseviers et al., 2014).

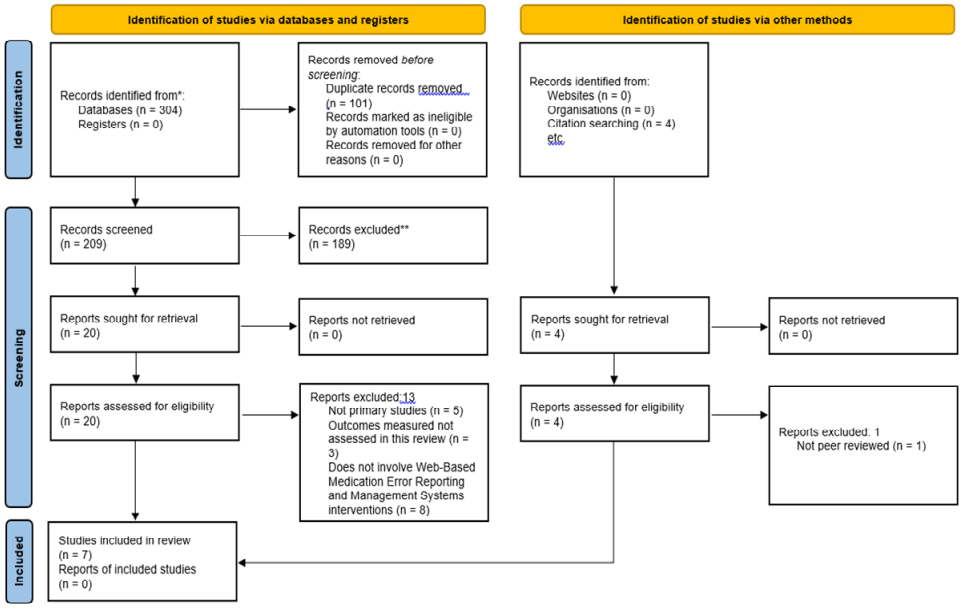
Table 2 Summary of reviewed studies

First author (year)	*Study design*	*Sample size*	*Intervention*	*Outcomes*
Mira et al. (2014)	Randomised control trial	99 participants	A medication self-management app (called ALICE)	The ALICE app improves adherence and helps reduce rates of medication errors. Elderly patients with no previous experience with information and communication technologies are also capable of effectively using the app designed to help them take their medicine more safely.
Greene et al. (2010)	Cohort study	5,823 medication error reports	A web-based reporting tool which was not named	Data collected from a nursing home medication error system can provide helpful information on medication errors that can be useful in nursing homes for continuous quality improvement efforts
Elseviers et al. (2014)	Observational study	1,730 participants	Electronic tools (ACOVE, BEDNURS, beers or drug – drug interaction) for the assessment of potentially inappropriate prescribing	The implementation of a computerised monitoring system of potentially inappropriate medications is highly recommended to improve the quality of prescribing.
Goldstein et al. (2014)	Randomised control trial	60 adults	A telemedicine medication reminder system (an electronic pill box)	Overall adherence was high, however, a subset of the participants exhibited relatively poor adherence, and reminding alone did not appear sufficient to improve adherence in this group.
Mira et al. (2015)	Observational study	61 patients	TUMEDICINA (YourMedicine) which captures the ean-13 or the QR from the packaging of the medication and converts it into spoken instructions	The study results support the use of such technology to increase patient safety taking multiple medications safety.

Table 2 Summary of reviewed studies (continued)

First author (year)	*Study design*	*Sample size*	*Intervention*	*Outcomes*
Grindrod et al. (2014)	Observational study	35 participants	Four medication management applications which are MyMedRec, DrugHub, Pillboxie, and PocketPharmacist	With training, adults aged 50 and over can be capable and interested in using mHealth applications for their medication management
Mertens et al. (2016)	Observational study	24 patients	Medication Plan app (version 1.3)	A mobile app for medication adherence increased adherence in elderly users undergoing rehabilitation.

Figure 1 PRISMA flow diagram (see online version for colours)



The outcomes measured in six of the included studies involve the users' mastery of the different web applications (Mira et al., 2014; Goldstein et al., 2014; Mira et al., 2015; Grindrod et al., 2014; Mertens et al., 2016; Greene et al., 2010). The study that did not measure the users' mastery of the web applications used web-based systems to assess potentially inappropriate medication (Elseviers et al., 2014). Only one study measured medication adherence (Mertens et al., 2016). Another study also considered mainly the score ratings of the applications by the users (Mira et al., 2015). Two studies measured medication adherence while also considering the users' score ratings of the applications (Mira et al., 2014; Goldstein et al., 2014), and two studies considered whether any errors occurred while the patients were using the applications (Mira et al., 2015; Greene et al., 2010). See Table 2 for a summary of all the studies characteristics.

Table 3 Results from the critical appraisal of methodological quality

JBI critical appraisal checklist for qualitative research										
Studies	1	2	3	4	5	6	7	8	9	10
Grindrod et al. (2014)	*Y*	*Y*	*Y*	*Y*	*Y*	*N*	*U*	*Y*	*Y*	*Y*
Total	1/1	1/1	1/1	1/1	1/1	0/1	O/1	1/1	1/1	1/1
JBI critical appraisal checklist for studies reporting prevalence data										
Studies	1	2	3	4	5	6	7	8	9	
Greene et al. (2010)	*Y*	*U*	Y	*Y*	*Y*	*Y*	*Y*	*Y*	*Y*	
Mira et al. (2015)	*Y*	*Y*	*Y*	*Y*	*Y*	*Y*	*Y*	*Y*	*Y*	
Total	*2/2*	*1/2*	*2/2*	*2/2*	*2/2*	*2/2*	*2/2*	*2/2*	*2/2*	
JBI critical appraisal checklist for cohort studies										
Studies	*1*	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*	
Mertens et al. (2016)	*Y*	*Y*	*Y*	*Y*	*N*	*U*	*Y*	*Y*	*Y*	
Total	1/1	1/1	1/1	1/1	0/1	0/1	1/1	1/1	1/1	
JBI critical appraisal checklist for randomised controlled trials													
Studies	1	2	3	4	5	6	7	8	9	10	11	12	13
Mira et al. (2014)	Y	Y	Y	Y	U	N	Y	Y	Y	Y	Y	Y	Y
Goldstein et al. (2014)	Y	Y	Y	Y	U	U	Y	Y	Y	Y	Y	Y	Y
Total	2/2	2/2	2/2	2/2	0/2	0/2	2/2	2/2	2/2	2/2	2/2	2/2	2/2
JBI critical appraisal checklist for analytical cross-sectional studies								
Studies	1	2	3	4	5	6	7	8
Elseviers et al. (2014)	N	Y	Y	Y	N	U	Y	Y
Total	0/1	1/1	1/1	1/1	0/1	0/1	1/1	1/1

Notes: Y = yes; N = no; U = unclear.

3.3 Quality appraisal of the included studies

The studies were appraised using the standardised critical appraisal checklists for ten-item, nine-item, nine-item, 13-item and eight-item checklists for qualitative, quantitative, cohort, randomised control trials and cross-sectional studies. Table 3 presents the results from the critical appraisal. Overall, there were concerns with 16 out of the 71 different domains across all the studies.

3.4 Results of synthesis

3.4.1 Interventions

All the studies measured how different web-based applications improved drug safety in assisted living facilities. Beyond that, two studies developed new applications for their study (Mira et al., 2014, 2015). For instance, an application called ALICE developed by one study can be accessed via mobile devices or computers by elderly persons taking multiple medications with the aim of improving adherence and safe use of medication (Mira et al., 2014). Another study developed an application called TUMEDICINA that

can also be accessed via mobile devices or computers, which transforms barcodes and quick response (QR) codes into verbal instructions to facilitate the safer use of medication by patients in assisted living facilities (Mira et al., 2015). The remaining five studies used applications that had already been developed to measure how they improved drug safety in assisted living facilities (Goldstein et al., 2014; Grindrod et al., 2014; Mertens et al., 2016; Greene et al., 2010; Elseviers et al., 2014). For instance, one study used applications called Telehealth and m-Health, which acted as passive medication-taking logs, which are essentially electronic pillboxes that remind patients of what type of medicine to take and the time of taking the medication (Goldstein et al., 2014).

Another study assessed the effectiveness and usability of four medication management applications (MyMedRec, DrugHub, Pillboxie, and PocketPharmacist), where usability was ascertained based on the applications' design, functionality, simplicity, and accessibility (Grindrod et al., 2014). One study however did not disclose the web-based reporting system they used (Greene et al., 2010). Finally, one study used an application called Medication Plan, which allowed users to set reminders of the type of medication they should use and the time for taking the medication to help reduce medication errors (Mertens et al., 2016).

3.4.2 Thematic analysis

3.4.2.1 Users' mastery of the web applications

In all studies that assessed users' mastery of the web applications, all the participants proved to master the use of the different applications, e.g., how to log in to and log out of the applications via mobile devices and computers, register their information, and other functions. The two randomised controlled trials found that patients and nurses in assisted living facilities that do not use web-based applications have minimal understanding with little or no mastery of the web applications (Mira et al., 2014; Goldstein et al., 2014). Evidence shows that users preferred to practice with the applications in order to master their usage, with one study showing that an average of two-hour practice per day per patient for four days was enough to enable them master the use of such applications (Grindrod et al., 2014).

3.4.2.2 Medication adherence

The three studies that measured adherence found that users do not fully adhere to the use of web-based applications, which was one of the causes of medication errors in assisted living facilities (Mira et al., 2014; Goldstein et al., 2014; Mertens et al., 2016). It is important to add that, the daily compliance in taking prescribed medication, especially when reminded by the Medication Plan application, was the standard for measuring adherence in one study (Mertens et al., 2016). As it was a crossover trial, the researchers found that before the implementation of the Medication Plan application, only nine out of the 24 patients included in the research adhered to their medication plan. Nonetheless, after the implementation of the Medication Plan application, 19 out of the 24 patients adhered to their medication plan. The patients cited the reminders by the application as the contributing factor to adherence. In another study, the overall adherence rate for the two devices they studied was 78% (Goldstein et al., 2014). They explained that users who

received reminders only adhered to them 79% of the time and users who set passive medication reminders adhered 78% of the time. This means that reminders sent by the web-based applications to take medicine at a certain time were not 100% effective. In another study, the application they developed called ALICE improved adherence to medication taking schedules by 88.8% for the experimental group, while in the control group, adherence to medication taking schedules was 54.5% (Mira et al., 2014).

3.4.2.3 Score ratings of the applications by the users

Three studies focused on the score ratings of the different applications they used (Mira et al., 2015; Goldstein et al., 2014; Mira et al., 2014). The mean satisfaction score for the ALICE application among its users was 8.5 out of 10 (Mira et al., 2014). The researchers associated a higher mean score with improvement in drug safety management and helpfulness in managing medication. In another RCT, there was a statistically significant difference between the satisfaction means of the experiment group and the control (Goldstein et al., 2014). The participants who used the Telehealth and m-Health applications reported higher satisfaction rates compared to those who relied on instructions given to them verbally by their nurses. Additionally, the mean satisfaction score for the TUMEDICINA application among its users was 8.3 out of 10 (Mira et al., 2015). The participants rated the simplicity and clarity of use as the most important factors of the application. There was no difference between the elderly patients with regards to understanding of use of computers when accessing the web application.

3.4.2.4 Medication errors that occurred

There are two studies that measured the medication errors that occurred with the implementation of the web-based applications (Mira et al., 2015; Greene et al., 2010). In the former, there was 21.3% reduction in medication errors such as confusion of drugs, taking medication at the wrong time, taking more than the amount that is required, and poor mixing of drugs. This study compared their findings with the previous year's medication error records of the nursing homes included in their research. In the other cohort, serious errors, e.g., wrong drug administration reduced by 52% from 612 errors per year to 203 errors after the implementation of different web applications (Greene et al., 2010).

4 Discussion

4.1 Outcomes

This study fills a significant gap in the literature by synthesising web-based medication errors that occur in assisted living facilities. Overall, adherence was high in the studies that measured adherence (over 75%) and for the two RCTs, the researchers found that adherence in the control group was low compared to the experimental group (Mira et al., 2014; Goldstein et al., 2014). In one study, the researchers found that users on average accessed the applications four times a day to check their medical logs (Goldstein et al., 2014). Nonetheless, as a limitation, the high adherence rather observed in the different studies might be due to the small sample size in most of the studies. A small sample size

can undermine the internal and external validity of any study and this has practical implications for five of the selected studies (Faber and Fonseca, 2014). This may mean that their findings may not be generalisable to the entire population.

Notwithstanding this limitation, their findings are largely in line with the systematic review by Kaushal et al. (2003) who reviewed the cumulative evidence on the effects of CPOE and clinical decision support systems (CDSSs) on medication safety. They found that the se of COPE and isolated CDSSs can substantially reduce medication error rates. This is consistent with our findings that web-based medication error reporting and management systems interventions are useful in safeguarding the safety of patients during medication management. Beyond medication management, web-based interventions have proven useful for patient empowerment, improving employee well-being and effectiveness, and promoting healthy eating, as supported by in other systematic reviews (Samoocha et al., 2010; Carolan et al., 2017; Hamel and Robbins, 2013).

As additional limitations, the cognitive ability of the study participants was not clearly tested in the six studies where the data was collected from patients. It is important to make such a determination particularly as cognitive ability of a user has the potential to affect medication adherence. The cost of the web-based application was also not clearly discussed in the selected studies. There have been a plethora of evidence highlighted the limited amount of resources in healthcare (Mosadeghrad, 2014; Emanuel et al., 2020; Zhang et al., 2010). This should necessitate a fair allocation framework when distributing these limited resources across entire healthcare systems (Emanuel et al., 2020). Hence, in this context, although the web-based applications seem to be less cost intensive as they do not require significant investments in any sophisticated technologies, it is important to undertake the cost benefit analysis, the findings for which will help provide legitimacy to the decision to adopt such technologies to reduce medication errors.

Although these web-based systems do not capture each and every medication error, as they depend on spontaneous reporting, yet they can help identify the root cause of the problem or the patterns that led to an error, thus allowing healthcare managers, professionals and policymakers to undertake appropriate quality improvement measures (Bravo et al., 2016). As an illustration, the adverse event systems can collect detailed data about an error incident with regards to the medications or personnel involved in the errors and compile this information on a comprehensive online drug and personnel database, which can then be used to inform decision making for quality improvement (Brady et al., 2009). Therefore, these web-based technologies, which have proven useful in many hospitals and other high-risk industries, hold promise as a feasible method for tackling medication errors in assisted living facilities (Quintana et al., 2011; Ahmed et al., 2016; Nuckols et al., 2014; Avery et al., 2012; Howell et al., 2017).

5 Conclusions

The application of web-based technologies to address medication errors in acute care settings have been well documented in the wider literature, but this is not the case for assisted living facilities such as nursing homes. Also, the issue of medication errors and drug safety may have varying implications for different service users and stakeholders, particularly for patients and healthcare professionals who are often impacted the most.

Hence, they are more likely to have a higher degree of interest in issues relating to medication errors and drug safety. For any intervention that seeks to address these issues, it is important to appropriately manage the expectations of all key stakeholders in order to sustain any quality improvement initiative.

One quality improvement initiative that holds promise in addressing the issues of medication errors and drug safety in assisted living facilities involves the use of web-based application technologies. Evidence from this study indicates that medication reminders and other notifications contained within web applications have improved medication adherence and led to medication error reduction. This study also shows that poor training systems led to poor adherence or use of the web-based technologies. Therefore, for web-based error reporting applications to improve medication management systems, there is the need for adequate training of all users on the use of these new applications. The training and positive engagement of all users and affected stakeholders are equally as important as the technologies to ensure their effectiveness in medication error management and improving drug safety, especially in assisted living facilities. Hence, there is the need to explore change management strategies which involves adequate training protocol and their adaptation to local situational or organisational contexts, to guide the introduction of web-based medication error reporting and management systems within various assisted living facilities. Although evidence from this study reinforces the efficacy of a web-based error reporting system in managing medication errors, the scope of the evidence is limited. There is the need for further primary research on the cost effectiveness of web-based application technologies for managing medication error and for improving drug safety in assisted living facilities. This will strengthen evidence-base to inform health managers or policy makers on the feasibility of introducing such technologies across specific and wider healthcare systems.

References

Agyemang, R.E.O. and While, A. (2010) 'Medication errors: types, causes and impact on nursing practice', *British Journal of Nursing*, Vol. 19, No. 6, pp.380–385.

Ahmed, A., Roumani, A., Szucs, K., Zhang, L. and King, D. (2016) 'The effect of interactive web-based monitoring on breastfeeding exclusivity, intensity, and duration in healthy, term infants after hospital discharge', *Journal of Obstetric, Gynecologic & Neonatal Nursing*, Vol. 45, No. 2, pp.143–154.

Aitken, M. and Gorokhovich, L. (2012) *Advancing the Responsible Use of Medicines: Applying Levers for Change*, SSRN: 2222541.

Avery, A.J., Rodgers, S., Cantrill, J.A., Armstrong, S., Cresswell, K., Eden, M., Elliott, R.A., Howard, R., Kendrick, D., Morris, C.J. and Prescott, R.J. (2012) 'A pharmacist-led information technology intervention for medication errors (PINCER): a multicentre, cluster randomised, controlled trial and cost-effectiveness analysis', *The Lancet*, Vol. 379, No. 9823, pp.1310–1319.

Ball, M.M., Whittington, F.J., Perkins, M.M., Patterson, V.L., Hollingsworth, C., King, S.V. and Combs, B.L. (2000) 'Quality of life in assisted living facilities: viewpoints of residents', *Journal of Applied Gerontology*, Vol. 19, No. 3, pp.304–325.

Bowman, S. (2013) 'Impact of electronic health record systems on information integrity: quality and safety implications', *Perspectives in Health Information Management*, Fall, Vol. 10, No. 1c, pp.1–19.

Brady, A.M., Malone, A.M. and Fleming, S. (2009) 'A literature review of the individual and systems factors that contribute to medication errors in nursing practice', *Journal of Nursing Management*, Vol. 17, No. 6, pp.679–697.

Bravo, K., Cochran, G. and Barrett, R. (2016) 'Nursing strategies to increase medication safety in inpatient settings', *Journal of Nursing Care Quality*, Vol. 31, No. 4, pp.335–341.

Carolan, S., Harris, P.R. and Cavanagh, K. (2017) 'Improving employee well-being and effectiveness: systematic review and meta-analysis of web-based psychological interventions delivered in the workplace', *Journal of Medical Internet Research*, Vol. 19, No. 7, p.e271.

Elliott, R., Camacho, E., Campbell, F., Jankovic, D., St. James, M.M., Kaltenthaler, E., Wong, R., Sculpher, M. and Faria, R. (2018) 'Prevalence and economic burden of medication errors in the NHS in England. Rapid evidence synthesis and economic analysis of the prevalence and burden of medication error in the UK', Policy Research Unit in Economic Evaluation of Health and Care Interventions (EEPRU) [online] http://www.eepru.org.uk/wp-content/uploads/2018/02/eepru-report-medication-error-feb-2018.pdf.

Elseviers, M.M., Vander Stichele, R.R. and Van Bortel, L. (2014) 'Quality of prescribing in Belgian nursing homes: an electronic assessment of the medication chart', *International Journal for Quality in Health Care*, Vol. 26, No. 1, pp.93–99.

Emanuel, E.J., Persad, G., Upshur, R., Thome, B., Parker, M., Glickman, A., Zhang, C., Boyle, C., Smith, M. and Phillips, J.P. (2020) 'Fair allocation of scarce medical resources in the time of COVID-19', *New England Journal of Medicine*, Vol. 382, No. 21, pp.2049–2055.

Faber, J. and Fonseca, L.M. (2014) 'How sample size influences research outcomes', *Dental Press Journal of Orthodontics*, Vol. 19, No. 4, pp.27–29.

Gallagher, P., Lang, P.O., Cherubini, A., Topinková, E., Cruz-Jentoft, A., Errasquín, B.M., Mádlová, P., Gasperini, B., Baeyens, H., Baeyens, J.P. and Michel, J.P. (2011) 'Prevalence of potentially inappropriate prescribing in an acutely ill population of older patients admitted to six European hospitals', *European Journal of Clinical Pharmacology*, Vol. 67, No. 11, pp.1175–1188.

Goldstein, C.M., Gathright, E.C., Dolansky, M.A., Gunstad, J., Sterns, A., Redle, J.D., Josephson, R. and Hughes, J.W. (2014) 'Randomized controlled feasibility trial of two telemedicine medication reminder systems for older adults with heart failure', *Journal of Telemedicine and Telecare*, Vol. 20, No. 6, pp.293–299.

Greene, S.B., Williams, C.E., Pierson, S., Hansen, R.A. and Carey, T.S. (2010) 'Medication error reporting in nursing homes: identifying targets for patient safety improvement', *BMJ Quality & Safety*, Vol. 19, No. 3, pp.218–222.

Grindrod, K.A., Li, M. and Gates, A. (2014) 'Evaluating user perceptions of mobile medication management applications with older adults: a usability study', *JMIR mHealth and uHealth*, Vol. 2, No. 1, p.e3048.

Grissinger, M. (2016) 'From the hospital to long-term care: protect vulnerable patients during handoff', *Pharmacy and Therapeutics*, Vol. 41, No. 4, p.204.

Haddaway, N.R., Collins, A.M., Coughlin, D. and Kirk, S. (2015) 'The role of Google Scholar in evidence reviews and its applicability to grey literature searching', *PloS One*, Vol. 10, No. 9, p.e0138237.

Hamel, L.M. and Robbins, L.B. (2013) 'Computer-and web-based interventions to promote healthy eating among children and adolescents: a systematic review', *Journal of Advanced Nursing*, Vol. 69, No. 1, pp.16–30.

Handler, S.M., Hanlon, J.T., Perera, S., Saul, M.I., Fridsma, D.B., Visweswaran, S., Studenski, S.A., Roumani, Y.F., Castle, N.G., Nace, D.A. and Becich, M.J. (2008) 'Assessing the performance characteristics of signals used by a clinical event monitor to detect adverse drug reactions in the nursing home', in *AMIA Annual Symposium Proceedings*, American Medical Informatics Association, Vol. 2008, p.278.

Hansen, R.A., Cornell, P.Y., Ryan, P.B., Williams, C.E., Pierson, S. and Greene, S.B. (2010) 'Patterns in nursing home medication errors: disproportionality analysis as a novel method to identify quality improvement opportunities', *Pharmacoepidemiology and Drug Safety*, Vol. 19, No. 10, pp.1087–1094.

Howell, A.M., Burns, E.M., Hull, L., Mayer, E., Sevdalis, N. and Darzi, A. (2017) 'International recommendations for national patient safety incident reporting systems: an expert Delphi consensus-building process', *BMJ Quality & Safety*, Vol. 26, No. 2, pp.150–163.

Kaushal, R., Shojania, K.G. and Bates, D.W. (2003) 'Effects of computerized physician order entry and clinical decision support systems on medication safety: a systematic review', *Archives of Internal Medicine*, Vol. 163, No. 12, pp.1409–1416.

Kozak, J.K. and Mithani, A. (2015) 'Prevalence of adverse drug events in long term care: variations in screening between nurses and physician-pharmacist reviewers', *Journal of Gerontology & Geriatric Medicine*, Vol. 1, No. 7.

Mertens, A., Brandl, C., Miron-Shatz, T., Schlick, C., Neumann, T., Kribben, A., Meister, S., Diamantidis, C.J., Albrecht, U.V., Horn, P. and Becker, S. (2016) 'A mobile application improves therapy-adherence rates in elderly patients undergoing rehabilitation: a crossover design study comparing documentation via iPad with paper-based control', *Medicine*, Vol. 95, No. 36, pp.1–8.

Mira, J.J., Guilabert, M., Carrillo, I., Fernández, C., Vicente, M.A., Orozco-Beltrán, D. and Gil-Guillen, V.F. (2015) 'Use of QR and EAN-13 codes by older patients taking multiple medications for a safer use of medication', *International Journal of Medical Informatics*, Vol. 84, No. 6, pp.406–412.

Mira, J.J., Navarro, I., Botella, F., Borrás, F., Nuño-Solinís, R., Orozco, D., Iglesias-Alonso, F., Pérez-Pérez, P., Lorenzo, S. and Toro, N. (2014) 'A Spanish pillbox app for elderly patients taking multiple medications: randomized controlled trial', *Journal of Medical Internet Research*, Vol. 16, No. 4, p.e99.

Mosadeghrad, A.M. (2014) 'Factors influencing healthcare service quality', *International Journal of Health Policy and Management*, Vol. 3, No. 2, p.77.

Nuckols, T.K., Smith-Spangler, C., Morton, S.C., Asch, S.M., Patel, V.M., Anderson, L.J., Deichsel, E.L. and Shekelle, P.G. (2014) 'The effectiveness of computerized order entry at reducing preventable adverse drug events and medication errors in hospital settings: a systematic review and meta-analysis', *Systematic Reviews*, Vol. 3, No. 1, pp.1–12.

Pierson, S., Hansen, R., Greene, S., Williams, C., Akers, R., Jonsson, M. and Carey, T. (2007) 'Preventing medication errors in long-term care: results and evaluation of a large scale web-based error reporting system', *BMJ Quality & Safety*, Vol. 16, No. 4, pp.297–302.

Quintana, Y., Patel, A.N., Naidu, P.E., Howard, S.C., Antillon, F.A. and Ribeiro, R.C. (2011) 'POND4Kids: a web-based pediatric cancer database for hospital-based cancer registration and clinical collaboration', in *Studies in Health Technology and Informatics*, Vol. 164, pp.227–237.

Samoocha, D., Bruinvels, D.J., Elbers, N.A., Anema, J.R. and van der Beek, A.J. (2010) 'Effectiveness of web-based interventions on patient empowerment: a systematic review and meta-analysis', *Journal of Medical Internet Research*, Vol. 12, No. 2, p.e1286.

Stefanacci, R.G. and Haimowitz, D. (2012) 'Medication management in assisted living', *Geriatric Nursing*, Vol. 33, No. 4, p.304-e1.

Zhang, P., Zhang, X., Brown, J., Vistisen, D., Sicree, R., Shaw, J. and Nichols, G. (2010) 'Global healthcare expenditure on diabetes for 2010 and 2030', *Diabetes Research and Clinical Practice*, Vol. 87, No. 3, pp.293–301.