Telemetric activity monitoring as an indicator of long-term changes in health and well-being of older people

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P.Paavilainen, I.Korhonen, M.Partinen. Telemetric activity monitoring as an indicator of long-term changes in health and well-being of older people. Gerontechnology 2005;4(2) 77-85. **Background** Supporting independent living for older people is essential not only for the older people themselves, but also for the social and health care sectors. For this reason, there exists a need for unobtrusive telecare and telehealth solutions enabling independent living of the older adults. In this study, we demonstrate how telemetric activity monitoring offers a promising tool for long term monitoring to detect changes in the health status and over-all well-being of older people. **Methods** A telemetric activity monitoring system integrated with an intelligent social alarm system was used to monitor circadian activity rhythm of elderly nursing home residents (n=16, mean age 85.1 years, range 58-97) for several months. Changes in the activity rhythm were compared with clinical observations of health status of the subjects. The results are given as case reports. **Results** The results suggest an association between the changes in the actual health status and the circadian activity rhythm. **Conclusion** Telemetric activity monitoring offers a practical tool for long term monitoring to detect changes in health status in older adults in their normal environments.

Keywords: activity monitoring, telehealth, telecare, elderly

In recent years, monitoring health and functioning of older people has come into focus in gerontechnological research, as monitoring is perceived to be a useful tool for promoting independent living of the elderly[1,2]. Not only is independent living essential for the older people themselves, but also it is fundamental to society. In a situation of ongoing demographic transitions with a growing number of older people and decreasing number of working population, it has been noticed that home-based social and health care services are quite cost-efficient[1]. A clear shift from clinic-centric to community-centric healthcare has emerged[2] and more and more social and health care services are provided at home instead of institutions. There is also evidence that home-based support

reduces mortality and admissions to long term care[3]. Therefore, it is obvious that technological solutions to promote independent living of older people are welcomed.

Telecare and telehealth systems are typically used as instruments to promote independent living of older people. Telecare refers to provision of care remotely or virtually by using communication technology[4]. Examples of the telecare systems include, for instance, access control of a person with dementia to prevent night time wandering; fire, burglary and flood alarm systems or social alarm systems, which allow a person to call for help just by pressing a panic button of the alarm device. Telehealth in turn refers to enabling a clinical process to be conducted remotely[4], and examples of telehealth typically include monitoring of vital signs at home. Telecare and telehealth systems may be used to improve continuity or quality of care or to replace a significant portion of home visits by virtual visits[5]. Telecare systems with alarm functions improve the safety of the users through providing continuous mechanisms for fast corrective actions when the user needs acute help. However, more proactive telehealth solutions enabling preventive actions should be welcomed. The earlier the deterioration of the health status of an old person is noticed, the better the opportunities for cure and rehabilitation.

Currently there are a lot of studies concerning monitoring of older people or their living environments at home and in institutions. Some of the studies were based on monitoring using passive infrared sensors to monitor demented elderly patients in the hospital as Banerjee et al.[6] have done or activity of the older people is inferred from interactions with objects as in the study of Philipose et al.[7]. In addition, despite several research projects and pilots related to telehealth solutions, few solutions have reached a required level of maturity to be used as a part of daily care for an average elderly person in institutions or at home settings.

Quality of circadian activity rhythm and sleep/wake rhythm is associated with the well-being of the elderly. Epidemiological studies suggest that 40-70% of the elderly population suffers from chronic sleep disturbances[8], of which about 50% go unnoticed by primary care physicians[9]. Sleep disturbances endanger the subjective and objective general physical health of the elderly[8], and sleep problems and untreated insomnia significantly increase the risk for falling[10,11]. Disturbed sleep is also associated with mental health problems and life satisfaction[8]. As a consequence, sleep disturbances strongly affect autonomy and self-care of the elderly in terms of limitations of management of activities of daily living and increase in need for home care[8]. In demented subjects, nocturnal awakenings are strongly related to cognitive and functional deterioration and sleep problems are common factors for institutionalisation[12]. Hence, continuous monitoring of the quality of the circadian rhythm and sleep/wake cycle would potentially allow a sensitive, but non-specific method for monitoring changes in both physical and mental well-being.

In this study, we used IST Vivago® WristCare[13-14] to monitor the health and well-being of the elderly. This system is an intelligent social alarm system which provides continuous monitoring of user activity. The system consists of a wrist unit with a panic button, a wireless base-station, and software for receiving alarms and monitoring data from the wrist unit (see Figure 1). The system is available both for institutional and home use, and it is in routine use among several thousands of users in dif-

Figure 1. The IST Vivago® WristCare system for activity level monitoring (3001 wrist unit, base unit, IST bus adapter and Vista software)

The objective of this paper is to present some case reports, where changes in the physical health status of elderly nursing home residents are visually compared with the changes in the quality of the circadian activity rhythm measured longitudinally.

ferent European countries. In addition to the panic button, the wrist unit includes sensors for the detection of movements, temperature and skin conductivity. By using these sensor readings, the system is able to provide automatic alarms or notifications of wrist unit removal, extended passivity, immobility, or hypothermia. In addition, the system includes access control (for instance, fugue detection for demented persons) and self-testing features.

The IST Vivago® system provides a social alarm system which goes beyond the capabilities of traditional social alarm systems with its automatic alarming features[14]. In addition, the system provides continuous monitoring of user activity, extending it to a telehealth device. The activity monitoring is comparable with actigraphy and provides accurate detection of sleep/wake cycle (both methods providing about 80% minute-to-minute agreement with polysomnography)[15]. The activity monitoring also reflects changes in circadian cycle induced, for instance, by dementia[16]. This integration of a reactive telecare solution (alarms) with a preventive telehealth one (activity monitoring) is especially attractive as the former functions significantly improve the motivation of elderly subjects to continuously use the device during their daily life[14].

Methods

This prospective case study was carried out in a small home-like nursing home located in southern Finland in 2002-2003. All residents (n = 16) of the nursing home (one man and 15 women; mean age 85.1 years) participated in the study. Participants or their relatives in case of severe dementia of the residents were asked to give their written consent to the study. The Ethics Committee for Studies in Healthy Subjects and Primary Care, of the Helsinki and Uusimaa Hospital District, approved the study.

The IST Vivago® system has been used in the nursing home as a nurse call and alarm system for several years. Therefore, all residents were used to wearing the device and the staff of the nursing home was experienced to use the system. The activity monitoring data were available continuously for over one year. The subjects wore the device all the time, except while bathing. Activity data were not available during the periods the subjects left the nursing home, but these periods were relatively rare.

Medical records and case histories of the subjects were available as well as routine daily notes made by the staff. These records and notes were studied from November 2002 to March 2003, and significant changes were visually

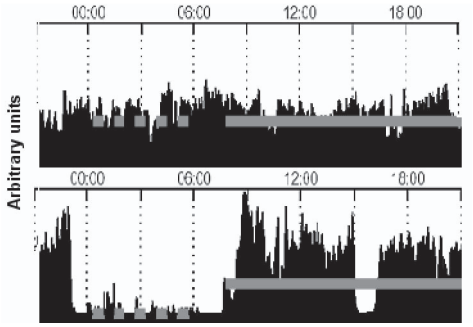

Figure 2. Calculation of the night-to-day activity ratio. Dashed line indicates the mean activity during the night while solid line is the mean activity during the day. With poor circadian rhythm (upper panel) these levels are close to each other and the ratio is close to 1, while with good circadian rhythm the ratio is significantly smaller than 1

compared with the activity signal measured. All subjects were screened for dementia with the Clinical Dementia Rating Scale (CDR)[17] and the Folstein Mini-Mental State Examination (MMSE)[18] and for depressiveness by using a 5-item Geriatric Depression Scale (GDS-5)[19]. Functional ability was assessed by using the Barthel Index (BI)[20].

The quality of the circadian activity rhythm was quantified by computing the mean activity during daytime (from 09:00 to 21:00) and night time (from 00:00 to 06:00), and their ratio (night-to-day activity ratio; see Figure 2.). More detailed data of the activity signal analysis is given in Paavilainen et al.[16]. Due to the small number of subjects and their heterogeneity in this study, the results are given as case reports.

Results

Demographic characteristics, main diagnosis and general health status, and main changes in the health status of all subjects are given in Table 1. In many cases, no significant changes occurred in health or sleep rhythm during follow-up. In those cases where changes in health and well-being were identifiable either by nursing notes or case records, changes in circadian activity rhythm often paralleled these events (Table 1). We chose to present in detail three case reports (Cases 10, 11 and 14) which demonstrate how problems in health and overall well-being can be seen in the activity curve, and one case which illustrates stable well-being and diurnal rhythm (Case 4). Numbering of case reports is the same as numbering in Table 1.

Case 4

An 84-year-old woman had no previous diagnosed medical conditions on admission, but only mild cognitive disorders (MMSE 21, CDR 0.5). Her functional ability was good (Barthel score 90), and she used only a mild tranquilizer in the evenings to help her to fall asleep in the same room with her roommate. She slept well and was alert during the daytime. In her activity curve (Figure 3, first panel from top), a clear circadian rhythm (low night-to-day ratio) with only a marginal increase during the monitoring period is visible. A slight increase of the rhythm in mid-October may be attributed to the change of the wrist sensor (IST Vivago® wrist unit) into a new model with slightly better sensitivity for low level activities.

Case 10

A moderately severely demented (MMSE 14, CDR 3) 83-year-old woman with satisfactory functional ability (Barthel score 65) had Alzheimer's disease (treated with donepezil 10 mg per day), arthritis (treated with rofecoxib 12.5 mg per day) and open angle glaucoma (treated with pilocarpine eye drops). She was also depressed for which she received citalopram 10 mg per day. At the beginning of 2002, her overall health status was relatively good, but from June it started to worsen gradually. Going by nursing records, there was increased in-

Table 1. Demographic characteristics and drop outs. Detailed reports of cases in bold are given in text. [1] f=female, m=male; [2] MMSE, Mini Mental Examination, Scale 0-30; [3] CDR, Clinical Dementia Rating Scale, Scale 0-3; [4] BI, Barthel Index, Scale 0-100; [5] CVD, Cardiovascular diseases; [6] Dementia NUD, Dementia of unspecified type; [7] SSS,Sick Sinus Syndrome; [8] COPD, Chronic Obstructive Pulmonary Disease; [9] DM, Diabetes Mellitus; [*] Data not shown

CASE	Age	Sex[1]	MMSE[2]	CDR[3]	BI[4]	Diagnoses and health status	Changes in the activity curve
1	90	f	22	2	50	Vascular dementia, CVD[5]; Slowly physically deteriorated; from mid-Jan 2003 abdominal pain and poor sleep; Hospitalized March 5th due to abdominal problems; Died March 12th	Worsened day/night ratio[*]
2	97	f	12	3	25	Alzheimer's disease, arthritis; Unstable sleep/wake rhythm, worsened during the follow-up, mostly due to progressive dementia; Very old age	Worsened day/night ratio[*]
3	90	f	11	3	90	Dementia NUD[5], CVD[5], depressed; Poor sleep, agitated and confused; Hospitalized in early Jan 2003 due to weakened physical and mental condition	Greater variability from day to day[*]
4	84	f	21	0.5	90	**See case report in text**	
5	74	f	29	0	85	COPD[6], CVD[5]; No health or sleep problems; Residing in the nursing-home due to functional disabilities	Clear circadian rhythmicity, no changes[*]
6	86	f	20	0.5	60	Alzheimer's disease, SSS[7]; Quite good sleep/wake rhythm, occasional awakening at nights; No problems during the follow-up	Clear circadian rhythmicity, no changes[*]
7	80	f	22	1	85	Vascular dementia, stroke; No health or sleep problems during the follow-up	Clear circadian rhythmicity, no changes[*]
8	94	f	12	3	45	Vascular dementia, DM[9], CVD[5]; Gradually decreased physical health, frail and fatigued, several falls; Sudden worsening in Nov 2002, hospitalized Nov 26th , died Dec 8th	Gradually decreased daytime activity, suddenly worsened day/night ratio and greater day-by-day variability in November[*]
9	85	f	20	1	75	Vascular dementia, CVD[5]; Sleep problems mostly due to physical conditions (pain in joints and eczema); Interventions for pain and skin problems improved sleep; Light therapy was used to normalize sleep/wake cycle, too	Improvements in day/night ratio, no dramatic changes[*]
10	83	f	14	3	65	**See case report in text**	
11	83	f	23	0.5	45	**See case report in text**	
12	96	f	20	0.5	70	No diagnosed conditions or sleep problems	Clear circadian rhythmicity, no changes[*]
13	58	f	18	1	75	Stroke, epilepsy, mental problems; Poor sleep, anxious and agitated at nights and daytime; Hip fracture, hospitalized early-Jan 2003	Poor day/night ratio, great day-to-day variability, no changes[*]
14	86	f	20	3	20	**See case report in text**	
15	89	m	30	0.5	90	COPD[6], blind. Poor sleep and sleep/wake rhythm; physically inactive, but mentally very active	Poor day/night ratio, no changes[*]
16	87	f	23	0.5	25	CVD[5], mild memory problems; Mentally anxious, poor sleep and very tired at daytime; Poor sleep/wake rhythm	Poor day/night ratio, no changes[*]

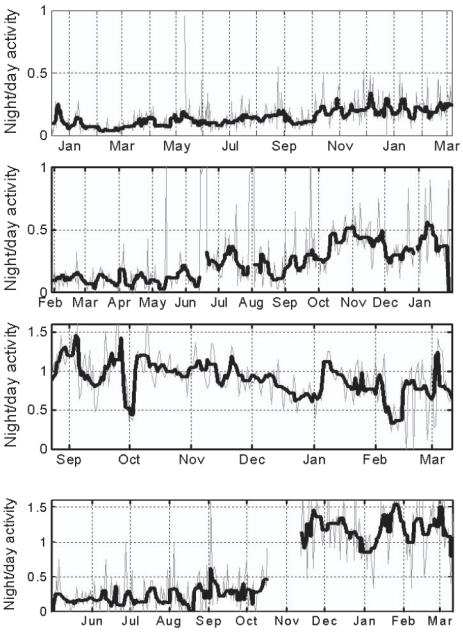

Figure 3. Long-term trends in circadian activity rhythm. The first panel (Case 4) shows a clear circadian rhythm (low night-to-day ratio) with only marginal changes during the monitoring period. The second panel (Case 10) illustrates deteriorated circadian rhythm associated with worsening health status (ascending graph). The third panel (Case 11) illustrates ameliorated sleep/wake rhythm in December (downward graph) and worsening medical conditions (ascending graph) in early January and at the turn of January and February. In the fourth panel (Case 14) the night-to-day ratio was generally below 0.5 until mid-October indicating good circadian rhythm. Since November, the ratio increased simultaneously with worsening medical condition. Temporary recovery in health status in December was seen in the ratio as a downward graph. In all panels, the trend in circadian rhythm (bold line) was calculated by moving median value over seven days of night-to-day activity ratio (thin line)

cidence of falls, changes in diurnal rhythm, sleep problems and tiredness during the daytime. Her physical functioning decreased and she had trouble in moving and eating. Noteworthy, this worsening was not associated with any acute medical conditions. At the end of January, she got pneumonia, for which she was hospitalised, where she died on February 2003.

The night-to-day activity ratio (see Figure 3, second panel from top) was low until June indicating strong circadian rhythm. From late June, the ratio climbed gradually indicating deteriorated circadian activity rhythm associated with worsened overall health status.

Case 11

An 83-year-old woman had Myasthenia Gravis (treated with pyridostigmine and azathioprine, and citalopram for concomitant depression), mild cognitive problems (MMSE 23, CDR 0.5) and decreased functional ability (Barthel score 45). She was placed in a double room with a severely demented lady. Due to her roommate's disturbed sleep and agitated behaviour, she experienced sleeping difficulties. After transfer of the roommate at the beginning of December, her sleeping complaints were reduced. At the beginning of January, she became confused, slept badly and was very tired. A diagnosis of urinary track infection (UTI) was made on January 15, and after a few days of antibiotic medication, her symptoms were reduced. Two weeks after the UTI diagnosis, she had mild fever and became restless. Following acute bronchitis was diagnosed in January 30. After antibiotic treatment (phenoxymethylpenicillin) her condition improved temporarily. Since February, her overall condition worsened and she was hospitalised in April as her need for care increased and the resources of the nursing home were not sufficient.

The night-to-day activity ratio in this case (see Figure 3, third panel from top) was generally poor (fluctuating around 1) but improved in December at the time of transfer of the roommate. The rhythm worsened again in early January due to UTI, which was diagnosed several days later than were the changes in the circadian rhythm. Recovery from the UTI and bronchitis was associated with improvement of the circadian rhythm in early February, however, only for a brief period. The worsening of the general condition was once again reflected in the worsening of the circadian activity rhythm.

Case 14

An 86-year-old woman had vascular dementia (MMSE 20, CDR 1), decreased functional ability (Barthel score 20), coronary artery disease and congestive heart failure (treated with digoxin, carvedilol and furosemide) and asthma (treated with theophylline). During 2002, her overall health status was relatively good, but in October she was hospitalised due to cardiac problems. After discharge, she was restless and confused, her sleep was poor, and she was very tired during the daytime. Due to these problems, her sleeping medication (temazepam 10 mg) was discontinued. On December 10, her condition deteriorated, because of worsening cardiac failure. She was treated with intensified furosemide (diuretic), bed rest and pain medication. Her physical condition improved temporarily, but her dementia progressed during the winter (MMSE 15 in March 2003).

The night-to-day activity ratio from May 2002 to mid-October (see Figure 3, lower panel) was generally below 0.5 indicating significantly lower night-time activity compared with daytime activity, suggesting a strong circadian activity rhythm. After discharge, the ratio drastically worsened due to decreased daytime and increased night-time activity reflecting significantly compromised medical condition, and later again possibly due to the progression of dementia. Temporary recovery in health status and in circadian rhythm was seen in early December.

Discussion

The presented cases suggest that monitoring the circadian activity signal produced by the IST Vivago® system provides a sensitive, but non-specific method for monitoring changes in the health status of older people. In many instances, the changes in the quality of the circadian rhythm paralleled or even preceded (Case 11 with UTI) the clinical notes of significant changes in the physical health status, such as acute diseases. This is not surprising as some earlier studies have associated poor circadian rhythm or sleep disturbances with the poor physical or mental health or life satisfaction (for review, see Van Someren[8]).

As the IST Vivago® system is capable of measuring the sleep/wake cycle[15] and circadian rhythm in the elderly[16], it is logical that the changes in the health status are reflected as changes in the activity signal, especially when it is compared with one's own history. On the other hand, all changes in the circadian activity rhythm could not be associated with the clinical notes in the medical records or nursing documentation, suggesting that the method is sensitive to sub-clinical changes of variation in the circadian activity rhythm. Obviously, the association between the circadian activity rhythm and changes in the health status should be a subject for further studies in controlled settings.

As changes in the circadian activity rhythm may be induced by various different factors, both physical and psychological, the method is not capable of indicating the reason for the change.

Hence, it should be considered as a screening or follow-up tool and in case of significant changes, a home nurse or physician consultation may be applied for actual diagnosis.

In this observational study, we presented 16 case reports of which four in detail. These case reports are preliminary results to find out how this kind of monitoring would be useful in the elderly care. Because of a small number of subjects (n = 16) and their heterogeneity, no statistical analyses were possible. The system used in the study offers both traditional manual social alarms and automatic alarms based on activity monitoring, and continuous telemetric activity monitoring. Our aim was not to examine the alarms or actions that occurred on the basis of them, but to study the relationship between the activity curves and noticed changes in health and well-being qualitatively.

Ethical issues, such as a threat to compromise privacy, arise when people are monitored for long periods in their normal surroundings. This is true for most of the new technologies penetrating individuals' life. At present it is commonly accepted that critically ill patients are monitored all the time, for instance in intensive care units. However, monitoring in every day life is a different issue from an ethical point of view, and ethical considerations should be included in the application of this technology. Our practical experience in this and earlier studies (unpublished observations) is that few older users or their relatives consider telemetric activity monitoring as threatening their integrity. Instead, many of them have expressed that this kind of technology increases their feeling of security and helps them to maintain their privacy through extended possibilities to continue their living in their current environment longer. Hence, obviously, there are pros and cons concerning the use of the technology. In further studies systematic data should be collected to study this balance in more detail and in a larger context than just activity monitoring.

Conclusion

Telemetric activity monitoring systems have recently become available both for home and institutional use. The most promising feature of the method, such as embodied in the IST Vivago® system, is that it integrates the telecare alarms (reactive measures) with health monitoring (preventive measures) in one single device, which is unobtrusive to wear and which the users are motivated to use because of the alarm features. These results suggest that the method can be used to monitor changes in health status and to follow-up on the effects of treatment in elderly care institutions.

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