Evaluating the Impact of Bed Exit Sensor Notification Settings and Response Times on Fall Prevention in Inpatient Wards

Kazuko Imaizumi*[1] and Naoko Amaya[2]

[1] Chiba Institute of Science, PhD Program in Disaster Management Major, 5-8, Shiomicho, Choshi City - 288-0025, (Chiba) Japan
[2] Wayo Women's University, Department of Nursing, 2-3-1, Konodai, Ichikawa City - 272-8533, (Chiba) Japan
k-imaizumi@saiseikai-mkj.jp

Abstract. This study is an 11-month observational study aimed at evaluating the impact of bed exit sensor notification settings and response completion times on fall prevention. Data was collected from 47 patients with prior falls to monitor alert frequency, notification settings, and response times. Analysis suggested that frequent alerts were associated with declines in cognitive and mobility functions, potentially contributing to alarm fatigue among nursing staff. Optimizing these settings may help reduce falls and alleviate nurse workload.

Keywords: Bed Exit Sensors, Fall Prevention, Notification Settings, Alarm Fatigue

1 Introduction

Falls have become a crucial issue in aging societies, especially within healthcare and long-term care facilities, where they are known to lead to serious health problems. Injuries resulting from falls can cause severe conditions, such as fractures and head injuries, which delay patient recovery, decrease quality of life, and escalate treatment costs [1]. Consequently, fall prevention is recognized as a critical issue in healthcare settings, highlighting an urgent need for preventive measures. Existing studies on fall prevention have identified factors such as age, physical and cognitive decline, and medication use as major contributors to fall risk [2] [1]. Additionally, prolonged hospitalization can further elevate fall risk by accelerating declines in strength, balance, and cognitive function.

Given this context, healthcare facilities actively implement fall prevention strategies, with bed exit sensors being widely adopted in many clinical settings. Bed exit sensors detect restless movements or attempts to leave the bed, issuing alerts to prompt early intervention by nursing staff. This technology aims to prevent fall incidents through timely responses, especially for patients at high fall risk [3]. By allowing staff to monitor patient activity in real-time, bed exit sensors play a significant role in ensuring patient safety. However, in Hospital

E. Fachrial and S. Suhartomi (eds.), *Proceedings of the 1st International Conference on Lifestyle Diseases and Natural Medicine (ICOLIFEMED 2024)*, Advances in Health Sciences Research 84,
https://doi.org/10.2991/978-94-6463-664-2_13

A, the availability of bed exit sensors has occasionally been limited, preventing their use when needed. In response, beds with built-in sensors have been installed throughout the facility, alongside the development of a fall prevention manual to promote effective sensor utilization. Despite these efforts, falls among patients have not declined.

This study aims to clarify the impact of specific patient characteristics, notification conditions, notification frequency, and response completion time on fall prevention,with the goal of proposing optimal notification settings for healthcare environments.

2 Literature Review

Previous studies have partially reported on the effectiveness of bed exit sensors. For example, [4] demonstrated an association between bed exit sensors and a reduction in patient fall rates. They also highlighted the importance of considering factors such as "alarm fatigue," the ability of nursing staff to respond to alarms promptly, and the selection of appropriate sensor modes based on patient profiles. Additionally, [5] found a 19% increase in falls among elderly inpatients with sensors installed on beds, bed chairs, or chairs. Brusco et al. (2020) reported that false alarms were the most frequently observed (n = 74, 52%), followed by true alarms (n = 67, 47%) and no-alarm incidents (n = 3, 2%). Furthermore, [6] revealed that nurses view bed exit sensors negatively and expressed a preference for alternative fall risk management strategies. These findings underscore the need to establish optimal sensor settings and usage protocols.

The literature generally recognizes the contribution of bed exit sensors to fall prevention, yet reports also indicate instances where sensors are ineffective or produce false or excessive alarms, potentially delaying nurse responses. Frequent notifications can lead to alarm fatigue among nursing staff, increasing fall risk due to slower response times. Therefore, empirical research is limited regarding how notification conditions, notification frequency, and response completion time affect fall risk. Additionally, to enhance the effectiveness of fall prevention measures, it is essential to understand how nurses perceive and respond to sensor notifications, ensuring appropriate actions are taken.

3 Methods

3.1 Study Design and Participants

This study is an 11-month observational cohort study conducted at Hospital A. The study subjects were 47 patients (22 males and 25 females) who, despite management with bed exit sensors for fall prevention, experienced falls between October 2023 and August 2024. The age range of participants was 65 to 92 years (mean age: 76.4 years, SD: ±8.5 years), and the length of stay ranged from 10 to 120 days (mean: 45.7 days, SD: ±22.3 days). Among the 47 patients, some experienced multiple falls, resulting in a total of 62 falls.

3.2 Measurement Items and Definitions

In this study, the following items related to fall risk were measured. Table 1 presents the items and their descriptions.

Table 1. Survey Items and Content

Patient Attributes	Age, Gender, Length of Stay, Presence of Mobility Impairment, Presence of Cognitive Impairment
Notification Count	Daily Notification Count per Patient. The number of times the bed exit sensor was triggered, generating notifications to the nursing staff.
Response Completion Time	Average Time from Sensor Activation to Response Completion: Records the mean duration from when the sensor is triggered to the completion of the nursing response.
Get-Up (0 Sec)	Triggered the moment the patient begins to sit up in bed. When it is necessary to immediately detect when a patient begins to sit up.
Get-Up (1 Sec)	Triggered 1 Second After the Patient Begins to Sit Up Restless Behavior in Bed with Unstable Edge-of-Bed Position, Risk of Falling from Bed, and Slightly Rapid Movements.
Get-Up (3 sec)	Triggered 3 Seconds After the Patient Begins to Sit Up Restless Behavior in Bed with Unstable Edge-of-Bed Position, Risk of Falling from Bed, and Movements That are not Particularly Fast.
Sitting (Edge-of-Bed Position)	Triggered When the Patient Sits on the Edge of the Bed and Partially Lifts Their Weight Able to Maintain Edge-of-Bed Position, but Unsteady in standing and waling, with high risk of falling shortly after leaving the bed.
Bed Exit	Triggered when the patient leaves the bed. Used for patients requiring ambulation monitoring. This setting is intended for patients who are stable while standing but may require supervision due to unsteadiness while walking.
Monitoring 60 Sec	Triggered if the patient does not return to bed within 60 seconds of leaving. For patients who have difficulty walking long distances, exhibit wandering behavior, or use a urinal or portable toilet at the Bedside
Monitoring 5 min	Triggered if the patient does not return to bed within 5 minutes of leaving. For patients who are generally independent in using the bathroom but may require monitoring for abnormalities in the Bathroom or if they might have difficulty returning to bed.

Note: The conditions for use are not absolute. Always adjust the notification settings according to the patient's specific condition.

3.3 Analysis Methods

Mean and Standard Deviation: Basic statistics were calculated for the notification counts and response completion times under each notification condition.

t-Test and ANOVA: Comparisons of notification counts and response completion times based on each notification condition and patient attributes, assessing significant differences between groups. Correlation Analysis: Evaluation of the relationships between notification frequency, response completion time, and patient attributes (such as cognitive function and walking impairment). Tukey HSD Test: Multiple comparisons among notification conditions to identify conditions with significant differences. Data analysis was performed using Stata 18.0 [9].

4 Results

4.1 Basic Attributes

The average age of the 47 patients was 76.4 years (SD ±8.5 years), and the average length of stay was 45.7 days (SD ±22.3 days). The sample consisted of 22 males (47%) and 25 females (53%).

4.2 Statistics by Notification Condition

Notification Frequency (per day) The average daily notification frequency for each notification condition is shown

Table 2. Average Notification Frequency

Notification Count	Average	SD	Min	Max
Bed Exit	6.54	8.73	0.03	31
Get-up 0s	17.87	18.38	0.04	38.72
Get-Up 1s	282.28	616.47	0.03	1385
Get-up 3s	7.46	8.9	0.09	34.4
Sitting	8.54	8.06	0.33	36.5
Monitoring 60s	1.21	8.73	0.08	2.69
Monitoring 5m	0.76	0.86	0.11	2.03

Response Completion Time (in minutes) The average response completion time for each notification condition is shown below.

Table 3. Average Response Completion Time

Response Time	Average	SD	Min	Max
Get-Up (1s)	4.56	2.35	2.26	8.31
Get-Up (3s)	4.7	3.21	0.68	12.67
Sitting	6.64	5.7	1.6	30.98
Monitoring 60s	17.66	13.28	3.36	41.19
Monitoring 5m	28.62	26.32	5.35	66.34

4.3 Statistical Analysis Results

t-Test (Notification Frequency and Response Completion Time) Significant differences were observed in many pairs of notification conditions. Examples of conditions with significant differences include: Notification Frequency: Bed Exit vs. "Get up 0 sec" ($t = -8.58, p < 0.001$). Response Completion Time: Get up 1 sec vs. "Monitoring 5 min" ($t = -24.42, p < 0.001$) Homogeneity of Variance Test (Levene's Test) Levene's test was conducted to examine the homogeneity of variance for notification frequency and response completion time. Significant variance differences were observed for both variables (Notification Frequency: $p = 0.0067$, Response Completion Time: $p = 0.027$). Consequently, t-tests for unequal variances were applied.

4.4 Correlation Between Patient Attributes, Notification Frequency, and Response Completion Time

In the correlation analysis of patient attributes with notification frequency and response completion time, dementia and walking impairment were found to have significant effects on both notification frequency and response completion time (Table 4).

Table 4. Correlation Between Patient Attributes, Notification Frequency, and Response Time

Attribute	Notification Frequency (Correlation Coefficient, p-value)	Response Time (Correlation Coefficient, p-value)
Age	0.20 ($p = 0.15$)	0.18 ($p = 0.18$)
Dementia	0.45 ($p < 0.01$)	0.39 ($p < 0.05$)
Gait Impairment	0.30 ($p = 0.05$)	0.25 ($p = 0.07$)

4.5 Relationship Between Notification Conditions, Notification Frequency, and Response Completion Time

An analysis of notification frequency and response completion time based on the number of notification conditions used revealed a trend: patients with more notification conditions tended to have higher notification frequency and longer response completion times (Table 5).

Table 5. Impact of the Number of Notification Conditions on Notification Frequency and Response Time

Number of Notification Conditions	**Notification Frequency (Mean $\pm$ SD)**	**Response Time Mean $\pm$ SD**
1-3 Conditions	3.4 ± 1.2	5.2 ± 2.0
4 or More Conditions	7.6 ± 2.4	9.3 ± 3.8

4.6 Comparison Between Dementia and Non-Dementia Patients

A comparison of notification frequency and response completion time between dementia and non-dementia patients showed that dementia patients had significantly higher notification frequencies and longer response completion times under the "Bed Exit" and "Monitoring 60 sec" conditions (Table 6)

Table 6. Comparison Between Dementia and Non-Dementia Patients

Notification Condition	**t-value**	**p-value**
Bed Exit (Leave)	2.169	0.036
Watch 60s	3.45	0.001

5 Discussion

5.1 Analysis of Notification Conditions and Frequency

Significant differences in notification frequencies were observed between "Monitoring 5 min" and other conditions (e.g., "Get Up 0 sec" and "Leave"). Notifications triggered by "Monitoring 5 min" were notably less frequent, likely due to its selection for a limited subset of patients. A substantial proportion of the inpatients were advanced in age, often with compromised mobility due to conditions and muscle weakness from prolonged bed rest. Therefore, conditions like “Get Up 0 sec” and “Get Up 1 sec” were preferred to promptly capture movement initiation from bed.

The “Get Up 1 sec” and “Get Up 0 sec” notifications showed high frequency, with “Get Up 1 sec” far surpassing other conditions. This highlights the need to capture initial movement off the bed, though it also suggests a higher occurrence of false positives. Movements unrelated to fall risk, such as reaching for objects or shifting position, may have triggered unnecessary alarms, emphasizing a need for refined parameters.

5.2 Notification Conditions and Response Completion Time

In the "Monitoring 5 min" setting, the response completion time was found to be significantly longer compared to other notification conditions (such as "Get-Up 0 sec" or " setting "). This is likely because "Monitoring 5 min" is triggered when a patient has been away from the bed for five minutes, making it suitable for monitoring behaviors like wandering. As this often involves responding to patients who are further from the bed, more time is required to complete the response. Additionally, this setting is intended for situations where a five-minute interval without observation is acceptable, contributing to a delayed response compared to other settings with shorter activation times.

In contrast, settings like "Get-Up 1 sec" and "Get-Up 3 sec," which activate within a shorter timeframe, tend to facilitate quicker responses. Statistical analysis using a t-test confirmed that the response completion times for "Get-Up 1 sec" and "Get-Up 3 sec" were significantly shorter than for other conditions. This indicates that these settings enable rapid intervention for patients who need immediate assistance with bed-related activities to prevent falls. Consequently, these quick-response settings are shown to support timely intervention for high-risk patients, enhancing fall prevention efforts.

5.3 Differences in Variance Among Notification Conditions (Levene’s Test Results)

Significant differences in variance were identified across conditions for both notification frequency and response time, with Levene’s test indicating non-homogeneity. This suggests considerable variation in response speed and frequency among patients, potentially influenced by individual factors such as cognitive or physical impairments. These findings underscore the necessity of customizing sensor settings to the specific needs and capabilities of each patient. Analysis across conditions revealed that “Get Up 1 sec” and “Get Up 0 sec” frequently captured non-harmful movements, increasing the rate of false alarms. The dependence of notification frequency and response time on individual patient attributes, as shown by Levene’s test, highlights the importance of tailored sensor settings.

5.4 Correlation Between Patient Attributes, Notification Frequency, and Response Time

Patients with dementia tend to have a higher frequency of notifications (correlation coefficient $= 0.45, p < 0.01$). Additionally, they also show a tendency for longer response completion times (correlation coefficient $= 0.39, p < 0.05$). This suggests that patients with dementia may exhibit restless behaviors that frequently trigger sensors, leading to more frequent responses. The extended response time may also indicate that not all situations require immediate action.

Patients with mobility impairments also show a tendency toward higher notification frequency (correlation coefficient $= 0.30, p = 0.05$). However, the relationship between mobility impairment and response completion time, while present, does not reach statistical significance (correlation coefficient $= 0.25, p = 0.07$). For patients with mobility impairments, irregular movements and cautious actions may make the sensor more sensitive to activation.

Patients with dementia or mobility impairments tend to have higher notification frequencies due to their behavior characteristics, and dementia patients specifically show a trend toward longer response times. Although agitated or irregular movements increase the risk of falls, some situations do not require immediate intervention to prevent falls, making it challenging to determine the most appropriate notification settings.

5.5 Relationship Between the Number of Notification Conditions and Frequency/Response Time

Patients with four or more notification conditions had higher notification frequencies and longer response times. An increase in notification condition changes may reflect changes in patient behavior, resulting in higher frequencies. Additionally, the difficulty in finding optimal settings for these patients may have contributed to frequent condition adjustments.

5.6 Comparison Between Dementia and Non-Dementia Patients

These results indicate that dementia patients receive more notifications and have longer response completion times under the "Bed Exit" and "Monitoring 60 sec" conditions. Dementia patients are more likely to leave the bed unconsciously, emphasizing the need for prompt response. Additionally, settings that detect prolonged bed exit tend to result in delayed response times for dementia patients, suggesting the need for earlier intervention.

5.7 Total Notifications and Fall Incidents Over 11 Months

Among 47 patients who experienced falls over 11 months, there were a total of 32,890 notifications, with 62 actual falls recorded. This results in a notification-to-fall probability of approximately 0.18%, suggesting that the majority of notifications either successfully prevented falls or were triggered by low-risk, routine activities without danger. This indicates that most notifications did not result in problematic situations. There is a need to develop a more precise system for detecting patient behaviors that are likely to lead to falls.

6 Conclusion

The findings indicate that patient behaviors can be monitored effectively to prevent falls through timely responses, highlighting the need for bed exit sensor settings tailored to individual patient characteristics. While these settings are often aligned with patient needs, notifications are sometimes triggered by routine, non-hazardous activities, and delayed response times were observed with certain notification settings that take longer to detect patient movements. Additionally, selecting appropriate notification conditions for patients with dementia or mobility impairments proved challenging.

This suggests the importance of optimizing notification settings by more accurately selecting and possibly re-evaluating current settings to enhance notification accuracy. By reducing unnecessary alarms, fall prevention effectiveness could be improved, and the workload for nursing staff could be reduced. Out of the 32,890 notifications over the 11-month period, only 62 (approximately 0.18%) were linked to actual falls, with most notifications either helping to prevent falls or resulting from low-risk, routine activities. Thus, while the current settings contribute to risk reduction, many notifications were unrelated to fall-inducing actions.

Going forward, it is essential to develop notification settings that more precisely detect only actions leading to potential falls, thereby reducing unnecessary alarms and alleviating alarm fatigue among nursing staff. Furthermore, implementing notification settings customized to each patient's characteristics and risk levels would allow for quicker responses to high-risk situations. Such improvements are expected to further enhance the effectiveness of fall prevention, contributing to both patient safety and the reduction of healthcare workers' burdens.

7 Conflict of Interest

There are no conflicts of interest to disclose. This study received approval from the Ethics Review Board of the Clinical Research Center at Saiseikai Central Hospital, Tokyo.

References

1. Rubenstein, L. Z. (2006). Falls in older people: Epidemiology, risk factors, and strategies for prevention. *Age and Ageing*, 35(Suppl. 2), ii37–ii41. DOI: 10.1093/ageing/afl084.

2. Grimley Evans, J. (2001). Falls in older people: Risk factors and strategies for prevention by Stephen Lord, Catherine Sherrington, Hylton B. Menz [Review of the book *Falls in older people: Risk factors and strategies for prevention*, by S. Lord, C. Sherrington, & H. B. Menz]. *Family Practice*, 18(4), 470. DOI: 10.1093/fampra/18.4.470.
3. Schmitt, B. (2013, April). A team approach to fall prevention. *Patient Safety & Quality Healthcare*. Available at: https://www.psqh.com.
4. Seow, J. P., Chua, T. L., Aloweni, F., Lim, S. H., & Ang, S. Y. (2022). Effectiveness of an integrated three-mode bed exit alarm system in reducing inpatient falls within an acute care setting. *Japan Journal of Nursing Science*, 19(1), e12446. DOI: 10.1111/jjns.12446.
5. Cortés, O. L., Piñeros, H., Aya, P. A., Sarmiento, J., & Arévalo, I. (2021). Systematic review and meta-analysis of clinical trials: In-hospital use of sensors for prevention of falls. *Medicine*, 100(43), e27467. DOI: 10.1097/MD.0000000000027467.
6. Considine, J., Berry, D., Mullen, M., Chisango, E., Webb-St Mart, M., Michell, P., Darzins, P., & Boyd, L. (2023). Nurses' experiences of using falls alarms in subacute care: A qualitative study. *PLOS ONE*, 18(6), e0287537. DOI: 10.1371/journal.pone.0287537.
7. Oliver, D., Daly, F., Martin, F. C., & McMurdo, M. E. T. (2004). Risk factors and risk assessment tools for falls in hospital in-patients: A systematic review. *Age and Ageing*, 33(2), 122–130. DOI: 10.1093/ageing/afh017.
8. Capezuti, E., Zwicker, D., Mezey, M., & Fulmer, T. (Eds.). (2008). *Evidence-based geriatric nursing protocols for best practice* (3rd ed.). Springer Publishing Company.
9. Stata Corp. (2023). *Stata Statistical Software: Release 18.0*. College Station, TX: Stata Corp LP.