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Evaluation of a novel photography-based home assessment protocol for identification of environmental risk factors for falls in elderly persons

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Summary

PRINCIPLES: To evaluate the validity and feasibility of a novel photography-based home assessment (PhoHA) protocol, as a possible substitute for on-site home assessment (OsHA).
METHODS: A total of 20 patients aged ≥65 years who were hospitalised in a rehabilitation centre for musculoskeletal disorders affecting mobility participated in this prospective validation study. For PhoHA, occupational therapists rated photographs and measurements of patients' homes provided by patients' confidants. For OsHA, occupational therapists conducted a conventional home visit.
RESULTS: Information obtained by PhoHA was 79.1% complete (1,120 environmental factors identified by PhoHA vs 1416 by OsHA). Of the 1,120 factors, 749 had dichotomous (potential hazards) and 371 continuous scores (measurements with tape measure). Validity of PhoHA to potential hazards was good (sensitivity 78.9%, specificity 84.9%), except for two subdomains (pathways, slippery surfaces). Pearson's correlation coefficient for the validity of measurements was 0.87 (95% confidence interval [CI 0.80–0.92, $p < 0.001$). Agreement between methods was 0.52 (95%CI 0.34–0.67, $p < 0.001$, Cohen's kappa coefficient) for dichotomous and 0.86 (95%CI 0.79–0.91, $p < 0.001$, intraclass correlation coefficient) for continuous scores. Costs of PhoHA were 53.0% lower than those of OsHA ($p < 0.001$).
CONCLUSIONS: PhoHA has good concurrent validity for environmental assessment if instructions for confidants are improved. PhoHA is potentially a cost-effective method for environmental assessment.

Key words: *gome assessment; photography-based home assessment; elderly; environmental falls risk factors; geriatrics*

Introduction

Elderly people often fall, sometimes with serious consequences [1–3]. Multiple risk factors combine to increase the risk of falls. These include decreased function and environmental hazards [4, 5]. Examples of home hazards are staircases, doorsteps, slippery surfaces and missing handrails [5–11]. International guidelines recommend that occupational therapists (OTs) conduct on-site home assessments (OsHA) so that risk factors can be detected and reduced [1, 5, 12–18]. Although considered the standard for home assessment, OsHA is seldom performed because it requires considerable health care resources. Lower cost alternatives are needed. Our goal was to evaluate a newly developed protocol for photography-based home assessment (PhoHA) for concurrent validity, determine how well it agreed with OsHA, and examine its feasibility for the evaluation of environmental factors that might contribute to falls among elderly people.

Methods

Study population

The following patients were eligible for this prospective validation study: patients aged 65 years or more who had been referred for inpatient rehabilitation of a musculoskeletal disorder affecting mobility to the rehabilitation centre in Valens (Switzerland) between December 2010 and September 2011 and who were living <60 km away from the rehabilitation centre. Patients were included if OsHA had been prescribed and if a confidant was available. Patients were excluded if OsHA had been performed prior to the index hospital admission. To ensure valid informed consent, patients who had a Mini Mental State Examination (MMSE) score of <24 points or insufficient German language skills were also excluded. The study was approved by the Ethics Committee of the Canton St. Gallen, Switzerland (EKSG 10/108/2B). All participants and confidants gave written informed consent.

Measurements

Measurements for the evaluation of validity and agreement between methods

For each participating patient, a PhoHA and an OsHA were performed independently of each other. The order in which the two assessments were performed was random. PhoHA involved a confidant taking photographs at the patient's home and an OT evaluating the photographs at the rehabilitation centre. For OsHA, another OT, who was not involved in the PhoHA of this patient, visited the patient's home, evaluated the environmental factors on-site, and coded the findings in a usual OsHA protocol. The OT involved in the PhoHA was blinded for the findings of the OsHA in this patient and the OT performing the OsHA was blinded for the findings of this patient's PhoHA. All OTs were chosen from a pool of OTs experienced in the conduction of home assessments.

For PhoHA, one of the authors (HD) developed a protocol for confidants based on the OsHA protocol. The PhoHA protocol contained instructions on where and how to take photographs, a checklist for filling in measurements to be taken with the tape measure (e.g., height of doorsteps) and questions about the home environment (e.g. the number of stairs). An OT, not involved in the OsHA of the patient, taught the patient's confidant how to use both the PhoHA protocol and a digital camera. For the home visit, the confidant received the PhoHA protocol, the digital camera and a tape measure. Confidants then visited the patient's home and went through the PhoHA protocol while the patient was still in the rehabilitation centre. After completing PhoHA, confidants returned the completed PhoHA protocol and the digital camera and memory card containing the photographs to the rehabilitation centre by post. An OT then coded the presence or absence of predefined environmental factors in the participant's home (e.g., presence or absence of carpet borders in the living room) based on an evaluation of the digital photographs. The final data from PhoHA contained dichotomous scores (potential hazards) and continuous scores (measurements with tape measure), and covered the same environmental factors as were assessed in OsHA.

Measurements for the evaluation of feasibility

Cost analysis of PhoHA and OsHA comprised of personnel as well as material costs. Personnel costs for the OT (including social insurance costs) were based on a rate of 49.30 Swiss francs per hour. For PhoHA, time for instruction of confidants by the OT and for the OT's completion of the PhoHA protocol were measured and resulting personnel costs were calculated. Material costs of PhoHA included costs for digital equipment (16.54 Swiss francs per PhoHA) and costs for the parcel postage (9.00 Swiss francs per PhoHA). For OsHA, personnel costs were calculated based on the measured travel time to the participant's home and time spent conducting and analysing the OsHA. Material costs of OsHA included travel expenses of 0.75 Swiss francs per driven km.

Confidants' willingness to complete the PhoHA was assessed with seven questions. Interviewees were asked if they willingly conducted the PhoHA, if they would do a PhoHA again, if the instructions by the OT and the protocol were clear, if the time demand was reasonable, if they encountered difficulties, and if the camera was easy to use. Four-point Likert-scales, ranging from full agreement to full disagreement, were provided for the answers.

Statistical analysis

The OsHA with its moderate to good validity and reliability was considered the gold standard [19]. Environmental factors were divided into nine categories. We compared the completeness of the information provided by the PhoHA to the gold standard. We assessed concurrent validity by calculating sensitivity and specificity for dichotomous scores and Pearson's correlation coefficients for continuous scores [20]. Bonferroni procedures reduced type I error; adjustment for 6 comparisons resulted in the use of a p value <0.01 as the level of significance. Sensitivity refers to the proportion of environmental hazards identified by the PhoHA, compared to those identified by OsHA. Specificity refers to the proportion of non-hazardous environmental factors correctly identified by the PhoHA. As measures of agreement between PhoHA and OsHA, Cohen's kappa coefficients with 95% confidence intervals (CI) were calculated for dichotomous scores, and intra-class correlation coefficients (ICC) with 95% CI for continuous scores [21]. ICC values were interpreted like Kappa values ($\leq$0.2 indicating poor, 0.21–0.40 fair, 0.41–0.60 moderate, 0.61–0.80 good, and >0.80 very good agreement) [22]. As the protocols were completed by OTs chosen from a pool, we used a one-way analysis of variance (ANOVA) in which the subject was a random effect and the rater was viewed as measurement error. This is why we chose ICC model 1.1 [23]. Pearson's correlation coefficients, Cohen's kappa coefficients and ICC were calculated separately for each category of environmental factors as well as overall for all categories combined by using a weighted mean (weighted for the number of observations in the category). For overall coefficients, a combined p value was calculated using Fisher's method [24]. Costs were compared with a paired sample t-test. We used MedCalc version 9.7.3.0 for the analysis of dichotomous scores, and SPSS version 18 for the analysis of continuous scores.

Results

During the study period, 82 patients ≥65 years were referred for inpatient rehabilitation of a musculoskeletal condition affecting mobility to the rehabilitation centre and were living <60 km away. We excluded patients who refused study participation (n = 21), who had no available confidant (n = 8), for whom OsHA was previously performed (n = 7), whose Mini Mental State Exam score was <24 (n = 3), or who had insufficient German language skills (n = 2). Of the remaining 41 patients, 11 patients were missed for inclusion (i.e., were not asked for study participation) and 10 patients were discharged before OsHA could be organised, leaving a final study population of 20 patients.

The mean age of study participants was 73.0 ± 4.9 years (range 66–82 years). A total of 15 patients (75.0%) were female, and five patients (25.0%) were male. All patients had clinical evidence of mobility impairment; this was due to osteoarthritis or fractures of hip or knee in ten patients (50.0%), spinal stenosis or degenerative spine disease in nine patients (45.0%), and lower limb amputation in one patient (5.0%). Sixteen patients (80.0%) needed a walking aid. Eleven patients (55.0%) lived with a partner, whereas nine patients (45.0%) lived alone. The mean distance from the rehabilitation centre to the participants' home was 33.4 ± 13.4 km. The mean age of the 20 confidants (ten female and ten male) conducting the PhoHA was 58.3 ± 15.6 years (range 23–77 years).

Completeness of information

Table 1 shows the completeness of information obtained by the PhoHA, compared to the gold standard for the nine separate categories of environmental factors. The PhoHA provided ≥75% of the information obtained by the OsHA in seven out of the nine categories. Overall, the PhoHA ascertained 1120 environmental factors (79.1%) of the 1416 factors obtained by the gold standard. The 1120 environmental factors concomitantly identified with both home assessments were used to determine concurrent validity and agreement between the two methods.

Concurrent validity

Of the 1,120 environmental factors, 749 had dichotomous scores (potential hazards) and 371 continuous scores (measurements with tape measure). Of the 749 potential hazards, 280 were rated by the gold standard as hazards present at the patients' homes. The PhoHA revealed 221 hazards, corresponding to an overall sensitivity of 78.9%. Compared with the 469 potential hazards rated by the gold standard as not present, the PhoHA congruently rated 398 factors. This corresponded to an overall specificity of 84.9%. Sensitivities and specificities for each category of environmental factors are separately shown in table 2. The PhoHA missed between 10.8% (doorsteps) and 59.4% (pathways) of the hazards. The Pearson's correlation coefficient for the validity of continuous measures was 0.87 overall (95% CI 0.80–0.92, p <0.001). The Pearson's correlation coefficients for each separate category of environmental factors are shown in table 3. Associations between OTs and confidants were high.

Agreement between PhoHA and OsHA

Agreement between methods was moderate overall for dichotomous (Cohen's kappa coefficient 0.52, 95% CI 0.34–0.67, p <0.001) and very good for continuous scores (intraclass correlation coefficient 0.86, 95% CI 0.79–0.91, p <0.001). Cohen's kappa coefficients for each separate category of environmental factors are shown in table 2 and ICC values separate for each category in table 3. For assessment of staircases, doors, doorsteps and furniture, agreement was good to very good. Moderate agreement was found for flooring, handrails and toilets. Agreement on pathways was fair, except for the width of parking places, which was very good. Poor agreement was found for slippery surfaces.

Feasibility

For PhoHA, OTs spent a mean time of 25 ± 7 minutes (range 10–30 minutes) for the instruction of the confidants and 38 ± 14 minutes (range 30–90 minutes) for the analysis of the PhoHA protocol. Together with the costs for digital equipment and parcel postage, the resulting total costs for one PhoHA were 77 ± 43 Swiss francs. For OsHA, the OT spent a mean time of 71 ± 31 minutes (range 20-142 minutes) for driving to the participant's home, a mean time of 53 ± 22 minutes (range 35–130 minutes) for conducting the OsHA, and a mean time of 15 ± 14 minutes (range 0-70 minutes) for analysing the OsHA. The mean distance driven was 67 ± 27 km (range 12–120 km). The resulting total costs for one OsHA were 164 ± 43 Swiss francs which was significantly higher than for one PhoHA (p <0.001). The relative cost reduction by PhoHA was 53.0% compared with OsHA.

A total of 18 of 20 confidants (90.0%) answered the questions about their willingness to complete the PhoHA. Confidants needed on average 60 ± 23 minutes to conduct the PhoHA. Confidants' acceptability was high: all confidants answered that the protocol was clear and easy to use, that the PhoHA was easy to perform, and that the time allocated to it was reasonable: they would again perform a PhoHA in future. In addition, 17 confidants (94.4%) answered that the digital camera was easy to use, and one (5.6%) said that the camera was not operative (which was due to an empty battery). A total of 16 confidants (88.9%) already had experience in the use of a digital camera.

Table 1: Completeness of information obtained by the PhoHA compared with the gold standard (on-site home assessment) for the nine separate categories of environmental factors.

Category of environmental factors	Number of environmental factors identified by PhoHA	Number of environmental factors identified by OsHA	Completeness of information of PhoHA compared with OsHA
Staircases	206	262	78.6%
Doors	121	137	88.3%
Doorsteps	190	247	76.9%
Slippery surfaces	47	92	51.1%
Flooring	159	173	91.9%
Pathways	256	325	78.8%
Handrails	66	101	65.3%
Furniture	56	59	94.9%
Toilets	19	20	95.0%
Total all categories	1,120	1,416	79.1%

OsHA = on-site home assessment; PhoHA = photography-based home assessment

Discussion

This prospective validation study of PhoHA revealed several promising findings. First, PhoHA captured the majority of the environmental factors obtained by the OsHA. Second, with the exception of pathways and slippery surfaces, concurrent validity and agreement between the two methods was moderate to very good for the assessed environmental factors. Third, its high acceptability and satisfaction ratings by confidants, as well as its lower cost, make PhoHA a feasible option.

The present study proposes a novel and innovative concept for home assessment. To the best of the authors' knowledge, the present study is the first evaluation of this form of PhoHA for environmental assessment in elderly persons. One previous study investigated the risk factors for environmental falls in older patients using video recordings, and found a validity that was comparable to the present study [25]. However, video-based assessment was performed by a technician and not by OTs or confidants. Furthermore, the two hours needed for the video-based assessment was twice as high as for the PhoHA.

Validity and agreement were low for the assessment of pathways and slippery surfaces. It was difficult to identify slippery surfaces by photographing them. Therefore, assessment of slippery surfaces should be added to the written PhoHA protocol and confidants should be instructed on how to evaluate them. Photographs did not always capture the whole room, and thus obstructed pathways were often missed in PhoHA. Using cameras with wide angle lenses will likely improve detection rate and validity.

The study has some limitations. First, the generalisability of this study's findings is limited, given the small sample size of 20 hospitalised patients at one rehabilitation centre. However this study does demonstrate proof of principle, suggesting that PhoHA should continue to be validated in different settings. Second, approximately 50% of eligible patients refused to participate in the study, which raises questions about the protocols acceptability for patients and/or their confidants. For this study, patients were informed that they were taking part in a research project, and PhoHA was not an integral part of clinical care. Under these circumstances, a participation rate of almost 50% is excellent because patients could not be assured that this method would have benefits. Thirdly, this study did not evaluate inter-rater reliability of PhoHA interpretation by OTs. Validity of PhoHA might therefore differ to some extent from the findings in this study. Fourth, to make the study less complex, we did not evaluate lighting conditions in the home assessments. As photographs may not provide adequate information on lighting conditions, we suggest adding evaluation of lighting to the PhoHA protocol. Fifth, PhoHA, in its current form, is not capable of directly observing the interactions between falls risk factors at the patient's home and the patient. Finally, cost savings depend on the distance between the hospital and the patients' home. In the present analysis, the average distance was 33.4 km and the cost savings were 87 Swiss francs per person. For the purpose of the feasibility of the present study, patients living far away from the hospital (>60 km) were excluded. If the average distance was 100 km, cost savings would amount to 141 Swiss francs per person.

The present study has research implications. First, based on the results of the present study the PhoHA can be refined (e.g., improved protocol for the assessment of slippery sur-

Table 2: Sensitivity, specificity and Cohen's kappa coefficients of the photography-based home assessment for the dichotomous scores in each category compared with the gold standard (on-site home assessment).

Category	Environmental factors in category	Number of observations	Sensitivity	Specificity	Cohen's kappa coefficient (95% confidence interval, p value)
Staircases	Presence of stairs or uneven stairs, and irregular height of steps	105	87.2%	89.7%	0.77 (0.65–0.90, p <0.001)
Doorsteps	Presence of doorsteps	131	89.2%	89.4%	0.79 (0.68–0.89, p <0.001)
Slippery surfaces	Presence of slippery/moist surfaces or loose rugs, absence of non-slip mats in bathroom	47	66.7%	68.3%	0.20 (–0.06–0.45, p = 0.10)
Flooring	Presence of uneven flooring (by carpet borders, stone coverings or sticking-out tiles)	159	77.1%	81.6%	0.59 (0.46–0.71, p <0.001)
Pathways	Presence of obstructed pathways (e.g. by furniture or other objects)	241	40.6%	87.6%	0.26 (0.01–0.42, p <0.001)
Handrails	Absence of appropriate handrails	66	87.2%	73.7%	0.60 (0.34–0.81, p <0.001)

Table 3: Pearson's and intraclass correlation coefficients of the photography-based home assessment for the continuous scores in each category compared with the gold standard (on-site home assessment).

Category	Environmental factors in category	Number of observations	Pearson's correlation coefficient (95% confidence interval, p value)	Intraclass correlation coefficient (95% confidence interval, p value)
Staircases	Measurement of numbers and dimensions of steps	101	0.75 (0.65–0.83, p <0.001)	0.72 (0.61–0.80, p <0.001)
Doors	Measurement of door width in rooms and elevators	121	0.95 (0.93–0.96, p <0.001)	0.95 (0.93–0.96, p <0.001)
Doorsteps	Measurement of threshold/doorstep heights	59	0.94 (0.90–0.96, p <0.001)	0.94 (0.90–0.96, p <0.001)
Pathways	Measurement of parking place width	15	0.96 (0.89–0.97, p <0.001)	0.93 (0.81–0.98, p <0.001)
Furniture	Measurement of seat and bed heights	56	0.92 (0.87–0.97, p <0.001)	0.92 (0.87–0.95, p <0.001)
Toilets	Measurement of toilet heights	19	0.58 (0.17–0.82, p = 0.01)	0.57 (0.18–0.81, p = 0.003)

faces, pathways and lighting) and validated in different settings (e.g., evaluation in ambulatory elderly patients, employment of local caregivers instead of confidants, evaluation of inter-rater reliability). Second, future research should investigate whether suggested changes in the home environment based on the findings of a PhoHA are implemented and whether these changes reduce falls or improve other outcomes. Previous research has shown that modifications of home environment based on OsHA can reduce falls and health care costs [26–30], but the effectiveness of home assessment to reduce falls seems to depend on the way it is performed [31]. Potentially, PhoHA might be even more effective than OsHA because the involvement of confidants in the treatment might improve the adherence of patients to follow the recommendations resulting from the home assessment [5, 32–35].

Home assessments are recommended by international guidelines, but are often not performed due to financial reasons [15, 36]. PhoHA might be a good substitute for the costly OsHA in patients with an available confidant. It might become useful not only for temporarily hospitalised patients, but also for ambulatory elderly patients who have mobility problems. Valid information can be obtained with PhoHA, but before it can be recommended as a substitute for OsHA, PhoHA has to be revised to include instructions for the assessment of slippery surfaces, pathways and lighting and tested in a wide variety of settings.

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