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Daily activities and fall risk – A follow-up study to identify relevant activities for sensor-based fall risk assessment

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Abstract

The demographic change will lead to an increase in the incidence of falls in the elderly. Technological progress allows for unobtrusive physical activity measurement with miniature sensors, e.g. accelerometers. Yet it is unclear which activities or activity patterns are associated with an increased fall risk. The aim of the research for this paper is to identify daily physical activities associated with a high fall risk. A one-year follow-up study was conducted with n=50 geriatric patients who took part in a telephone interview to assess fall events, their consequences and a set of daily physical activities. Descriptive analysis of the data shows that there are marked differences between fallers (n=21) and non-fallers (n=29) in the overall activity level, the amount of shopping activity and associated locomotion, and in the intensity of light household work. The results confirm that there are differences in typical daily activities between fallers and non-fallers that may be used as parameters to enhance fall prediction models.

Keywords:

Accidental falls, Motor activity, Assisted living facilities, Sensors

Introduction

It is a well-known fact that the future demographic development will lead to an increase in the elderly population, both in absolute and relative numbers [1]. This change in population composition will lead to a rise in the prevalence of chronic diseases and in multi-morbidity. Physical activity is an important and independent factor in the etiology of many chronic diseases, including diabetes mellitus, cardiovascular diseases, musculoskeletal diseases, certain types of carcinomas and even affective diseases (e.g. [2, 3]). Along with the recent development of wellness and exercise support systems, this has led to a rush in sensor-based activity recognition/analysis projects in the last decade, because automated assessment even during long-term periods in daily life has become feasible due to the rapid development in sensor technology and mobile computing power.

With regards to the demographics, however, falls are a predominant problem. It is estimated that the annual cost of falls and their consequences amounts to $20 billion in the U.S. [4]. Furthermore, falls are associated with a high risk to retain functional limitations as well as the so-called ‘post-fall syndrome’ that comes along with an increased fear of falling, leading to a vicious circle of ever-decreasing activity leading to a loss of muscle mass (sarcopenia) and so on [5]. Individual fall risk is associated with gait parameters that can be measured with miniature accelerometers [6-8]. There is also evidence showing that persons with a high risk of fall-related fractures risk tend to be less active in their daily lives than those with a low risk [9].

One of the most relevant applications of activity measurement could be to identify persons with a high fall risk by identifying gradual changes in daily activity patterns. Thus, persons with an increasing risk may be prompted to get timely intervention to reduce individual fall risk [10]. It remains unclear, however, what types of activities and activity patterns are correlated with a high fall risk.

Therefore the aim of our research for this paper was to identify those daily physical activities which are the most relevant for identifying persons with a high fall risk.

Materials and Methods

Study population

The basic population for this study are all elderly persons, the selection population were all patients that received in-patient treatment at the Department for Geriatric Medicine of the Braunschweig Medical Center, Germany, between April 24th and October 18th, 2007. These patients were enrolled in a previous study that investigated the use of sensor-based gait parameters to identify persons with a high fall risk [11]. Altogether n=119 subjects with a mean age of 80 years participated.

For the study at hand these 119 persons were contacted by mail and asked to participate in a one-year follow-up study to assess their fall history and their daily activity profile. 50

subjects agreed to participate in our study and gave written consent.

Telephone interviews

In order to identify an adequate telephone assessment tool to record daily activities, the first author conducted a search for suitable questionnaires on the Internet and in corresponding scientific journals. To the authors' knowledge, the only activity questionnaire that has been designed and validated for elderly people is the questionnaire presented by Voorips et al. [12], containing ten questions concerning the amount of light and heavy household work, the number of persons, rooms and floors taken care of in the household, meal preparation, number of stairs walked daily, shopping, and mode of transportation when moving in one's hometown and for shopping. Each answer is scored on a scale from 0 (low activity) to 4 points (high activity).

Within the interviews, fall history was assessed following the criteria proposed in the *Prevention of Falls Network Europe* consensus [13]. A 'faller' was defined as a person having sustained at least one "unexpected event in which the participants come to rest on the ground, floor, or lower level" ([13], p.1619).

The interviews were conducted by co-author AR, a registered nurse and diploma student at the Peter L. Reichertz Institute for Medical Informatics.

Data analysis

We chose two different approaches for data analysis. The first method was a descriptive analysis of the point values for all ten questions. As the answers are scored on an ordinal scale, we chose to calculate rank sums for each score and to present the results in a bar diagram (Figure 1).

The second approach was an exploratory analysis of the relevance of each activity score. We chose to calculate the *information gain* and to rank the parameters accordingly. In information theory, the information gain is defined as the amount by which a parameter is able to decrease total entropy. It is measured in *bits* and used by several pattern classification algorithms to choose a parameter to split a dataset, e.g. by the C4.5 algorithm [14].

Results

Descriptive analysis of rank sums

Figure 1 shows a bar diagram with the rank sums for each activity sub-score and the sum of all scores. While differences between the two groups of fallers (n=21) and non-fallers (n=29) can be seen in the rank sums of all activity parameters, the largest differences can be observed for the mode of locomotion when shopping, the overall amount of shopping activity, engagement in light household activities such as washing the dishes or dusting. The smallest rank sum differences are found for the number of stairs walked daily and – correspondingly – the number of floors in a person's living surroundings. Finally, the overall activity sum score also shows an obvious difference between fallers and non-fallers.

Information gain analysis

The calculation of the parameters' information gain yielded only three activity sub-scores with a positive gain value. These are shown in Table 1. All other sub-scores were not applicable to split the given dataset into fallers and non-fallers.

Table 1 – Information gain value ranking of activity sub-scores

activity parameter	information gain [bits]
shopping – mode of locomotion	0.155
amount of shopping activity	0.127
amount of light household work	0.119

Discussion

First of all, it can be observed that – despite the limited sample size – there is marked difference in overall activity between the two groups, indicating that persons with a high fall risk have a low activity intensity. This can be observed in the activity sum score, but also in all sub-scores. This confirms results of Stevens et al. who report a higher activity in patients who do not sustain a fall-related fracture, provided that they do not suffer from any limitations in terms of an ADL-score ≥ 0 [9]. For patients with such limitations, the odds ratio is reported as 3.2 to sustain a fall-related fracture.

Among the different daily activities that have been measured by our questionnaire, the largest differences between the two groups can be observed in the intensity of shopping activity on the one hand and in the mode of transportation or locomotion when going shopping on the other hand (Figure 1). This result is confirmed by the highest ranks of these two items in the information gain calculation (Table 1). It may be concluded that persons who have a high fall risk either do not or less often go shopping on their own or – if they do so – rather use a means of transportation (car, public transportation) that does not require advanced motor skills such as bicycling or walking – possibly with shopping bags. The reasons for this may be manifold. Firstly, as fall risk is related to functional limitations in performing demanding motor activities such as repeated sit-to-stand transitions or alternate steps [15], shopping may be regarded as a demanding task requiring multiple physical skills, and – as such – changes in this activity might be regarded as an early indicator for the onset of motor functional limitations. Secondly, falls often lead to the 'post-fall syndrome' [5], leading to a vicious circle of increasing fear of falling, subsequent limitation of personal and social activities, leading to a further increase of fall risk, and so on. In our sample, 61.9% (13 out of 21) of the persons who fell within the study year had at least one fall event before. The post-fall syndrome therefore might be one of the reasons for shopping

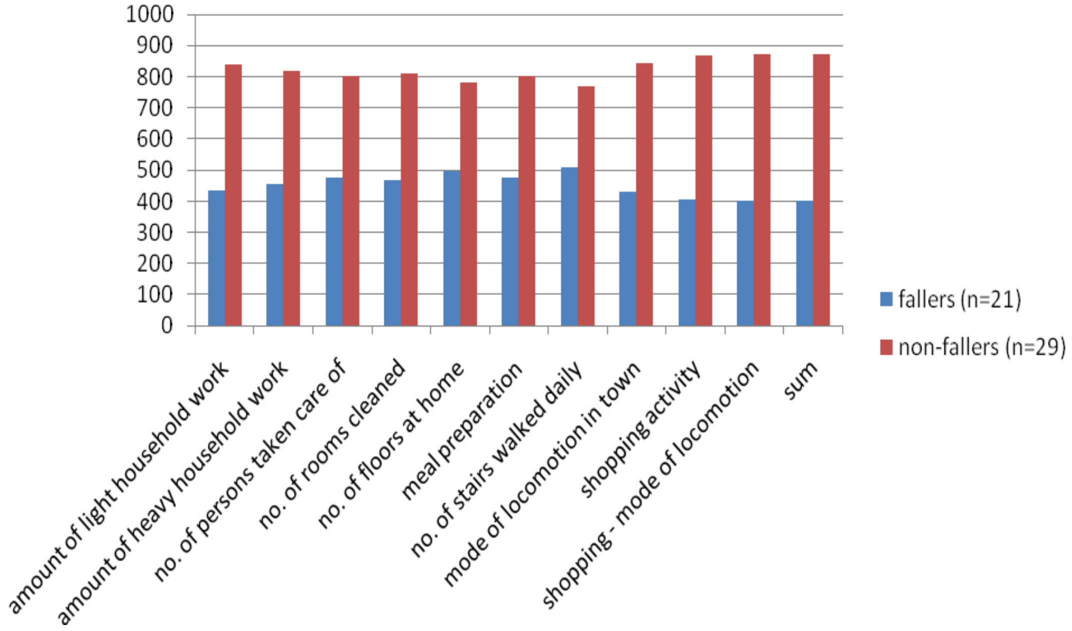

Figure 1- Rank sums for ten different daily activities and the sum score for fallers (n=21, blue) and non-fallers (n=29, red) in the one-year follow-up study

activity differences. It might be noted that shopping is regarded as one important social activity for elderly persons, so that these limitations may have severe consequences for social participation and integration.

From a technical perspective, the sensor-based assessment of shopping activity is possible if a mobile sensor system is used. In a previous study with five elderly persons wearing a multi-sensor system, the authors were able to identify shopping activity with an accuracy of 79.9% [16]. In another study it has been shown that activities such as driving a car (90.4%), riding a train (86.4%) and riding in a car (64.0%) can also be identified with a moderate to good correctness, if a classification is trained on individual sensor-based movement data [17]. Thus, it can be concluded that the two most important daily activities that were identified by our study setup can be assessed automatically and therefore can be used to enhance fall prediction models.

Apart from shopping activity, group differences have also been shown for the amount of light household work. This indicates that these activities. however 'light' they are, tend to be more difficult for persons with a high fall risk. This, again, may be interpreted as a consequence of the progressive loss of functional motor ability on the one hand [18], and of the post-fall syndrome on the other hand [5]. The activities explicitly mentioned in the validated questionnaire are washing the dishes, sewing and dusting. It might be argued that these require heterogeneous motor and cognitive skills that cannot be distinguished by just one question. Nevertheless, this item seems to be a further indicator for an increased individual fall risk.

It may be argued why the authors have not chosen to use established scores such as the *Katz Index of Independence in Activities of Daily Living* (ADL) [19], the *Barthel Index* [20] or the *Instrumental Activities of Daily Living* (iADL) [21]. These are clinical scores that help to assess functional limitations, and they are scored by external reviewers. The crucial factor, however, is that they do not allow to quantify physical activity and therefore were deemed inappropriate for our purpose.

Limitations

First of all, the sample is not very large (n=50). Only 42% of the persons contacted agreed to participate in our follow-up study. Apart from declining due to personal reasons that were not specified any further, several persons had moved to unknown locations and quite a few had died already. This sample therefore should not be regarded as being representative.

Secondly, the authors have chosen a descriptive analysis instead of a confirmatory analysis of the data in order to avoid the problem of multiple testing. The authors believe that this kind of analysis using the rank sums is rather appropriate for the task at hand.

Finally, it may be argued that the set of activities that is assessed by the questionnaire only provides a rough approximation of daily activities, and that it lacks the granularity necessary for an all-encompassing activity assessment. The authors agree with that, but – as stated above – are not aware of another, more detailed questionnaire that has been validated for use with elderly people.

Conclusion

This is the first study that has assessed the relationship between the amount of different daily activities of elderly people in their home environment and their fall risk with regard to the potential of sensor-based activity measurement. A low amount of or no shopping activity, a passive way of individual locomotion when going shopping and the inability to perform even light housework could be identified as indicators of a high fall risk in our follow-up study. Our future work will be directed towards the sensor-based, long-term assessment of these activities to provide a further, valid source of information to be integrated in automated fall prediction models.

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