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ORIGINAL ARTICLE

The effectiveness of a fall detection device in older nursing home residents: a pilot study

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Abstract

Background: Real-world research to evaluate the effect of device technology in preventing fall-related morbidity is limited. This pilot study aims to investigate the effectiveness of a non-wearable fall detection device in older nursing home residents.

Methods: The study was conducted in a nursing home with single-resident rooms. Fall detection devices were randomly set up in half of the rooms. Demographic data, comorbidities, lists of medications, and functional, nutritional, and frailty status were recorded. The residents were followed up for 3 months. The primary outcome was falls and the secondary outcome was all-cause mortality.

Results: A total of 26 participants were enrolled in the study. The study group consisted of 13 residents who had a fall detection device in their rooms. The remaining 13 residents on the same floor formed the control group. Participants had a mean age of 82 ± 10 years and 89% of the residents were female. The most prevalent comorbidity was dementia. Two residents from the control group and one resident from the study group experienced a fall event during follow-up. The fall events in the control group were identified retrospectively by the nursing home staff, whereas the fall in the study group received a prompt response from the staff who were notified by the alarm. One resident was transferred to the hospital and died due to a non-fall related reason.

Conclusion: Device technology may provide an opportunity for timely intervention to prevent fall-related morbidity in institutionalized older adults.

Key words: *fall detection device, falls, nursing home, older adults.*

INTRODUCTION

One third of adults aged over 65 experience a fall every year[1] and almost half of fallers have a repeat fall within the next year.[2] Fall-related injuries are not only associated with increased morbidity and health-related costs, but are also related to increased mortality.[1,3,4] Up to 10% of falls lead to life-threatening injuries including hip fractures and traumatic brain injury.[5] Indeed, falls are the leading cause of traumatic brain injury-related deaths in older adults.[6] Unfortunately, older adults with dementia are more likely to fall and sustain fall-related injuries compared to their peers with normal cognition.[7,8]

Multifactorial interventions are associated with a reduction in fall rate.[9] In addition to fall risk assessment, these interventions include exercise, environmental modifications, and technological aids.[9] Technological devices designed for fall detection and prevention include personal protectors, walking aids, and alarm systems.[9]

Up to 80% of older adults are unable to get up after a fall and almost one third have to lie on the floor for at least an hour.[10] Inability to get up after a fall is associated with serious injury, hospital admission, and institutionalization. Although not capable of preventing falls, alarm systems for fall detection may help avoid fall-related morbidity by alerting caregivers in case of unwitnessed falls and enabling quick response.

As falls continue to pose a major threat despite the best efforts of healthcare professionals, the potential contribution of technology-driven approaches to reduce fall-related morbidity and mortality is increasingly appreciated.[11] However, most studies on technological devices to date have been conducted on young and healthy volunteers.[12] The aim of this study was to investigate the effectiveness of a non-wearable fall detection device with older nursing home residents, as compared with a control group.

METHODS

Patient selection and analysis

This pilot prospective observational study was conducted in a nursing home in Istanbul. The nursing home consisted of five floors with a heterogeneous resident profile. Individuals with the highest risk of falls were clustered on the first floor, which was the floor chosen for the study. All residents in the nursing home had private rooms. Patients who did not consent to participate, patients with end-stage cancer, and patients who were bed bound were excluded from the study. Engineers randomly set up fall detection devices in half of the rooms on the floor, and the remaining rooms were left without a device. All components of multi-domain fall risk intervention recommended in the world guidelines were implemented for all residents by the same medical team. The primary outcome was falls and the secondary outcome was all-cause mortality.

Demographic data; comorbidities; lists of medications; functional, nutritional, and frailty status; and fear of falling were recorded at the initial presentation. Blood pressure and heart rate were measured in the seated position and after 1 and 3 min of standing, respectively.

Frailty status was evaluated with the FRAIL scale, where 0 points is categorized as normal/robust, 1–2 points as pre-frail, and 3 to 5 points as frail.[13] The Mini Nutritional Assessment-Short Form (MNA-SF) was used to assess nutritional status.[14] The MNA-SF is a nutritional screening tool, where 12 points and above are considered as normal nutritional status, 8–11 points as malnutrition risk, and 7 points and below as malnutrition. The Katz Activities of Daily Living (ADL) scale[15] and Lawton-Brody Instrumental Activities of Daily Living Scale (IADL)[16] were used to evaluate functionality. In the Katz ADL, 13–18 points indicate independence, 7–12 points semi-dependence, and 0–6 points dependence. The Lawton IADL tool defines 0–8 points as dependent, 9–16 points as semi-dependent, and 17–24 points as independent. The Fear of Falling Questionnaire-Revised (FFQ-R), a valid self-report tool, was used to quantify fear of falls.[17,18] The FFQ-R consists of six items rated on a Likert-type scale with higher scores indicating greater fear of falling. Comprehensive geriatric assessment was administered to all residents by the same geriatrician. The participants were followed up for 3 months.

Study findings were confirmed with camera recordings by an independent physician who was blinded to the study.

Written informed consent for the study was obtained from the residents or their proxies. The ethical review board of a university hospital approved the study protocol (Marmara University Ethical Committee, Protocol number: 22.07.2022.1102). The study was conducted in accordance with the Declaration of Helsinki.

The fall detection device

Vayyar's fall detection device was used for the study. The device employs multiple radio frequency antennas and advanced signal-processing algorithms to capture and analyse the reflected radio waves. Features of the device are as follows.

1 Radar Sensing: The device is located within the living space, such as on a wall or ceiling, and emits low-power radio waves into the environment.
2 Reflection Analysis: The device analyses the radio waves reflected back from the surrounding objects and uses these reflections to build a 4D imaging radar picture of the environment.
3 Fall Detection Algorithm: A sophisticated algorithm continuously monitors the radar images for signs of a fall event. The algorithm is designed to identify specific patterns and movements associated with falls. Initially, the device goes into a 'fall suspected' stage of about 40 s, during which radar reflections are analysed by the device to confirm or disqualify a fall event. If the algorithm verifies that the current event meets the criteria for a 'fall', which is a measurement of a height difference

within a certain amount of time, it moves into the 'fall confirmed' stage, during which audible and visual notifications begin. After 90 s, the device goes into the 'calling' stage.

Table 1 Characteristics of the study participants

Variables	$n = 26$, n (%)
Age†	82. 4 ± 9.5 (60–100)
Gender (M/F)	3 (11.5)/23 (88.5)
Device installed	13 (50.0)
Marital status	
Single	1 (3.8)
Married	2 (7.7)
Widowed	23 (88.5)
Walking aid use	4 (15.4)
Vision impairment	12 (46.2)
Hearing impairment	6 (23.1)
Smoking	1 (3.8)
Alcohol consumption	1 (3.8)
Previous fracture	5 (19.2)
Falls in the last year	14 (53.8)
Fear of falls	17 (65.4)
Fall incident during follow-up	3 (11.5)
FFQ-R score†	12.5 (0–18)
Orthostatic hypotension	7 (26.9)
Dementia	20 (76.9)
HT	16 (61.5)
Depression	12 (46.2)
Number of comorbidities†	4.0 (1–7)
Number of drugs†	10.0 ± 3.1 (4–16)
Weight†	63.6 ± 10.8 (41–82)
BMI†	26.32 ± 3.97 (18.67–35.49)
Calf circumference†	35.3 ± 3.5 (27–43)
Nutritional status	
Normal	1 (3.8)
Malnutrition risk	21 (80.8)
Malnutrition	4 (15.4)
FRAIL score†	2 (0–5)
Frailty status	
Robust	8 (30.8)
Pre-frail	5 (19.2)
Frail	13 (50.0)
ADL status	
Independent	12 (46.2)
Semi-dependent	12 (46.2)
Dependent	2 (7.7)
IADL	
Independent	3 (11.5)
Semi-dependent	12 (46.2)
Dependent	11 (42.3)
Fasting glucose†	100.0 (72–181)
Haemoglobin†	12.0 ± 1.0 (10.1–14.5)
Mortality	1 (3.8)

ADL, Activities of Daily Living; BMI, body mass index; FFQ-R, Fear of Falling Questionnaire-Revised; F, female; HT, hypertension; IADL, Instrumental Activities of Daily Living; M, male; MNA-SF, Mini-Nutritional Assessment-Short Form.
† Numeric variables were presented as median (minimum–maximum) or mean ± SD. BMI is calculated as weight in kilograms divided by height in meters squared.

4 Real-Time Detection: Once a fall is detected, the device triggers an alert, which can be in the form of an audible alarm, a notification sent to a caregiver's smartphone, or a signal sent to a monitoring centre. The real-time nature of the detection enables immediate response and assistance.
5 Fall Risk Analysis: Along with detecting falls, the device also monitors bed exits and other movements with a potential fall risk, in the following manner.
   - Bed Exit Detection: By analysing changes in the radar reflections, the device can detect when an individual is out of bed. This triggers a bed exit notification on the device dashboard.
   - Bend-Over Movement Detection: In addition to bed exits, the device detects an abrupt change in height, such as when a resident bends over to pick something up from the ground. This is also how the device senses a real fall. Hence, fall alarms are evaluated in two categories, 'fall alarm with fall incident' and 'fall alarm without fall incident'.

Statistical analysis

We investigated the parameters for normality by using visual (histograms and probability plots) and Kolmogorov–Smirnov tests. We described the numerical variables as mean ± standard deviation for normal variables and as median (minimum–maximum) for skew-distributed ones. We showed categorical variables as frequencies. An alpha value of less than 0.05 was used as the level of significance. We used SPSS (statistical package for social sciences) for Windows 21.0 program for the analysis.

RESULTS

A total of 26 participants were enrolled in the study. The study group consisted of 13 residents who had a fall detection device in their rooms. The remaining 13 residents on the same floor formed the control group. Participants had a mean age of 82 ± 10 years and 89% of the residents were female. Dementia was the most prevalent comorbidity ($n = 20$, 77%). Characteristics of the study participants are presented in Table 1.

Table 2 shows the comparison of the study and the control groups. Four residents in the study group were using walking aids. The study group was less

Table 2 Characteristics of the study and the control groups

Variables	No device (control group) n = 13, n (%)	Device installed (study group) n = 13, n (%)	P-value
Age[†]	81.9 ± 9.3 (65–100)	82.7 ± 10.1 (60–95)	0.83
Gender (M/F)	2 (15.4)/11 (84.6)	1 (7.7)/12 (92.3)	0.54
Walking aid use	0 (0.0)	4 (30.8)	**0.01**
Vision impairment	5 (38.5)	7 (53.8)	0.43
Hearing impairment	3 (23.1)	3 (23.1)	0.10
Previous fracture	2 (15.4)	3 (23.1)	0.62
Falls in the last year	6 (46.2)	8 (61.5)	0.43
Fall incident during follow-up	2 (15.4)	1 (7.7)	0.54
FFQ-R score[†]	9.0 (0–18)	14.0 (4–18)	0.34
Orthostatic hypotension	4 (30.8)	3 (23.1)	0.66
Number of comorbidities[†]	3.0 (1–7)	5.0 (2–7)	0.16
Number of drugs[†]	9.1 ± 3.2 (4–15)	10.8 ± 3.0 (5–16)	0.23
BMI[†]	26.5 ± 4.8 (18.7–35.5)	26.2 ± 3.2 (20.9–33.7)	0.84
Calf circumference[†]	34.9 ± 4.2 (27–43)	35.6 ± 2.9 (31–40)	0.63
MNA-SF score[†]	11 (8–14)	10 (3–11)	0.18
Frailty			
Robust	4 (30.8)	4 (30.8)	
Pre-frail	3 (23.1)	2 (15.4)	0.87
Frail	6 (46.2)	7 (53.8)	
ADL			
Independent	4 (30.8)	8 (61.5)	
Semi-dependent	7 (53.8)	5 (38.5)	0.10
Dependent	2 (15.4)	0 (0.0)	
IADL			
Independent	1 (7.7)	2 (15.4)	
Semi-dependent	2 (15.4)	10 (76.9)	**0.001**
Dependent	10 (76.9)	1 (7.7)	
Fasting glucose[†]	92.0 (72–181)	110.0 (72–166)	0.46
Haemoglobin[†]	12.3 ± 1.1 (10.3–14.5)	11.8 ± 0.9 (10.1–12.9)	0.25
Mortality	0 (0.0)	1 (7.7)	0.23

Bold values denote statistical significance at the $p < 0.05$ level.
ADL, Activities of Daily Living; BMI, body mass index; FFQ-R, Fear of Falling Questionnaire-Revised; F, female; IADL, Instrumental Activities of Daily Living; M, male; MNA-SF, Mini-Nutritional Assessment-Short Form.
[†] Numeric variables were presented as median (minimum–maximum) or mean ± SD. BMI is calculated as weight in kilograms divided by height in meters squared.

dependent in IADL compared to the control group (IADL score of 16 versus 8, $P = 0.01$). There were no other significant differences between the study and the control groups. Two residents from the control group and one resident from the study group experienced a fall event during follow up. The fall events in the control group were identified retrospectively by the nursing home staff, whereas the fall in the study group received a prompt response from the staff who were notified by the alarm. All findings were confirmed with video footage. Alarm categories and the number of residents in each category are shown in Table 3. False alarms were generated when the residents extended their legs out of the bed, as well as twice by the cleaning staff, and once by the movement of the curtains in the room. The false alarm rate per day was 0.22. Fall alarms without fall incident were generated by bend-over movement, either to pick up an object from the floor or during prayer.

Table 3 Alarm categories and the number of residents in each category

	n = 13, n (%)
Total number of false alarms, median (min-max)	2.0 (1–6)
Fall alarm without fall incident[†]	7 (53.8)
False alarm	7 (53.8)
No vision	6 (46.2)
Fall alarm with fall incident	1 (7.6)

[†] "Fall alarm without fall incident" refers to bend-over movement that triggers an alarm without resulting in a real fall.

Comparison of variables according to falls and device instalment are presented in Table 4. One resident was transferred to the hospital and died due to a non-fall related reason.

Table 4 Comparison of variables according to falls and device instalment

Variables	No falls (n = 23), n%			Falls (n = 3), n%		
	No device (n = 11)	Device installed (n = 12)	P value	No device (n = 2)	Device installed (n = 1)	P-value
Age†	80.7 ± 9.4 (65–100)	82.3 ± 10.3 (60–95)	0.7	88.5 ± 7.8 (83–94)	88.0	0.1
Gender (M/F)	2 (18.2)/9 (81.8)	0 (0.0)/12 (100.0)	0.1	0 (0.0)/2 (100.0)	1 (100.0)/0 (0.0)	0.05
Walking aid use	0 (0.0)	4 (33.3)	**0.01**	0 (0.0)	0 (0.0)	–‡
Vision impairment	5 (45.5)	6 (50.0)	0.8	0 (0.0)	1 (100.0)	0.05
Hearing impairment	3 (27.3)	2 (16.7)	0.5	0 (0.0)	1 (100.0)	0.05
Previous fracture	0 (0.0)	2 (16.7)	0.1	2 (100.0)	1 (100.0)	–‡
Falls in the last year	4 (36.3)	7 (58.3)	0.3	2 (100.0)	1 (100.0)	–‡
FFQ-R score†	9.0 (0–18)	15.0 (4–18)	0.2	N.A.	4.0	–‡
Orthostatic hypotension	3 (27.3)	3 (25.0)	0.9	1 (50.0)	0 (0.0)	0.3
Number of comorbidities†	4.0 (2–7)	5.0 (2–7)	0.4	2.0 (1–3)	5.0	0.3
Number of drugs†	9.2 ± 3.3 (4–15)	10.3 ± 2.7 (5–15)	0.4	10.0	16.0	–‡
BMI†	27.70 ± 4.04 (22.67–35.49)	26.60 ± 2.89 (22.86–33.73)	0.5	19.80 ± 1.59 (18.67–20.92)	20.90	0.7
MNA-SF score†	11.0 (8–14)	10.0 (3–11)	0.1	8.0 (8–8)	10.0	–‡
FRAIL score†	2 (0–4)	2.5 (0–5)	0.8	2.0 (0–4)	0.0	0.7
Frailty						
Robust	3 (27.3)	3 (25.0)		1 (50.0)	1 (100.0)	
Pre-frail	3 (27.3)	2 (16.7)	0.8	0 (0.0)	0 (0.0)	0.3
Frail	5 (45.5)	7 (58.3)		1 (50.0)	0 (0.0)	
ADL score†	11 (6–18)	13 (8–18)	0.2	8.5 (6–11)	13	0.5
ADL						
Independent	4 (36.4)	7 (58.3)		0 (0.0)	1 (100.0)	
Semi-dependent	6 (54.5)	5 (41.7)	0.3	1 (50.0)	0 (0.0)	0.2
Dependent	1 (9.1)	0 (0.0)		1 (50.0)	0 (0.0)	
IADL score†	8.0 (8–24)	16 (8–24)	**0.03**	8 (8–16)	16	–‡
IADL						
Independent	1 (9.1)	2 (16.7)		0 (0.0)	0 (0.0)	
Semi-dependent	2 (18.2)	9 (75.0)	**0.003**	0 (0.0)	1 (100.0)	0.05
Dependent	8 (72.7)	1 (8.3)		2 (100.0)	0 (0.0)	
Mortality	0 (0.0)	1 (8.3)	0.3	0 (0.0)	0 (0.0)	–‡

Bold values denote statistical significance at the $p < 0.05$ level.
ADL, Activities of Daily Living; BMI, body mass index; FFQ-R, Fear of Falling Questionnaire-Revised; F, female; IADL, Instrumental Activities of Daily Living; M, male; MNA-SF, Mini-Nutritional Assessment-Short Form; N.A, data not available.
† Numeric variables were presented as median (minimum–maximum) or mean ± SD. BMI is calculated as weight in kilograms divided by height in meters squared.
‡ There are fewer than two groups for dependent variables. No statistics are computed.

DISCUSSION

Older adults have an increased risk for falls due to age-related physiological changes. Fall risk is even higher in nursing homes and care facilities, where psychogeriatric disorders are more prevalent.[19,20] A cross-sectional study that was conducted in Istanbul reported that the risk of falls was independently associated with cognitive impairment.[21] The relationship between cognitive impairment and abnormal gait may account for the increased fall risk in individuals with dementia.[22] Thus, older adults with dementia, who constituted the majority of our study population, are more likely to benefit from interventions aimed at reducing fall-related morbidity.

World guidelines for falls prevention and management for older adults emphasize the need for a predictive, as well as preventive, approach to determine the risk of falls and fall-related injuries.[23] Different from prior guidelines on falls, this recent guideline strongly recommends a multi-domain falls risk intervention which covers exercise, medication assessment, management of chronic diseases and vision problems, providing safe footwear, nutritional intervention and vitamin D replacement therapy, addressing incontinence, patient education, and environmental modification including technological devices.

Fall-detection technology is a non-invasive method that provides an opportunity to take early action to avoid fall-related outcomes. However, studies investigating the effect of technological devices have produced contradictory findings.[24–27] Moreover, approximately 90% of studies on fall detection systems are not applicable in the real-world setting.[28]

Attached to various body parts, wearable sensors have the advantage of monitoring the individual's activities continuously. Most studies to date aimed at utilizing wearable sensors for fall risk prediction and monitoring in Parkinson's disease.[29–32] However, studies so far have failed to associate wearable sensors and bed alarms with a reduction in falls.[24,25,33] Moreover, a prospective study conducted in multiple nursing homes has shown that approximately 75% of falls occur in the residents' rooms and bathrooms.[19] Therefore, continuous monitoring when the resident is outside one's room for meal time or for an activity may not be necessary, especially in nursing homes when the resident will likely be surrounded by caregivers.

Unlike wearable sensors, movement sensors are installed in the patient's room to collect preventive information and alert the caregiver, should an emergency arise. Movement sensors are not dependent on battery power, do not have to be carried around, and are easier to use compared to wearable devices. For this pilot study, we used a state-of-the-art movement sensor that enables rapid intervention by notifying the caregiver with a real-time fall alert. The fall event in the study group was followed by a prompt response from the staff who were notified by the alarm, whereas the two falls which occurred in the control group received no immediate attention.

Components of the comprehensive geriatric assessment were similar between the control and study groups. Residents in both groups had a high risk of falling. Four residents in the study group were using walking aids, which are associated with reduced stability when used incorrectly.[34] However, the residents enrolled in our study were using their assistive devices correctly, as the institution had a medical team responsible for conducting routine check-ups. The study group was less dependent in IADL compared to the control group. Dependency in IADL may be associated with increased fall risk in the control group. However, the sample size of the study is too small to make an accurate comparison between the two groups in terms of geriatric syndromes.

In addition to preventing fall-related morbidity, device technology may also reduce the number of people needed to care for an individual resident, thereby reducing institutional expenses. Cost-effectivity studies are highly warranted in this regard.

One of the goals of geriatric care is to provide home support and encourage independent living. Although the study was conducted in a nursing home, the device can also be used to notify the caregiver of an older individual in the home care setting. A very recent study has shown that fall risk associated with environmental hazards is more pronounced if the individual is living alone.[35] Hence, device technology may be particularly useful for older adults who live on their own.[35,36]

The perception of older adults regarding device technology has also been investigated. The study by Horton *et al*. has shown that use of technological devices provides a sense of security for older adults.[37] Similarly, in their study regarding an intelligent video monitoring system for fall detection at home, Londei *et al*. reported that almost all participants were in favour of the system.[38] An additional advantage of the device used in the present study is that it provides protection of privacy, as it utilizes non-intrusive radar technology without the need to record images.

STRENGTHS AND LIMITATIONS

The strengths of the study include the comprehensive assessment of the patients by a geriatrician, allowing for a multi-domain fall risk intervention in both the study and the control groups. However, this pilot study also has some limitations. First, the sample size was relatively small. Future studies with larger sample sizes are warranted to establish the role of fall detection devices in geriatric care. Second, the patients and the staff could not be blinded to the study. False alarms pose a major challenge as well, albeit few in number. The engineering team is working on ways to improve the system to reduce the rate of fall alarm without fall incident, as well as the rate of false alarms. Although a significant number of falls occur in bathrooms, an extra device could not be installed outside the patient rooms, which is another limitation of the study.

CONCLUSION

Falls are responsible for considerable morbidity and mortality among older adults. Hence, early detection of falls is of utmost significance. Device technology may provide an opportunity for preventive intervention in this regard, although its feasibility in different settings remains to be investigated. The rapid development of new technologies may empower healthcare professionals to prevent fall-related outcomes in older adults.

AUTHOR CONTRIBUTIONS

All authors contributed to the study conception and design. Material preparation, data collection and analysis were performed by NSD, MT, BA, and SCD. The first draft of the manuscript was written by BC and all authors commented on previous versions of the manuscript. All authors read and approved the final manuscript.

FUNDING INFORMATION

Asrometal A.Ş. provided the devices installed into resident rooms. The funder had no role in the design, data collection, data analysis, and reporting of this study.

DATA AVAILABILITY STATEMENT

The data that support the findings of this study are available from the corresponding author upon reasonable request.

ETHICS STATEMENT

The ethical review board of a university hospital approved the study protocol (Marmara University Ethical Committee, Protocol number: 22.07.2022.1102). The study was conducted in accordance with the Declaration of Helsinki.

CONSENT TO PARTICIPATE

Written informed consent for the study was obtained from the residents or their proxies.

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