



Non-therapist identification of falling hazards in older adult homes using digital photography

Katherine C. Ritchey ^{a,*}, Deborah Meyer ^b, Gillian H. Ice ^c

^a Department of Geriatrics and Gerontology, Ohio University Heritage College of Osteopathic Medicine Health Sciences Center, Athens, OH, United States

^b Department of Interdisciplinary Health Studies, Ohio University College of Health Sciences and Professions, Athens, OH, United States

^c Department of Social Medicine and Director of Global Health, Ohio University Heritage College of Osteopathic Medicine Health Sciences Center, Athens, OH, United States

ARTICLE INFO

Available online 21 September 2015

Keywords:

Fall prevention
Home safety
Falling hazards
Home assessments

ABSTRACT

Evaluation and removal of home hazards is an invaluable method for preventing in-home falls and preserving independent living. Current processes for conducting home hazard assessments are impractical from a whole population standpoint given the substantial resources required for implementation. Digital photography offers an opportunity to remotely evaluate an environment for falling hazards. However, reliability of this method has only been tested under the direction of skilled therapists.

Ten community dwelling adults over the age of 65 were recruited from local primary care practices between July, 2009 and February, 2010. In-home (IH) assessments were completed immediately after a photographer, blinded to the assessment form, took digital photographs (DP) of the participant home. A different non-therapist assessor then reviewed the photographs and completed a second assessment of the home. Kappa statistic was used to analyze the reliability between the two independent assessments.

Home assessments completed by a non-therapist using digital photographs had a substantial agreement (Kappa = 0.61, $p < 0.001$) with in-home assessments completed by another non-therapist. Additionally, the DP assessments agreed with the IH assessments on the presence or absence of items 96.8% of the time.

This study showed that non-therapists can reliably conduct home hazard evaluations using digital photographs.

© 2015 Published by Elsevier Inc. This is an open access article under the CC BY-NC-ND license (<http://creativecommons.org/licenses/by-nc-nd/4.0/>).

Introduction

Falls are the leading cause of unintentional fatal and non-fatal injury in those over the age of 65, with nearly half of older individuals falling in their home (Gill et al., 1999; Centers for Disease Control and Prevention NCFPaC, 2010, 2014). Studies suggest that most homes occupied by older adults have at least four falling hazards and that hazards are involved in 30–40% of in-the-home falls (Carter et al., 1997; Wyman et al., 2007; Stevens et al., 2014). Evaluation and removal of home hazards is an invaluable method for preventing falls, reducing the risk of injury and preserving independent living in the elderly (Stevens et al., 2001; Clemson et al., 1996; Gillespie et al., 2012; Robertson and Gillespie, 2013).

Several randomized control trials and subsequent meta-analysis have shown that home hazard assessments reduce the rate of falls by nearly 20%, therefore making them recommended components of multifactorial fall interventions (Clemson et al., 1996, 2008; Nikolaus, 2003; Campbell et al., 2005; Lord et al., 2006; Anon, 2011, 2012, 2013; Cumming et al., 1999; Day et al., 2002). However, effective hazard removal programs are cost-prohibitive from a public health perspective (Gillespie et al., 2012; Clemson et al., 2008; Lord et al., 2006). The significant time and labor required for in-home assessments performed by a skilled assessor, typically an occupational therapist (OT), and absent reimbursement for home safety services highlight factors impeding the provision of home assessments (Pynoos and Nishita, 2003).

Digital photography offers an opportunity to remotely evaluate the environment for falling hazards. Limited studies suggest that digital photography reliably identifies hazards related to falling (Daniel et al., 2013; Sanford and Butterfield, 2005). These studies relied on OTs to supervise photography training and conduct the digital home evaluation. This report therefore, investigates the concordance of digitally based home hazard assessments to in-home assessments completed by novice evaluators. By demonstrating that non-therapists can assess

* Corresponding author at: Geriatric Fellow, University of Washington, V.A. Puget Sound Health Care System, 1660 S. Columbian Way (S-182-GRECC), Seattle, WA 98108-1597, United States. Fax: +1 206 764 2569.

E-mail address: krhanke@uw.edu (K.C. Ritchey).

photographs for falling hazards, results of this study may encourage more sustainable approaches to home safety programs.

Methods

Participants

Primary care physicians (8 physicians in two separate practices) located in the Athens County region of Ohio were approached to help in the recruitment of participants. These physicians identified patients meeting the following criteria: 65 years or older; live independently at home; no hospitalizations in the prior month; no history of mild cognitive impairment or dementia as determined by their primary care physician. Recruitment occurred between July 2009 and February 2010. Participants were contacted, informed about the study and provided consent to the primary investigator. The study protocol, risks of procedures and consent were reviewed and approved by Ohio University Institutional Review Board.

Intervention design

A *de novo* assessment was created from validated home hazard forms but reduced in length to focus on three areas of high risk for falls in order to determine the feasibility and provide proof of concept that the use of photographs by non-therapists is a reliable method to assess home safety (Fischer et al., 2007; Clemson et al., 1999; La Grow et al., 2006). The final form had a total of 44 items limited to the living room (18), bedroom (18), and staircase (4) as these are high risk areas for falls (Carter et al., 1997; Clemson et al., 1996; La Grow et al., 2006). Items comprised of hazardous conditions associated with entrances, walkways, sitting areas, beds, handrails, steps, and lighting. Each item was scored independently where “yes” indicated a hazardous condition (HC) was present, “no” indicated a HC was not present, or “not-applicable” indicated the HC or location did not exist.

In order to ensure the *de novo* home hazard instrument was reliable, we first analyzed the agreement between two independent raters completing in-home (IH) assessments on the same home with the *de novo* home hazard form. Two medical student evaluators without prior home safety, occupational, or physical therapy training were recruited to complete ten (10) independent IH assessments. These assessments were done on the same day, in sequential order and blinded to each other's findings. Substantial reliability between the two IH assessments was obtained (Kappa = 0.681, $p < 0.001$) and confirmed that the digital photograph (DP) study could proceed with reliable home hazard form.

The reliability of home hazard identification by non-therapists using DP was evaluated by comparing a DP home assessment by one rater to an IH assessment of the same home by a different rater. Two different medical students, without prior home safety, occupational, or physical therapy experience, used the same *de novo* assessment form described above for either the DP or the IH assessments. A third non-therapist, medical student acted as the photographer and was blinded to the content of the home safety assessment form used by the DP and IH evaluators. A photographer's protocol developed specifically for this study by the primary investigator is described here in brief. The photographer received a succinct (<20 min) training session provided by primary investigator but otherwise had no other formal training on photography, home hazards or the *de novo* home assessment. The protocol specified room locations, camera angle, and distance and position to stand from landmarks (i.e. entrances, walls, the bed) to ensure that the rooms were captured in their entirety. One photograph was taken of the room entrance, five for each wall in a room and one for each side of the bed exposed (not touching a wall). On the day of the IH assessment, the photographer first entered the home and completed the photography protocol using a standard, commercially available digital camera. Once the photographer had left the premises, the IH evaluator entered the home completed the IH assessment. The DP evaluator, blinded to

the content of the IH assessment, then completed the DP assessment from the digital photographs once downloaded on a computer. The IH assessor provided all participants with a home safety checklist and brief education regarding home hazards after the assessment was completed. It took an average of 25 min to complete in IH assessment, 13 min to complete the photographs and 22 min to complete the DP assessment.

Statistical analysis

Power analysis completed prior to the study indicated that ten home assessments yielding 440 variables were required to detect substantial agreement (Kappa > 0.6) with a power of 0.8 between two independent raters (Cohen, 1960). An inter-rater reliability test using a generalized non-weighted Kappa Statistic was performed with SPSS, version 18.0, in March 2010. Observed agreement was calculated between each independent rater's responses to the 44 items over the 10 home assessments (for a total of 440 variables). Percentage agreement (PA) was derived by subtracting the percent disagreement obtained from the 2×2 or 3×3 table established by SPSS from 100.

There was no source of funding, grant or otherwise, which supported this work.

Results

A total of 11 participants were recruited to participate in IH and DP home assessments. One participant declined leaving 10 available for demographic information (Table 1) and analysis. DP assessments were concordant with the IH assessments on the presence or absence of HC 96.8% of the time. Discordant information was observed in four paired home assessments. In one case, two HC were present in the IH but where marked as “not applicable” in the DP assessment (0.4% of questions). For the other three cases, 10 HC were present in the DP but were absent in the IH assessment (3% of questions).

There was substantial agreement between the DP and IH assessments (PA = 78%, Kappa = 0.61, $p < 0.001$). A subset analysis of each room location indicated that the bedroom had slightly stronger agreement than the living room, with walkways within either room having the greatest reliability (Table 2). Photographs captured HC associated with walkways, beds, entrances, or exits with reasonable reliability (Table 2). The bed had the strongest agreement followed by walkways and entrance ways in the bedroom and living room. Moderate reliability was found for sitting areas and staircases but the Kappa value was not significant. Percent agreements for each of these areas were 62.5% and 83%, respectively (Table 2).

Informal comments provided by 10 participants to IH assessor indicated that the older adults appreciated the assessment of the home and education materials provided. There was no negative feedback suggesting that the participants felt reluctant to have strangers into their home to either take photographs or complete a home hazard assessment. The medical student assessors and photographer also had positive interactions with the older adults.

Table 1
Participant demographics.

	All	Female	Male
Total (n)	10	6	4
Age (mean)	78	78.4	77.2
Fallen in past year	63.8% (7)	57.1% (4)	60% (3)
Fear of falling	18.1% (2)	28.5% (2)	0
Live alone	63.8% (7)	85.7% (6)	20% (1)
Home assistance	18.1% (2)	28.5% (2)	0

Table 2
Inter-rater reliability and percent disagreement for the living room, bedroom and items within.

Areas	Number of questions ^a	Percent Agreement	Kappa	p-value
Living room	180	73	0.443	0.000
Entrances/exits	100	70	0.379	0.000
Walkways	40	87.5	0.679	0.000
Bedroom	180	78	0.568	0.000
Entrances/exits	100	74	0.461	0.000
Walkways	40	82.5	0.478	0.002
Bed	40	85	0.683	0.000

Boldface indicates statistical significance ($p < 0.01$)

^a Reflects the number of questions combined for all 10 assessments

Discussion

Despite established efficacy, the time, resources, and cost to perform in-home assessments prohibit widespread implementation of home hazard fall prevention programs. (Gillespie et al., 2012; Clemson et al., 2008; Lord et al., 2006) Herein, we report that non-therapists could reliably conduct a home hazard evaluation using digital photographs. This is the first study of its kind to show that non-skilled assessors can utilize photographs to identify falling hazards.

Though the primary aim of the study was overall reliability, analysis of individual rooms and sections within the rooms provided useful information regarding variability in photograph sensitivity and to highlight possible strengths and weaknesses of this approach. Agreement was stronger for bedroom HC compared to living room HCs. Though assessment form questions and directions were similar for these locations, bedroom assessments included 3–4 more photographs capturing the area around the bed. This additional set of photographs could have increased the sensitivity of DP assessments as indicated by the greater reliability of the bedroom assessments and by the observation that DP evaluations captured more HCs in 30% of cases. On the other hand, entrances/exits had the lowest reliability of any item section. A few explanations for this finding is the limited number of pictures (1) per entrance/exit, ability of photographs to distinguish small items (i.e. light switches, thresholds) assessed in this location or poor conditions (i.e. low light) diminishing the quality and sensitivity of photographs. Though beyond the scope of this project, a digital home hazard assessment holds a significant potential to support the remote implementation of home hazard prevention programs and could possibly improve upon the current standard of care.

There were some limitations to our study. For one, the small sample size reduced the power necessary to conduct analysis of individual items and identify the aspects of the assessment procedure reducing overall reliability. Secondly, the photographer was not reflective of a community dwelling older adult, however, given the simplicity of the photograph instructions and number of photographs required, it is plausible an older adult or surrogate could produce similar results. Lastly, we investigated the reliability of home hazard assessments as conducted by two non-therapists, omitting a comparison to a skilled assessor. Therefore, it is possible that our results indicate high concordance between novices but are inaccurate as compared to the gold standard. Studies have shown that non-therapists can identify hazards with consistency comparable to therapists (Day et al., 2002; Pighills et al., 2011). Thus, the study's conclusions retain clinical merit and serve as a foundation for future investigations.

Conclusions

Remote home safety and fall hazard assessments have the potential to transform community-based therapist services and public health interventions supporting aging in place. Results from this study support a non-therapist use of digital technology as a means for evaluating the home for falling hazards. Results from this study not only support the

use of digital technology but the use of non-skilled assistants as a means for expanding therapist home safety services. Future clinical trials will need to establish the sustainability and clinical efficacy of remote assessments that involve all high risk locations of the home with varying degrees of therapist, community resident or older adult involvement. These studies would need to address how reliable assessments completed by novices (i.e. older adults or confidants) are and how efficacious they are at reducing falls or encouraging older adult adherence to technology-based home safety modifications. Though there remains further refinement before digital evaluations replace in-home hazard assessments, there is strong evidence that mobile technologies utilized by non-clinicians can improve the provision of this much needed fall prevention service.

Financial disclosure

This study did not receive any financial support or funding.

Author contributions

KCR and GHI were responsible for the study concept and design. DM significantly contributed to study design. KCR and GHI was responsible for data analysis. All authors were responsible for interpretation of results, writing and editing of this manuscript.

The content of this article has not been previously published elsewhere. No financial disclosures were reported by the authors of this paper.

Conflict of interest statement

Katherine C. Ritchey: I had no conflict of interest or financial interest to disclose in relation to this manuscript.

Deborah Meyer: I had no conflict of interest or financial interest to disclose in relation to this manuscript.

Gillian H. Ice: I had no conflict of interest or financial interest to disclose in relation to this manuscript.

Acknowledgments

The authors would like to thank the physicians at University Medical Associates, Athens, Ohio who supported the recruitment of participants for the study. The authors are indebted to the contributions of the many medical students who volunteered their time completing the photography and home assessments. We would also like to thank Dr. Wayne Carlson and Dr. Victor Heh, who provided additional support in the study design and mentorship of the primary author. Finally, we would like to note special recognition of Dr. Alvin Matsumoto, Dr. Elizabeth Phelan and Dr. Mark Hanke, who provided manuscript guidance and review.

References

- Anon, 2011. Summary of the updated American Geriatrics Society/British Geriatrics Society clinical practice guidelines for prevention of falls in older adults. *J. Am. Geriatr. Soc.* 59 (1), 148–157.
- Anon, 2012. Prevention of falls in community-dwelling older adults: USPTF. Anon, 2013. Falls: assessment and prevention of falls in older adults. June, 2013 ed. National Institute of Clinical Excellence, London (June).
- Campbell, A., Robertson, M., La Grow, S., et al., 2005. Randomized controlled trial of prevention of falls in people aged >75 with severe visual impairment: the VIP trial. *BMJ* 331 (7520), 817–825.
- Carter, S., Campbell, E., Sanson-Fisher, R., Redman, S., Gillespie, W., 1997. Environmental hazards in the homes of older people. *Age Ageing* 26, 195–202.
- Centers for Disease Control and Prevention NCFPaC, 2010, 2014. Web-based Injury Statistics Query and Reporting System (WISQARS).
- Clemson, L., Cumming, R., Roland, M., 1996. Case-control study of hazards in the home and risk of falls and hip fractures. *Age Ageing* 25 (2), 97–101.
- Clemson, L., Fitzgerald, M., Heard, R., Cumming, R., 1999. Inter-rater reliability of a home fall hazard assessment tool. *Occup. Ther. J. Res.* 19 (2), 171–179.

- Clemson, L., Mackenzie, L., Ballinger, C., Close, J., Cumming, R., 2008. Environmental interventions to prevent falls in community-dwelling older people: a meta-analysis of randomized trials. *J. Aging Health* 20 (8), 954–971.
- Cohen, J., 1960. A coefficient of agreement for nominal scales. *Educ. Psychol. Meas.* 20, 37–46.
- Cumming, R., Thomas, M., Szonyi, G., et al., 1999. Home visits by an occupational therapist for assessment and modification of environmental hazards: a randomized trial of falls prevention. *J. Am. Geriatr. Soc.* 47 (12), 1397–1402.
- Daniel, H., Oesch, P., Stuck, A., Born, S., Bachmann, S., Schoenengerger, A., 2013. Evaluation of a novel photography-based home assessment protocol for identification of environmental risk factors for falls in elderly persons. *Swiss Med. Wkly.* 12 (143).
- Day, L., Fildes, B., Gordon, I., Fitzharris, M., Flamer, H., Lord, S., 2002. A randomized factorial trial of falls prevention among older people living in their own homes. *BMJ* 325, 128–133.
- Fischer, G., Baker, A., Koval, D., Lishok, C., Maisto, E., 2007. A field test of the cougar home safety assessment (version 2.0) in the home of older persons living alone. *Aust. Occup. Ther. J.* 54 (2), 124–130.
- Gill, T., Williams, C., Robison, J., Tinetti, M., 1999. A population-based study of environmental hazards in the homes of older persons. *Am. J. Public Health* 89 (4), 553–556.
- Gillespie, L., Robertson, M., Gillespie, W., Sherrington, C., Gates, S., Clemson, L., 2012. Interventions for preventing falls in older people living in the community. *Cochrane Database Syst. Rev.* 12 (9).
- La Grow, S., Robertson, M., Campbell, A., Clarke, G., Kerse, N., 2006. Reducing hazard related falls in people 75 years and older with significant visual impairment: how did a successful program work? *Inj. Prev.* 12, 296–301.
- Lord, S., Menz, H., Sherrington, C., 2006. Home environment risk factors for falls in older people and the efficacy of home modifications. *Age Ageing* 35 (2), ii55–ii59.
- Nikolaus, T.B.M., 2003. Preventing falls in community-dwelling frail older people using a Home Intervention Team (HIT): results from the randomized falls–HIT trial. *J. Am. Geriatr. Soc.* 51 (3), 300–305.
- Pighills, A., Torgerson, D., Sheldon, T., Drummond, A., Bland, J., 2011. Environmental assessment and modification to prevent falls in older people. *J. Am. Geriatr. Soc.* 59 (1), 26–33.
- Pynoos, J., Nishita, C., 2003. The cost and financing of home modifications in the United States. *J. Disabil. Policy Stud.* 14, 68–73.
- Robertson, M.C., Gillespie, L.D., 2013. Fall prevention in community-dwelling older adults. *JAMA* 309 (13), 1406–1407.
- Sanford, J., Butterfield, T., 2005. Using remote assessment to provide home modification services to underserved elders. *The Gerontologist* 45 (3), 389–398.
- Stevens, M., Holman, C., Bennett, N., 2001. Preventing falls in older people: impact of an intervention to reduce environmental hazards in the home. *J. Am. Geriatr. Soc.* 49 (11), 1442–1447.
- Stevens, J., Mahoney, J., Ehrenreich, H., 2014. Circumstances and outcomes of falls among high risk community-dwelling older adults. *Inj. Epidemiol.* 1 (5), 1–9.
- Wyman, J., Croghan, C., Nachreiner, N., et al., 2007. Effectiveness of education and individualized counseling in reducing environmental hazards in the homes of community-dwelling older women. *J. Am. Geriatr. Soc.* 55 (10), 1548–1556.