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Research report

# Evaluation of a sensing model to determine risk of falls in the elderly living alone based on trips to the toilet at night : Monitoring of activities and lifeline sensing during summer, autumn and winter

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Key words
elderly person, sensing, fall, nocturia, lifeline

## Abstract

Objective : Falls in the elderly are included in the geriatric syndromes and incidence increases with age. We analyzed the toilet at night by living alone elderly in the season using activity and lifeline sensing and investigated the risk of falls during the toilet at night.

Methods: This study was a longitudinal field study. The subjects were 16 elderly people living alone who received support at a community comprehensive support center. We captured frequency of the toilet, time spent in the toilet, water volume usage, and travel time between the bedroom and the toilet from sleeping to waking up of each subject by sensing. In addition, we also collected data based on body profile measurement and interviews.

Results : The frequency of the toilet at night was different between seasons. In the summer, frequency was $2.0\pm1.1$ times, $5.3\pm8.8$ times during the autumn and $8.2\pm5.6$ times during the winter ($p<0.05$). The time it took to reach the toilet from the bedroom also varied between seasons. The time to reach the toilet was $34.3\pm28.5$ seconds during summer, $46.9\pm38.7$ seconds during the fall and $113\pm102.7$ seconds in the winter ($p<0.05$).

Conclusion : It is possible to observe the toilet at night of elderly people living alone from activity and lifeline sensing by the season.

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## Introduction

The aging of the Japanese population has continued to the point that those 65 or older now account for 27.3% of the population[1]. Along with the aging of Japan, there are now 6,243,000 elderly people living alone and elderly households account for 26.3% of all households. These numbers are expected to increse[2]. Most of the elderly would prefer to live in familiar surroundings such as their homes or neighborhood as long as possible. There is a need to support the ability of the elderly to maintain life activities and live independently.

One of the factors leading to elderly requiring assisted living support are falls and falling down/falling-off (hereafter referred to as falls)[3]. The rate of falls among the community-dwelling elderly people in Japan range from a little under 10% to 20%. It has been reported 9% of men and 12% of women suffer bone fractures as a result of falling[4]. Falls in the elderly are included in the geriatric syndromes and incidence increases with age. Geriatric syndromes are highly associated with conditions that lead to impairment of functioning[5]. Although this condition is not lethal, the concept of geriatric syndromes remains vaguely defined. Neither the elderly as well as their family may be aware of the worsening condition and regard deterioration as part of aging until the elderly requires support. Among those elderly living alone, there is no one to notice the progression of deterioration to the point where outside support is needed ; however, it is difficult to assess the health of those elderly who are withdrawn and living in solitude with low activity level.

For these reasons, there is a need for a system that objectively assesses the ability of the elderly living alone to function within a familiar environment and detect changes linked to health care problems at an early stage[6]. Based on an evaluation of available sensors and other information technology-based monitoring systems for safety[7][8], emergency reporting[9] and health management[10-12]. It has been suggested that yearly changes as well as seasonality must be factored to assess the health condition of the elderly[12].

With the objective of developing a daily living activity sensing model for determining risk of falling in the elderly living along, during the period 2014 to 2017, we captured data on a longitudinal basis from wire-less home environment sensors as well as gas, water and electric using the lifeline data system. In addition, we also collected physical and psychological data based on body profile measurement and interviews. The significance of a daily living activity sensing model is maintaining privacy while facilitating early detection of safety and health condition issues[13].

The focus of daily activity monitoring was frequency of the toilet at night as the risk of falling in the elderly is linked to frequency. Falling increases the risk of femoral neck fractures twofold and can lead to a bed-ridden state as well as negatively affect prognosis[14].

By maintaining privacy while implementing longitudinal monitoring, we felt that we would be able to detect risk of falling during the toilet at night at an early stage. We feel that maintaining and expanding the elderly's daily living activities will contribute to increased life expectancy.

The objective of the study was to determine the risk of falling in the elderly living alone during the toilet at night using activity and lifeline sensing.

## Methods

1. Study design

This study was a longitudinal field study.

2. Study subjects

Sixteen elderly subjects living alone in City A and receiving support from a Regional Comprehensive Support Center were chosen for the study. Inclusion criteria were based on 2 criteria : self-reliant living and living with support. All participants and their supporting families gave informed consent.

Exclusion criteria were : those with dementia ; individuals with a diagnosis of high brain dysfunction who are unable to understand the point of the study or the ethical considerations associated with the study ; those with pace-makers ;

those using medical equipment at home ; those with no family care-givers making it impossible to obtain informed consent ; those with medium to large-sized pets which can lead generation of erroneous data and homes in which a municipal water meter is not available or not used.

3. Research method

1) Daily life activities and lifeline sensing

For this study, we utilized the National Institute of Information and Communications Technology's (NICT) mobile wireless bed and the Wi-Sun protocol to create a remote meter reading network for data gathering 24 hours a day, 365 days a year. The activities as well habits of each subject in the study were captured by placement of 10 wireless environmental, wireless door and power consumption sensors in the bedroom, hallway and toilet (Figure 1). In addition, using a distribution board for wireless metering of water and gas, lifeline data was generated. Each type of sensor was a prototype of NEC Solutions Innovators, Ltd. The data collected was sent over the internet to the Data Center for automated data capture, storage and management.

The International Continence Society (ICS) has defined nocturia as having to wake-up more than once[18]. Therefore, in this study, summer is defined by July 1 to 31 (2016), autumn (October 1 to 29, 2016) and winter (January 1 to 31, 2017). During these periods, life activities were followed using lifeline to extract data including when the subject went to bed, how often the subject went to the toilet based on frequency of toilet door opening/closure and the time it took for the subject to reach the toilet from the bedroom.

2) Physical measurements and interviews

Conducted at Kanazawa University during July 2 to 3 of 2016 for the summer period, September 20 to 21 of 2016 for the autumn period and January 5 to 6 in the winter of 2017.

(1) Demographics

Information on sex, age, nursing care requirement authorization, method of mobility, medical history, occurrence of falls were obtained from subjects based on an oral response.

(2) Physical function

① Leg muscle strength : For assessment of lower limb muscle strength, knee joint extension and bending muscle strength were utilized as these markers are highly associated with movement in daily life[15]. A physical therapist measured using a hand-held dynamometer (μ-tas MT1 ; ANIMA Co.) maximum isometric muscle strength.

② Gripping strength : It was measured using a Grip Track Commander (Nihon Media, Ltd) was taken in the standardized positioning recommended by the American Society of Hand Therapists with sitting position with the shoulder joint angle at the neutral position, elbow positioned at 90 degrees flexion and forearm and wrist at the neutral position.

③ Balance assessment : Static balance performance was conducted with eyes open and closed using a computerized force platform Gravicoda GS-10 (Anima Co., Tokyo, Japan) to measure locus length per time (LNG/TIME). Dynamic balance ability was assessed using the Functional Reach Test (FR) which measures the maximal distance one can reach forward beyond arm's length parallel to the floor while maintaining feet planted in a standing position.

④ Walking ability : The assessment involved a 5 m distance walking time and the Timed up & go test which measures basic functional ability.

⑤ Physical build : We assessed using weight and body mass index (BMI).

⑥ Bone density : We measured of the calcaneus was measured using MARK 8800 (Sensa, Ltd for speed of sound (SOS) measurements.

3. Analysis

One way analysis of variance was used to compare seasonal mean values using SAS JMP ver.11 and IBM SPSS Statistics Base System ver.23 Statistical significance was set at under 0.05.

4. Ethical considerations

This study was reviewed and approved by the institutional review board at the Medical Ethics Committee of Kanazawa University (review number 555-1). Informed consent to participate in the study was obtained orally and on paper from subjects as well as their family care-givers after explaining the objective of the study. Because of ethical considerations, daily activity and lifeline sensing data, physical measurements and information obtained from interviews were encoded to ensure privacy and proper storage/management of personal information.

## Results

1. Subject characteristics (Table 1)

The study involved 13 (21.3%) females and 3 (18.8%) men with a mean age of 78.7±6.9. Elderly subjects over 75 years of age constituted 60% of the participants. Ten (62.5%) of the subjects were certified to receive care under national health insurance nursing care authorization with 9 (56.3%) subjects receiving care under required assisted support level 1 and 1 (6.3%) subject under required assisted support level 2. With respect to mobility, 11 (68.8%) were ambulatory and 5 (31.3%) needed a cane or walker. All subjects used the toilet.

In each season, there was one fall for a total of 3 falls during the study period with 2 incidences of falling outside the home and 1 incidence of falling in the bedroom.

2. Seasonal frequency of getting up at night to urinate (Table 2)

Differences in mean frequency of the toilet at night were observed according to the season. In the summer, frequency was 2.0±1.1 times, 5.3±8.8 times during the fall and 8.2±5.6 times during the winter ($p<0.05$). The time it took to reach the toilet from the bedroom also varied according to the season. The time to reach the toilet was 34.3±28.5 seconds during summer, 46.9±38.7 seconds during the fall and 113±102.7 seconds in the winter ($p<0.05$). On the other hand, the time spent in the toilet as well as water volume used did not vary by the season.

3. Body function according to the season (Table 3)

No seasonal difference in physical ability as determined by muscle strength, balance, walking ability and bone density was observed.

## Discussion

In this study, we monitored seasonality differences in daily living activities based on lifeline sensing. By monitoring the toilet frequency of the elderly at night and the time required to walk between the bedroom and toilet, we clearly demonstrated that risk of falling differs based on the season. During the summer period, the mean frequency of the toilet at night was 2 while the frequency increased two-folds and four-folds, respectively, during the autumn and winter.

For those elderly living alone, the toilet requires the ability to execute following sequence : having the urge to urinate, recognition of the toilet and toilet bowl, mobility to the toilet, lowering one's under-garment, sitting on the toilet seat, urination/defecation, cleaning one-self, putting on one's clothes and returning to one's room. For this reason, nocturnal awakening as a result of frequent the toilet at night makes the elderly vulnerable to sleep disturbance. In addition, it can be predicted that increase of night-time the toilet during the autumn and winter increases the risk of falls.

The process of the toilet, toilet use frequency and when the toilet takes place using sensing modules has previously been reported[11) 13)]. In this study, by combining each subject's bedtime and arising time, we were able to include the toilet at night frequency to capture the total time per day to get to the toilet as well as return to the bedroom and time spent in the toilet to evaluate the mean required time per toilet event. Our results show that the total roundtrip time between the bedroom and toilet increases 3-fold in the winter and 2-fold in the fall. On the other hand, no seasonal difference in mean time spent in the toilet was observed. As it becomes more difficult for the elderly living alone to get to the toilet from the bedroom in the winter compared to the summer and fall, our findings indicate that there is a need for continued monitoring of night time toilet usage as this is a risk factor for falls.

During our study, no falls occurred during night in our subjects. This may be explained by the physical ability of the subjects as shown by muscle strength and balance ability. However, based on continued body measuring, muscle strength and balance ability in the elderly decreases between winter and spring. The northern regions of Japan receives heavy snowfall and surfaces freeze. It has been suggested that this can lead to a less active daily life leading to decreased ability to perform daily functions[17]. For this reason, in light of the seasonal change between winter and spring as well as aging leading to increased risk of falls, the accumulation of data by continued monitoring of daily activities and lifeline sensing has a high potential of being established as one index of a living activity sensing model.

## Conclusion

By monitoring living activities and lifeline sensing to determine the toilet at night in the elderly.

1. The frequency of the toilet at night was different between seasons.

2. The time it took to reach the toilet from the bedroom also varied according to the season.

Our results show the value of a living activity model based on the toilet at night as an indicator of increased risk of falls.

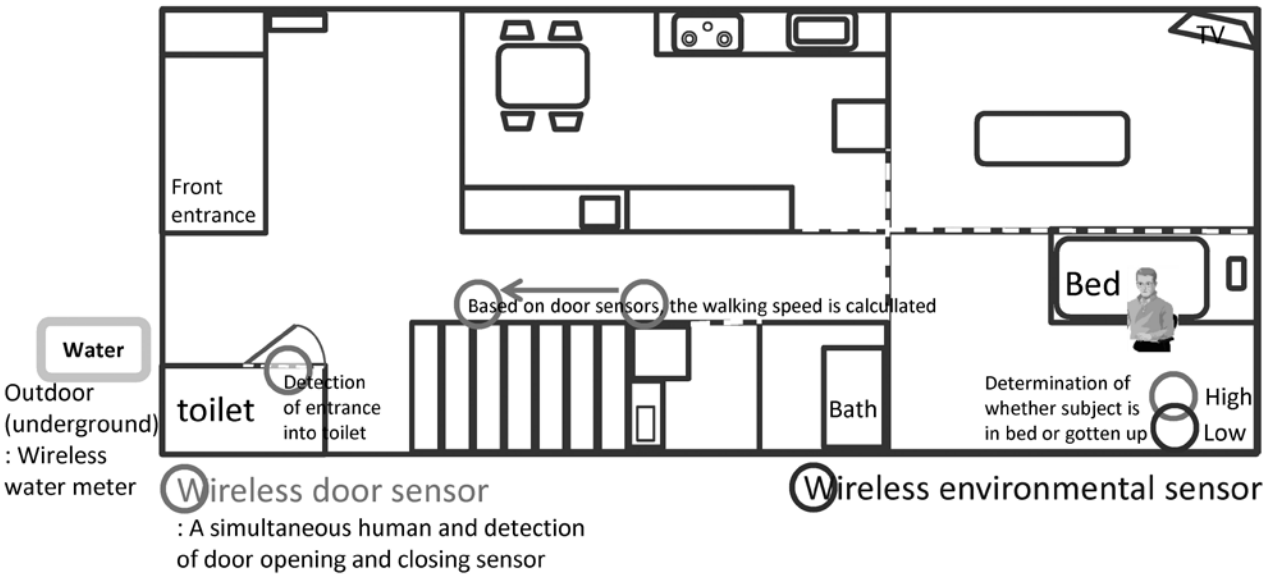


Figure 1. An example of a model for determining risk of falling in the elderly living along

Table 1. Subject characteristics

N=16

| | | n | % |
|---|---|---|---|
| Sex | Male | 3 | 18.8 |
| | Female | 13 | 81.3 |
| Age (yrs) | M ± SD 78.7 ± 6.9 | | |
| | 75< | 6 | 37.5 |
| | 75≧ | 10 | 62.5 |
| Required support level | 1 | 9 | 56.3 |
| | 2 | 1 | 6.3 |
| | None | 6 | 37.5 |
| Mobility | Walking | 11 | 68.8 |
| | Using walking aid | 5 | 31.3 |
| | Cane | 4 | |
| | Walker | 1 | |

Table 2. Mean seasonal the toilet at night frequency

N=16

| | Summer (July) Mean ± SD | Autumn (October) Mean ± SD | Winter (January) Mean ± SD | P value |
|---|---|---|---|---|
| Frequency of excretion (number) | 2.0 ± 1.1 | 5.3 ± 8.8 | 8.2 ± 5.6 | * |
| Time spent in the toilet (min/session) | 2.7 ± 1.6 | 2.4 ± 1.1 | 1.8 ± 0.7 | ns |
| Water volume usage (L /session) | 7.0 ± 3.2 | 5.3 ± 4.0 | 7.3 ± 2.9 | ns |
| Time required to move (sec) | | | | |
| Bedroom to toilet | 34.3 ± 28.5 | 46.9 ± 38.7 | 113.0 ± 102.7 | * |
| Toilet to bedroom | 61.1 ± 67.6 | 81.3 ± 61.7 | 199.9 ± 163.3 | * |

ANOVA　*p<0.05

Table 3. Physical ability according to season

N=16

| | | Summer (July) | Autumn (October) | Winter (January) | P value |
|---|---|---|---|---|---|
| Lower limb (kg) | Right knee joint extended | 12.9 ± 3.8 | 14.7 ± 5.4 | 15.0 ± 5.1 | ns |
| | Right knee joint bending strength | 9.7 ± 2.6 | 9.3 ± 2.6 | 9.3 ± 3.6 | ns |
| Gripping strength (kg) | Right hand | 17.5 ± 6.2 | 19.1 ± 8.8 | 18.6 ± 8.8 | ns |
| Balance ability (cm) | Locus length（Eyes opened） | 1.6 ± 0.6 | 2.1 ± 0.9 | 1.8 ± 0.9 | ns |
| | （Eyes closed） | 2.0 ± 0.8 | 2.9 ± 2.2 | 2.5 ± 1.0 | ns |
| | FR | 25.8 ± 3.3 | 23.6 ± 4.8 | 22.8 ± 5.8 | ns |
| Walking ability (sec) | 5 m Gait Speed | 3.9 ± 1.1 | 3.9 ± 1.1 | 3.9 ± 1.3 | ns |
| | Timed-up&Go Test | 10.0 ± 4.1 | 9.9 ± 3.3 | 9.1 ± 3.0 | ns |
| Physical build | Weight (kg) | 53.8 ± 10.6 | 57.2 ± 12.4 | 56.8 ± 11.4 | ns |
| | BMI | 23.2 ± 3.6 | 23.3 ± 3.3 | 23.2 ± 3.2 | ns |
| Bone density | SOS | 1765.3 ± 111 | 1797.9 ± 81.6 | 1812.6 ± 82 | ns |

Mean ± SD. One-way ANOVA

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# 独居高齢者の夜間排泄における転倒リスクを捉えられる生活行動センシングモデルの開発
## －夏季、秋季、冬季の生活行動・ライフラインデータを用いた検討－

正源寺　美穂[1)]，加藤　真由美[1)]，北岡　和代[2)]

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**キーワード**

高齢者，センシング，転倒，夜間頻尿，ライフライン

**要　旨**

目的：高齢者の転倒は老年症候群に含まれ、加齢に伴い増加する。本研究は、生活行動・ライフラインのセンシングにより、独居高齢者の季節による夜間排泄を明らかにし、夜間排泄時の転倒リスクを検討した。
方法：A市在住の地域包括支援センターが支援する独居高齢者16名に対し、縦断的フィールド研究を実施した。宅内のセンシングにより、就寝から起床時間における夜間排泄回数、所要時間、水道使用量、寝室とトイレ間の移動時間を捉えた。さらに身体測定と聞き取り調査を実施した。
結果：夜間排泄回数は、夏季は2.0±1.1回、秋季は5.3±8.8回、冬季は8.2±5.6回と季節間で差を認めた（p＜0.05)。寝室からトイレへの移動時間は、夏季が34.3±28.5秒、秋季が46.9±38.7秒、冬季が113±102.7秒と長く（p＜0.05)、復路も季節により異なった（p＜0.05)。一方、身体機能は維持され、季節による転倒発生状況の差はなかった。結論：独居高齢者の夜間排泄状況を縦断的に見守り、季節をふまえた生活行動センシングモデルとしての可能性が示唆された。