CONNECTIONS OF DAYTIME NAPPING AND VIGILANCE MEASURES TO ACTIVITY BEHAVIOUR AND PHYSICAL FUNCTIONING
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ABSTRACT
Ability to do different daily activities defines partly one’s independency. We study older adults’ daytime sleep behaviour (napping) with respect to user’s physical activity behaviour and physical functioning. The daytime sleep behaviour was measured via self-reported vigilance, actigraphy and bed sensor. Nineteen users took part in the study for three months. Especially actigraphy napping feature was found to have statistically significant correlation to number of steps, daily activity and self-reported exercise. According to the data, daily napping habits can also tell about the user’s physical ability level.

KEY WORDS
Actigraphy, bed sensor, daytime sleep, physical functioning, older adult

1. Introduction

Current demographic change (portion of the older adults in community is growing) is causing a lack in different resources and drives the research for new innovative solutions that enable successful aging. A physical ability to perform daily routines i.e. physical functioning is one of the corner stones of independent living. Automated, long-term monitoring of the physical functioning (functioning later on) at home environment could be beneficial. By taking preventive and rehabilitative actions early enough we could decrease potentially expensive future care needs and improve one’s quality of life.

Functioning consists of several areas. For example, in the EUNAAPA project (EUropean Network for Action on Ageing and Physical Activity; http://www.eunaapa.org/) researchers collected information about measures/tests which professionals are using in evaluation of the functioning of older adults. They identified nine different areas of functioning or connected topics:

- physical activity level
- endurance
- locomotion
- balance
- mobility
- manual dexterity and gross motor coordination
- muscular strength
- common indexes
- ADL (activities of daily living)

We recruited older adults to participate in the three-month study. During the study, different health-related observations were collected daily in the home environment. The data collection equipment and setup is explained in details in [1]. From the collected data we studied which of these methods are sensitive to indicate the level of functioning or changes in that level. In this paper, we discuss findings related to daily sleep behaviour.

It has been reported that sleep disturbances like insomnia and daytime napping have higher prevalence among older adults compared to other population. In addition to age, there are other factors causing sleep problems such as health status, medications, social and physical behaviour, and living surroundings. Chasens et al reported that sleepiness seems to have negative effect on amount of physical activity of a relatively healthy community-dwelling older adult which again is one factor of the functioning [2]. According to Gooneratne (in [2]) sleepiness had a negative correlation with vigilance. Poor sleep patterns can lead to excessive daytime sleepiness, which is associated with functional and cognitive decline together with a lowered amount of physical activity and exercise [2, 3]. Excess daytime sleepiness has been reported to be extremely common in nursing home residents. However, as Cochen [4] reported, the effects of sleep problems are not well known in very heterogeneous older populations. People with daytime sleepiness reported lower sleep quality and lower overall health. Due to high rates of symptoms of sleep disorders, Wilson suggested that screening for sleep disorders should be the new vital sign in medical care, especially in geriatrics (Wilson 2005 in [2]). Chasens concluded that sleep disturbances might have negative consequences to physical exercising and finally to functioning. However, more long term studies have to be conducted to gain more information on these dependencies.

In this study our objective is to find out if daytime napping and sleepiness related features measured via different wellness technologies tell about person’s functioning and physical activity behaviour.
2. Methods

2.1 Measuring daytime napping and sleepiness

We used three observation methods which could be associated to daytime napping and sleepiness.

1) Actigraphy: Vivago is a wrist-worn wireless activity monitor (IST WristCare, Vivago, Helsinki, Finland, similar to actigraphy; www.istsec.fi) and can observe a person’s activity and sleep/wake patterns 24/7. The method has been reported to perform sleep/wake detection with similar accuracy to actigraphy, which is the most commonly used alternative to polysomnography in sleep analysis. The Vivago (later on actigraphy) was reported to be highly sensitive to detect self-reported naps, although there were some discrepancies between individual algorithms which should be considered when no personalization of the algorithm is done [5]. The software related to the device offers minute-to-minute sleep/wake discrimination during the whole circadian. This classification data were used to calculate the daytime sleep features i.e. napping time.

2) Bed sensor: Vital signs during the bed time were collected using an electromechanical film sensor (Emfit Ltd, Vaajakoski, Finland; www.emfit.com). The bed sensor was installed below the user’s mattress. The device detects time spend in bed with one minute resolution. This information is used to calculate bed sensor based napping time during the day.

3) Self-reported vigilance: The participants reported their daily vigilance on 5-point Likert scale (5 represents a very active day) on paper [1]. This measure was hypothesized to tell about the daytime alertness and its opposite, sleepiness.

For the actigraphy and the bed sensor data the circadian was divided to a daytime (10am to 8pm) and a night-time (8pm to 10am). Actigraphy day napping time is a direct sum of presence feature in the bed during the daytime. The classification was obtained from the actigraphy’s software. If the actigraphy data were collected less than two hours during the day this day’s data were excluded from the analysis. If the sensor is off the wrist or out of the base station’s range the activity data is not available i.e. collected. The two-hour limit is purely heuristic. The bed sensor’s napping time is as well the direct sum of presence feature in the bed during the daytime (seconds in a minute).

2.2 Physical activity behaviour measures

During the study the participants reported daily the time they spent doing physical exercises (self-reported exercise); this did not include intensity information. If the subject did not report exercise for a certain day but reported something else in the diary (see [1]) self-reported activity was coded as zero minutes for these days. Steps were measured daily via pedometer (Walking style II, Omron Corp., Kyoto, Japan) and users wrote the result (number of steps) in the diary. An average daily activity measure from the actigraphy is used to describe the subject’s total daily activity behaviour (average daily activity). For this feature four hours of the actigraph data is needed for inclusion. The average is calculated from the absolute activity value from each minute given by the actigraphy’s software.

These three activity measures are used in the analysis. The average daily activity and actigraphy napping features are not independent measures and we assumed they would be heavily related. Table 1 summarizes the features used in the analysis.

### Table 1

<table>
<thead>
<tr>
<th>Measure</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Actigraphy napping time</td>
<td>Daily napping time calculated from the actigraphy’s sleep/wake classification between 10 am and 8 pm</td>
</tr>
<tr>
<td>Bed sensor napping time</td>
<td>Daily napping time calculated from the bed sensor bed occupancy detection between 10 am and 8 pm</td>
</tr>
<tr>
<td>Self-reported vigilance</td>
<td>The subjects reported daily their self assessed vigilance in the 5-point Likert scale</td>
</tr>
<tr>
<td>Steps</td>
<td>Number of steps from the pedometer for each day, which the subjects wrote down in the diary</td>
</tr>
<tr>
<td>Self-reported exercise</td>
<td>The subjects wrote down their physical activity amount in minutes observed by themselves</td>
</tr>
<tr>
<td>Average daily activity</td>
<td>Average of actigraphy’s minute-to-minute activity value between 10 am and 8 pm</td>
</tr>
</tbody>
</table>

2.3 Physical capacity and health measures

Before the study period, a gerontologist interviewed the participants and collected information related to subjects’ functioning and health. These items were:

- Mini mental state examination (MMSE): 0 to 30 (30 no memory problems)
- Activities of daily living (ADL): 15 to 60 (15 totally independent)
- Self rated health: 1 (good) to 5 (poor)
- Current exercise amount: 1=no, 2=daily, 3=3-5, 4=1-2, 5=rarely
- Sleep; hours per night
- Geriatric depression scale (GDS-15): 0 (no depression) to 15 (extreme depression)
- Sleeping pills usage: <yes, no>

At the beginning and the end of the study, a physiotherapist evaluated the participants’ functioning via several tests. The test set is developed by State Treasury for evaluating veterans’ functioning. The items included in this set were:

- Hand grip test of both hands
- Balance test (Standing with feet together, Retrieving object from floor, Turning 360 degrees, Tandem stance, Standing on one foot)
- Chair Stand 5 times
- Crouch times: crouch as many times you can (max 50)
- Step height
- Walking speed of 10 meters

2.4 Analysis

The data were analyzed from three different perspectives:
The users’ daily data were pooled together, and connection between napping features and activity behaviour were studied. Case-wise correlations were also analysed. The exclusion criterion for case-wise analysis was more than 10 samples for each data pairs e.g. step and actigraphy napping time.

The daily activity and napping features were averaged over seven days. Periods with three samples or more were included. Again the connection was studied.

The napping features were averaged and standard deviation (SD) calculated for the first month of the study period and connections with the functioning tests in the beginning of the study are analysed. The same analysis was done for the data of the last month of the study period. More than nine samples from the month were required that the feature was included in the analysis.

### 2.5 Subjects and data

The study group consisted of older adults who lived in an assisted living facility which provides accommodation and rehabilitation services for older and disabled people. During the study, they participated in a health intervention designed to increase their physical activity (Fig. 1). The inclusion criteria were: volunteering to participate in the intervention and the present study, having self-reported sleep problems, and loneliness or low physical activity level. The exclusion criteria were: having an acute disease, being in the active degeneration phase of a chronic disease, having a known disturbing event like a surgery during the study, a neurological disorder which prevented subject from using the system’s components, dementia, any physical limitation that prevented their participation in the guided physical exercise, or depression without a medication. The study was approved by the appropriate ethics committee.

The 19 older adult subjects (average age 78, SD=3, 14 females) collected data for a total of 1593 days. The average participation period was 84 days (range 19–107). We had two problems with the data collection during the study. 1) A wrong log off procedure shut down the manager software and caused six weeks loss of bed sensor data (excluding actigraphy data) from eight people in the first subgroup. 2) The actigraphy’s software, which was used to collect the actigraphy data, ran on a server computer at the facility. For an unknown reason the server was shut down during the summer vacation (most likely caused by the renovation work done in the building), causing a four-week loss of activity data in the second subgroup.

### 3. Results

#### 3.1 Daily napping and activity behaviour relationship

The napping features were not normally distributed (according to Kolmogorov-Smirnov test) and Spearman rank correlations were used in the analysis. There were statistically significant correlations between most of the three napping features (Table 2).

Table 3 presents the statistically significant relationships (Spearman) between the daily napping and the activity features.

#### 3.2 Case-wise correlations

Between steps and actigraphy napping time there were three cases with statistically significant correlations similar to the pooled data. Between self reported exercise and actigraphy napping time there were two cases with significant negative correlation which differs from the pooled data findings. Nine out of 14 (five do not have actigraphy data) had significant correlation between average daily activity and actigraphy napping time, which was expected since the features are based on the same device data.

There were two cases with significant negative correlation between bed sensor napping time and steps, one case with positive correlation between self-reported exercise and bed sensor napping time, and two cases with negative correlation between bed sensor napping time and average daily activity.

For self-reported vigilance five cases have positive significant correlation with steps, four cases have positive correlation with self-reported exercise, and one case have positive correlation with average daily activity.

There were no major changes in persons’ health status...
functioning and health measures

3.4 One month averaged napping data compared to amount of samples per case for the averaged data. Case-wise correlations were not calculated due to small the correlation is significant if parametric test is used. significant relationship disappeared (Table 4). However, napping time and self-reported exercise statistically compared to today to day analysis as the actigraphy’s napping time and self-reported exercise statistically significant relationship disappeared (Table 4). However, the correlation is significant if parametric test is used. Case-wise correlations were not calculated due to small amount of samples per case for the averaged data.

3.3. Seven-day average napping and activity behaviour feature relationship

Most of the seven-day average features are not normally distributed and Spearman rank correlation is used in the analysis. Concerning daily napping, a similar correlation remained than with the daily observations, although the connection between bed sensor and self-reported vigilance disappeared. There was only one change in correlations between averaged daily napping features and activity behaviour compared to day to day analysis as the actigraphy’s napping time and self-reported exercise statistically significant relationship disappeared (Table 4). However, the correlation is significant if parametric test is used.

Case-wise correlations were not calculated due to small amount of samples per case for the averaged data.

3.4 One month averaged napping data compared to functioning and health measures

Table 2
Spearman correlation coefficients between daily napping features

<table>
<thead>
<tr>
<th>Napping feature</th>
<th>Actigraphy napping time</th>
<th>Bed sensor napping time</th>
<th>Self-reported vigilance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Actigraphy napping time</td>
<td>-</td>
<td>0.547**</td>
<td>-0.221**</td>
</tr>
<tr>
<td>N</td>
<td>536</td>
<td>321</td>
<td>649</td>
</tr>
<tr>
<td>Bed sensor napping time</td>
<td>0.547**</td>
<td>-</td>
<td>-0.124**</td>
</tr>
<tr>
<td>N</td>
<td>321</td>
<td>870</td>
<td>649</td>
</tr>
<tr>
<td>Self-reported vigilance</td>
<td>-0.221**</td>
<td>-0.124**</td>
<td>-</td>
</tr>
<tr>
<td>N</td>
<td>536</td>
<td>649</td>
<td>1267</td>
</tr>
</tbody>
</table>

* Correlation is significant at the 0.05 level.
** Correlation is significant at the 0.01 level.

Table 3
Spearman correlations coefficients between daily napping and activity features

<table>
<thead>
<tr>
<th>Napping feature</th>
<th>Activity feature</th>
<th>Actigraphy napping time</th>
<th>Bed sensor napping time</th>
<th>Self-reported vigilance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Steps</td>
<td>N</td>
<td>-0.202**</td>
<td>-</td>
<td>0.159**</td>
</tr>
<tr>
<td>Self-reported exercise</td>
<td>N</td>
<td>0.996*</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Average daily activity</td>
<td>N</td>
<td>-0.616**</td>
<td>-0.414**</td>
<td>0.263**</td>
</tr>
</tbody>
</table>

* Correlation is significant at the 0.01 level.
** Correlation is significant at the 0.05 level.

Beginning of the study: Table 5 lists napping features’ Spearman correlations to functioning and health measures. Actigraphy napping time tends to be related to some functioning measures and self reported vigilance on the depression questionnaire result. In this population, actigraphy napping time differs between sleeping pill users and non users. Similar difference was observed for self-reported vigilance although the difference is not statistically significant (Fig. 2). Bed sensor napping time SD tends to be related to self reported sleep time.

End of the study: Functional tests had no statistically significant correlations with actigraphy napping time (except Crouch times correlation was almost statistically significant; P=0.92). Number of subjects in actigraphy napping time analyses was smaller (N=9 to 11) than in the beginning of the study due to missing actigraphy data or the performance tests. The bed sensor napping time or self-reported vigilance did not have statistically significant correlation to functional tests. For bed sensor and self-reported vigilance, the number of subjects in the analysis is between 8 and 12.

4. Discussion

4.1 Daily napping and activity behaviour features

Actigraphy napping time tend to have significant connection to activity/exercise features. However, self-reported exercise was correlated positively with actigraphy napping time although the correlation was small. This means that days which included more exercise tend to include more daytime napping. It has also been reported that older adults doing moderate to vigorous activities need to rest more during that day [6]. Meijer also found out that daily energy consumption was more related to lighter activities than high. Our findings are in line with these. However, two cases have strong negative correlation which conflicts the hypothesis and with seven days averaged data the connection disappeared. As mentioned earlier the study period was short and it might be normal not to see similar changes in individual level
than with the pooled data. In addition, the study period included exercise intervention which might affect the results. The self-reported exercise did not contain intensity information which should be included in the future studies.

The self-reported exercise and the steps have positive connection (0.257**, N=1153), the actigraph napping time and steps have negative connection (Table 1), but the self-reported exercise and the actigraph napping time have a small positive connection. We assume that steps can indicate light, moderate or even vigorous activities and it tells more about the total daily activity level, which would be the main reason for the strong connection between the average daily activity and the steps (0.616**, N=608). Again, we hypothesise that if an older person “exercising” they need rest, but if the day is just active without “exercising” they don’t have to sleep/rest during the day.

It would be important to study that if older adults are not “exercising” they don’t have to sleep/rest during the day. It would be important to study that if older adults are not doing “exercises” and still nap more than expected they could have some “health problems” e.g. degenerated functioning.

Average daily activity (-0.139**) and number of actigraphy data points during the day (-0.132**) have small negative correlation with self-reported exercise which might also indicate that the “exercises” have taken place out of range of the actigraphy’s base station (covers basically the facility and close surroundings). To gain good understanding about the real daily activity behaviour we should take all the activity features into account..

Bed sensor napping time had connection only to average daily activity. This might indicate that the bed sensor based napping feature is not very strongly related to the amount of daily activity (behaviour). Some people tend to sleep during the day in the bed (where the bed sensor is located) and some people tend to sleep for example on a couch where the sensor is not present, which most likely is one reason for these two measures (actigraph and bed sensor) to differ. This tells that bed sensor is more suitable for night time than daytime sleep behaviour monitoring. However, there are two individuals who had strong positive correlation between self-reported exercise and bed sensor napping time. These subjects potentially tend to sleep in their bed during the day.

Wrist or hip worn actigraphic devices are more suitable for monitoring the daytime sleep/rest behaviour on the group level. Day time sleep also seems to be an important

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** Table 5  

Spearman correlations coefficient between one month average and standard deviation of daily napping features and functioning/health (month in the beginning)

<table>
<thead>
<tr>
<th>Health and functioning</th>
<th>Napping features</th>
<th>Actigraphy napping time</th>
<th>Actigraphy napping SD</th>
<th>Bed sensor napping time</th>
<th>Bed sensor napping SD</th>
<th>Self-reported vigilance</th>
<th>Self-reported vigilance SD</th>
</tr>
</thead>
<tbody>
<tr>
<td>Self rated health</td>
<td>N</td>
<td>13</td>
<td>13</td>
<td>17</td>
<td>17</td>
<td>19</td>
<td>(almost -0.4)</td>
</tr>
<tr>
<td>Current exercise amount</td>
<td>-</td>
<td>13</td>
<td>13</td>
<td>17</td>
<td>17</td>
<td>19</td>
<td>-</td>
</tr>
<tr>
<td>Sleep/ hours per night?</td>
<td>-</td>
<td>13</td>
<td>13</td>
<td>17</td>
<td>17</td>
<td>19</td>
<td>-</td>
</tr>
<tr>
<td>Sleeping pills</td>
<td>-0.62*</td>
<td>-0.742**</td>
<td>13</td>
<td>13</td>
<td>17</td>
<td>17</td>
<td>(almost 0.45)</td>
</tr>
<tr>
<td>MMSE</td>
<td>10</td>
<td>10</td>
<td>16</td>
<td>16</td>
<td>16</td>
<td>19</td>
<td>19</td>
</tr>
<tr>
<td>GDS-15</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-0.61**</td>
<td>19</td>
<td>19</td>
<td>-</td>
</tr>
<tr>
<td>ADL</td>
<td>(almost 0.41)</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>19</td>
<td>19</td>
<td>almost (-0.44)</td>
</tr>
<tr>
<td>Right hand grip test</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>19</td>
<td>19</td>
<td>-</td>
</tr>
<tr>
<td>Left hand grip test</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>19</td>
<td>19</td>
<td>-</td>
</tr>
<tr>
<td>Balance test</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>19</td>
<td>19</td>
<td>-</td>
</tr>
<tr>
<td>Crouch amount</td>
<td>-0.82**</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>19</td>
<td>19</td>
<td>-</td>
</tr>
<tr>
<td>Chair stand 5 times</td>
<td>(almost 0.43)</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>19</td>
<td>19</td>
<td>-</td>
</tr>
<tr>
<td>Step height</td>
<td>(almost -0.39)</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>19</td>
<td>19</td>
<td>-</td>
</tr>
<tr>
<td>Walking speed 10 meters</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>19</td>
<td>19</td>
<td>-</td>
</tr>
</tbody>
</table>

** Correlation is significant at the 0.01 level.
behavioural measure to evaluate the health status i.e. functioning according to our findings.
Steps and self-reported vigilance seem to have interesting correlation (Table 2). The problem with self-reported vigilance in the study was that it did not have variance on individual level which might have a downside in long term analysis. This might tell from the subjects' ability to assess longer term changes in their health. For example, if one felt two months ago the same as now the health status could still have changed. This is why objective measures should also be used in long term monitoring of health.
On case-wise level, the connections between the features differed in some cases from the group level findings. This was expected as the study duration was only three months and no big health changes were observed. The couple of subjects who showed similar responses on individual level and in the pooled data could be interesting for a more thorough study to analyse what kind of reasons are behind the connections.

4.2 seven-day average data
The self-reported exercise did not have a statistically significant connection to other features. Steps had negative correlation to actigraphy napping time. This supports the daily data finding that the less you sleep during the day the more active you are when observing steps and general activity (average daily activity).
There is an almost significant correlation with the bed sensor napping time and the steps. However, this correlation is positive which is rather confusing when compared to the actigraphy napping time relationship with the steps. Moreover, the statistically significant correlation between self-reported vigilance and steps disappeared.

4.3 Functional capacity
The actigraphy napping time showed some interesting connections (in similar way as was hypothesized) to functioning tests. The actigraphy napping time values seem to be related to sleeping pill usage as well. Subjects reporting greater vigilance values did not use sleeping pills. One reason for this could be that if people sleep during the day they have difficulties with night time sleep and this is why they use sleeping pills. It could also be related to the fact that people with sleeping problems (sleeping pill users) are more passive during the day. Self-reported sleeping time (start level question) and bed sensor napping time SD connection can be related to subject's habits of either sleeping longer in the bed or going earlier to the bed. This might indicate that the time limit for day (from 10 am to 8 pm) is too long and it should be even narrowed. The bed sensor information could be used to adapt the daytime period positioning. Very interesting was also correlation between depression scale (GDS-15) and the self-reported vigilance. It would be of interest to study relationship between depression and objectively measured activity behaviour in longer term setup.
The functional tests should be combined to one common index and study if the objective measurements have a connection to that index as it might be more reliable measure of one’s functioning compared to the separate tests. For example, when dividing the subject into two groups according to ADL questionnaire result (cut off = 20) the actigraphy napping time (month average) seems to be quite a good measure to distinguish users between different functioning groups (Figure 3, Spearman, P = 0.109, 0.465, 1: N=8, 2: N=5). Again the population is small and more data is needed to find out how these methods can help e.g. care personnel, clinicians or users.

Figure 2. One month average actigraphy daily sleeping time and self-reported vigilance for sleeping pill users and non-users
5. Conclusions

Actigraphy based napping time tends to be related to personal functional capacity and activity behaviour according to the data. Monitoring of this feature could be beneficial for indicating health problems or even detecting changes in the health status. Different activity features (in our case: steps, self-reported exercise and average daily actigraphy activity) should all be considered to form a holistic personal activity profile as the features tend to describe somewhat different behaviour according to our findings. Self-reported vigilance had the downside of missing variance on individual level, and implies that objective measures are needed for revealing daily alertness status. It would be of interest to study the connection between depression and objectively measured activity behaviour in a long term study setup as self reported vigilance was found to have negative correlation with Geriatric Depression Scale (GDC-15).

Acknowledgement

We would like to thank the care facility personnel for their contributions.

References


