collection for the Hip fracture group was performed by interview, whereas for the others it was based on filling in a questionnaire. However, an earlier study found no differences between these two ways of responding [10].

We conclude that the Norwegian 16-item FES-I has good psychometric properties and that the seven-item version has very similar properties in fall-prone older persons. Data on sensitivity to change are needed in order to determine which version of the FES-I is best suited to measure change following interventions. Compared with previous studies, our results indicate that level of falls efficacy may depend on culture, and this aspect should be highlighted in further studies.

Key points

- The psychometric properties of the Fall Efficacy Scale-International (FES-I) in samples of fall-prone older persons are good.
- The seven-item FES-I has the same psychometric properties and discriminatory power as the original 16-item FES-I.
- Despite lower function, the Norwegian sample scored lower at fear of falling than what is reported in previous studies.

References


Detection of gait and postures using a miniaturised triaxial accelerometer-based system: Accuracy in community-dwelling older adults

SIR—Ageing is associated with a decrease in physical functioning and mobility [1, 2]. The performance of basic activities of daily living can become progressively difficult [2, 3]. Furthermore, the prevalence of illness increases with advancing age, which may also cause functional limitations. Maintaining physical activity in later life is related to a slower rate of motor decline, less disability and a lower incidence of specific chronic diseases [4–7]. Therefore, accurate knowledge of daily physical activity patterns is essential for assessment and intervention purposes.
Activity monitors based on body-fixed accelerometers and gyroscopes are available for continuous measurements of mobility-related activities [8], but few studies demonstrate evidence-based clinical applications in older people [9]. Often, systems consist of multiple sensors attached to different body parts [10–18]. More sensors provide more information, but minimal instrumentation is preferable for unobtrusive and long-term monitoring in real life.

Recently, the DynaPort MoveMonitor was introduced (McRoberts BV, The Hague, The Netherlands), a method to monitor physical activity with a high time resolution using a single and small wireless triaxial accelerometer, the MiniMod. The aim of the present study was to determine the accuracy of the DynaPort system for detecting gait (walking, shuffling) and postures (lying, sitting, standing) in community-dwelling older adults during activity sequences in a standardised setting (Study 1) as well as in a home environment (Study 2). The results were compared to video observation of the actual performance.

**Methods**

Twenty older adults (mean age = 68.5 years, SD = 7.4) participated in Study 1. First, a fixed activity sequence including walking trajectories (1.4, 2.3, 4.5 m, taking a three-step stair) and postures (sitting, standing, lying) were performed five times in a laboratory set-up. Thereafter, subjects were allowed to move freely for 3 min with the only instruction that taking the stairs, sitting and lying had to be completed at least once. For Study 2, five older adults were monitored 30 min in their home environment while doing similar activities as in Study 1 and usual domestic activities. During all measurements, subjects were video-recorded while wearing the MiniMod (84 × 50 × 8 mm; 44.5 g) at their lower back.

In the video analysis, the start and end of each activity was scored by an observer. Inter-rater reliability of this procedure was determined for the fixed sequence task by two independent raters in 10 subjects. Intraclass correlation coefficients (ICC) for the duration of walking, sitting, standing and lying were respectively 0.95, 0.78, 0.99 and 0.98. The category shuffling was added to the video analysis of the home data because more situations were expected where subjects would not walk, but also would not completely stand still. Results of blinded analysis of the acceleration data were compared to the video observation scores (‘criterion measure’) with a time resolution of 0.1 s. The percentage correspondence and non-correspondence between the two methods have been calculated for all activity data (i.e. over all subjects). Subsequently, sensitivity, specificity, positive predictive value and agreement were calculated per subject. Appendix 1 (see Supplementary data available in Age and Ageing online) provides a detailed description of the methods.

**Table 1.** Overall correspondence (bold) and non-correspondence (plain) between the video observation (rows) and DynaPort (columns) per activity category

<table>
<thead>
<tr>
<th>DynaPort</th>
<th>Lying</th>
<th>Sitting</th>
<th>Standing</th>
<th>Locomotion</th>
<th>Shuffling</th>
</tr>
</thead>
<tbody>
<tr>
<td>Video</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Laboratory</td>
<td>Fixed</td>
<td>Home</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fixed</td>
<td>99.8</td>
<td>99.7</td>
<td>98.9</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Free</td>
<td>0.1</td>
<td>0.3</td>
<td>1.1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Home</td>
<td>0.1</td>
<td>0</td>
<td>0</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Laboratory</td>
<td>Fixed</td>
<td>Home</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fixed</td>
<td>18.9</td>
<td>23.4</td>
<td>17.7</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Free</td>
<td>0</td>
<td>5.2</td>
<td>0.7</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Home</td>
<td>0</td>
<td>5.2</td>
<td>0.7</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Laboratory</td>
<td>Fixed</td>
<td>Home</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fixed</td>
<td>71.5</td>
<td>61.0</td>
<td>81.1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Free</td>
<td>17.0</td>
<td>31.7</td>
<td>7.6</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Home</td>
<td>9.3</td>
<td>5.8</td>
<td>1.2</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Table 2.** Mean sensitivity, specificity and positive predictive values (%)

<table>
<thead>
<tr>
<th>Category</th>
<th>Sensitivity</th>
<th>Specificity</th>
<th>Predictive value</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Laboratory</td>
<td>Home</td>
<td>Laboratory</td>
</tr>
<tr>
<td></td>
<td>Fixed</td>
<td>Free</td>
<td>Fixed</td>
</tr>
<tr>
<td>Lying</td>
<td>99.8</td>
<td>99.7</td>
<td>98.9</td>
</tr>
<tr>
<td></td>
<td>77.7</td>
<td>86.9</td>
<td>77.6</td>
</tr>
<tr>
<td></td>
<td>90.3</td>
<td>96.0</td>
<td>64.6</td>
</tr>
<tr>
<td>Sitting</td>
<td>65.6</td>
<td>63.3</td>
<td>83.2</td>
</tr>
<tr>
<td></td>
<td>82.9</td>
<td>91.2</td>
<td>78.7</td>
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<tr>
<td></td>
<td>98.7</td>
<td>97.6</td>
<td>76.8</td>
</tr>
<tr>
<td>Standing</td>
<td>70.8</td>
<td>49.4</td>
<td>80.1</td>
</tr>
<tr>
<td></td>
<td>87.8</td>
<td>90.3</td>
<td>77.7</td>
</tr>
<tr>
<td></td>
<td>90.3</td>
<td>43.8</td>
<td>80.2</td>
</tr>
<tr>
<td>Walking</td>
<td>86.9</td>
<td>91.9</td>
<td>93.5</td>
</tr>
<tr>
<td></td>
<td>77.8</td>
<td>81.5</td>
<td>71.8</td>
</tr>
<tr>
<td></td>
<td>96.1</td>
<td>80.7</td>
<td></td>
</tr>
<tr>
<td>Shuffling</td>
<td>–</td>
<td>4.7</td>
<td>–</td>
</tr>
<tr>
<td></td>
<td>–</td>
<td>–</td>
<td>47</td>
</tr>
<tr>
<td></td>
<td>–</td>
<td>–</td>
<td>85.5</td>
</tr>
</tbody>
</table>

Values are expressed in percentages.

Based on the video analysis, a total of 3,368 activities with a total duration of 312.3 min were assessed. Mean activity durations were shorter in the laboratory (fixed and free) than in the home environment, i.e. for lying (12.4 and 11.9 vs 24.2 s), sitting (2.3 and 4.1 vs 29.9 s), standing (3.0 and 2.7 vs 11.5 s) and walking (3.6 and 6.5 vs 7.8 s). Mean duration of shuffling (4.7 vs 6.1 s) was determined for the fixed sequence task by two independent raters in 10 subjects. Intraclass correlation coefficients (ICC) for the duration of walking, sitting, standing and lying were respectively 0.95, 0.78, 0.99 and 0.98. The category shuffling was added to the video analysis of the home data because more situations were expected where subjects would not walk, but also would not completely stand still.

Results of blinded analysis of the acceleration data were compared to the video observation scores (‘criterion measure’) with a time resolution of 0.1 s. The percentage correspondence and non-correspondence between the two methods have been calculated for all activity data (i.e. over all subjects). Subsequently, sensitivity, specificity, positive predictive value and agreement were calculated per subject. Appendix 1 (see Supplementary data available in Age and Ageing online) provides a detailed description of the methods.

**Results**

Table 1 presents the percentages of overall correspondence and non-correspondence between the output of the DynaPort MoveMonitor and the video analysis. Mean sensitivity, specificity and positive predictive values are given in Table 2. In Study 1, agreement per subject ranged between 68.3 and 85.9% (mean = 79.8%, SD = 6.9).
Appendix 2 (see Supplementary data available in Age and Ageing online) provides additional information on the results.

Discussion

The DynaPort MoveMonitor detected lying almost faultlessly in all circumstances. A high overall correspondence was found for walking too, particularly when subjects walked longer trajectories. A lower sensitivity (86.6%) was reached for the fixed protocol, in which 1.4-m walks were often classified as shuffling. Also, taking the three-step stair was several times classified as shuffling when subjects stepped slowly or paused at the stair. Whether this should have been considered as walking is debatable. However, at home, shuffling was not accurately detected and difficult to evaluate by video observation as well. For example, when sweeping, a subject repeatedly alternated standing and making a few steps. In these and similar situations, shuffling cannot always be clearly discriminated from standing or walking.

Moderate results were found for monitoring sitting and standing. In the laboratory, the mean duration of these postures was 2–4 s. Such short-lasting activities are difficult to detect. Quite a lot of sitting periods, predominantly on the edge of the bed, were not detected. This explains the misclassification of sitting as standing or lying, which were the preceding or following activities. Also, the ICC for sitting was lower than for other activity categories due to inter-observer differences in sitting periods on the edge of the bed. Hence, short durations and observation disagreements may have influenced the correspondence figures. However, missing short sitting periods, e.g. as part of getting out of bed, will have a minor effect on overall performance during measurements of days or weeks. Short standing periods were detected well, but frequent small differences with the video observation led to a lower overall correspondence. The mean sensitivity for sitting and standing improved to ~80% in the home environment, where the mean duration was up to four times longer. Higher sensitivities have been reported but were most often reached by using more than one sensor [12, 13, 15–22]. Furthermore, to our knowledge, validations of other methods did not include activities <5 s and also apply a 0.1 s time resolution.

Our study of detecting gait and postures was based on a precise analysis of a large number of fairly short activities. Thus, this evaluation was quite challenging and unforgiving, above all during the fixed sequence task. The latter is illustrated by the fact that in conditions where participants could perform subsequent activities in a slower pace (i.e. in the free sequence and at home), detection was generally better. Except for shuffling, the DynaPort MoveMonitor reached a mean sensitivity of ≥80% in the home environment. Results may further improve during prolonged monitoring when older adults are expected to have longer periods of sedentary activity.

It is concluded that the DynaPort MoveMonitor is a practical and valuable tool for objective, continuous assessment of walking and postures. In the present study, the time spent walking and lying was accurately detected. Monitoring of short periods of sitting and standing requires further fine-tuning. Since outcomes may be influenced by the specific evaluation procedures, it is suggested that some standardisation is desirable to better compare future validations of activity monitoring methods.

Key points

- Objective methods are needed for accurate assessment of daily physical activity patterns.
- Activity monitors based on a single sensor provide practical solutions for long-term unobtrusive monitoring of mobility-related activities in real life.
- The DynaPort MoveMonitor is a practical and valuable method for objectively evaluating gait and postures.

Acknowledgements

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Conflicts of interest statement

There are no conflicts of interest.

Supplementary data

Supplementary data mentioned in the text is available to subscribers in Age and Ageing online.

BAUKJE DIJKSTRA*, YVO KAMMSA, WIEBREN ZIJLSTRA
University Medical Center Groningen,
Center for Human Movement Sciences, University of Groningen,
A. Deusinglaan 1, PO Box 196, 9700 AD Groningen,
The Netherlands
Tel.: (+31) 50 363 2719; Fax: (+31) 50 363 3150;
Email: baukdijkstra@hotmail.com

*To whom correspondence should be addressed

References

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Age is no barrier to success at very high altitudes

SIR—As medical care improves and life expectancy continues to rise in most developed countries, older people are able to enjoy high-altitude adventures later in life [1]. All visitors to high altitude (>2,500 m) are at risk of illness, notably Acute Mountain Sickness (AMS), which is usually a self-limiting illness presenting between 6 and 12 h of arrival at altitude. Common features include headache, fatigue and weakness, nausea and vomiting and poor sleep [2]. Despite the increased prevalence of pre-existing medical conditions with age, the risk of AMS has been found to be lower in older people [3, 4]. More serious sequelae include high-altitude cerebral oedema and high-altitude pulmonary oedema that can be fatal if not recognised and treated promptly. There is an abundance of literature on AMS and altitude-related pathology [5–7]. However, there is little work specifically on Mt Kilimanjaro with its unique ascent profile [8].

Older people are no more susceptible to AMS than their younger counterparts [9], and increasing age is associated with less severe symptoms of AMS [1]. However, rapid ascent and extreme exertion will have a more marked physical effect due to age-related declines in maximum oxygen uptake [10], in VO₂ max [11] and in skeletal muscle mass [12]. The reduction in exercise capacity at altitude is predictable based on sea-level performance. Moderate altitude exposure is unsurprisingly associated with hypoxemia and sympathetic activation, although the overall physiological response to hypobaric hypoxia is comparable between younger and older people [13]. Surprisingly, however, there remains a paucity of information about this significant group of high-altitude adventurers. Our data about older people contributes to a necessary and important evidence base, particularly at altitudes over 5,000 m.

We studied the physiological characteristics and the incidence of AMS in tourist trekkers attempting the summit (Uhuru Peak) of Mount Kilimanjaro (5,895 m). The trekkers were recruited at Mandara hut (2,720 m), the first hut on the popular Marangu route. Physiological measurements and Lake Louise Scores (LLS) for AMS were taken at the end of the day's trekking over the 4- or 5-day ascent. Arterial