# Sensitivity and specificity of fall detection

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## Introduction

Elderly people desire to live at home, and thus, new technologies, such as automated fall detectors, are needed to support their independence and security. This study is part of the SensorBand-project. The aim was to evaluate different low-complexity fall detection algorithms using triaxial accelerometers attached at the waist.

## Methods

Triaxial acceleration data were collected using a device attached at the waist (Fig. 1A) from 20 voluntary middle-aged subjects (40–65 years old, performed falls and activities of daily living, ADL) and 21 voluntary older people (58–98 years old, performed ADL). Six different intentional falls (Fig. 1B, Table 1) were performed. Each subject performed a sequential ADL protocol including sitting down on a chair, picking up an object from the floor, lying down on a bed and getting up, and walking (Fig. 1C). Acceleration data were collected into a portable computer and fall detection simulation was done in a virtual environment (LabVIEW).

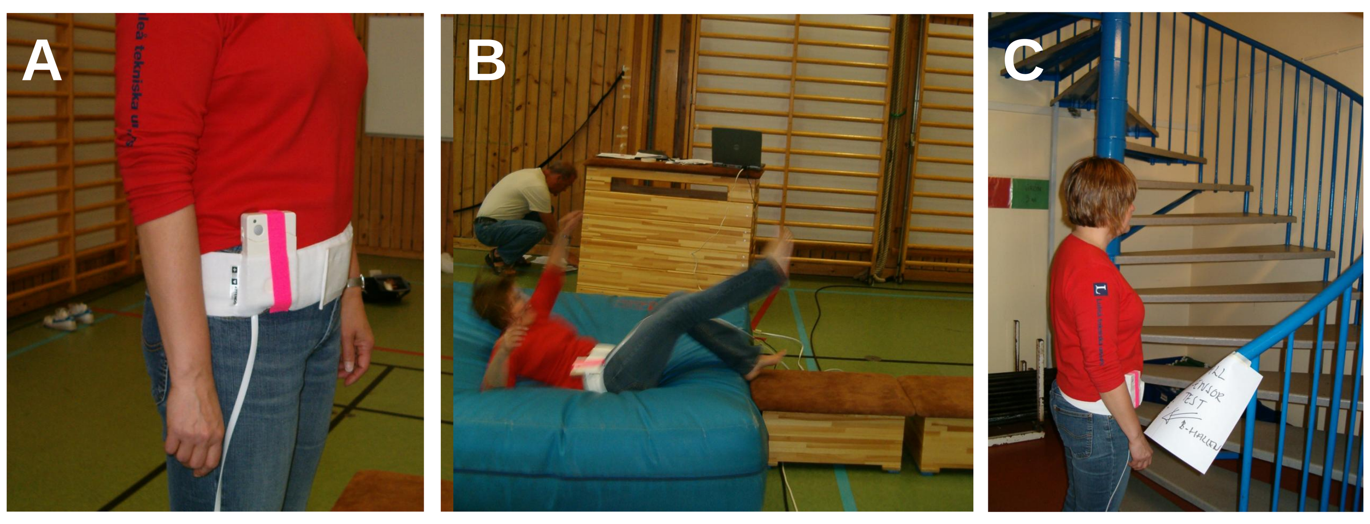


**Figure 1**. Acceleration signal collected from the waist (A) during intentional falls in laboratory environment (B) and ADL (C).

Parameters and algorithms for fall detection were similar to those in our previous studies[1,2]. Briefly, Algorithm 1 is based on detecting impact followed by horizontal posture (impact + posture). Algorithm 2 requires also the detection of free fall phase (start of fall + impact + posture, Fig. 2) and algorithm 3 requires in addition a high velocity towards the ground before impact (start of fall + impact + velocity + posture). Impact detection was tested with different accelerometry-derived parameters, such as 3D sum vector (SV) and calculated vertical acceleration (Z). End posture was monitored from low-pass filtered vertical acceleration.

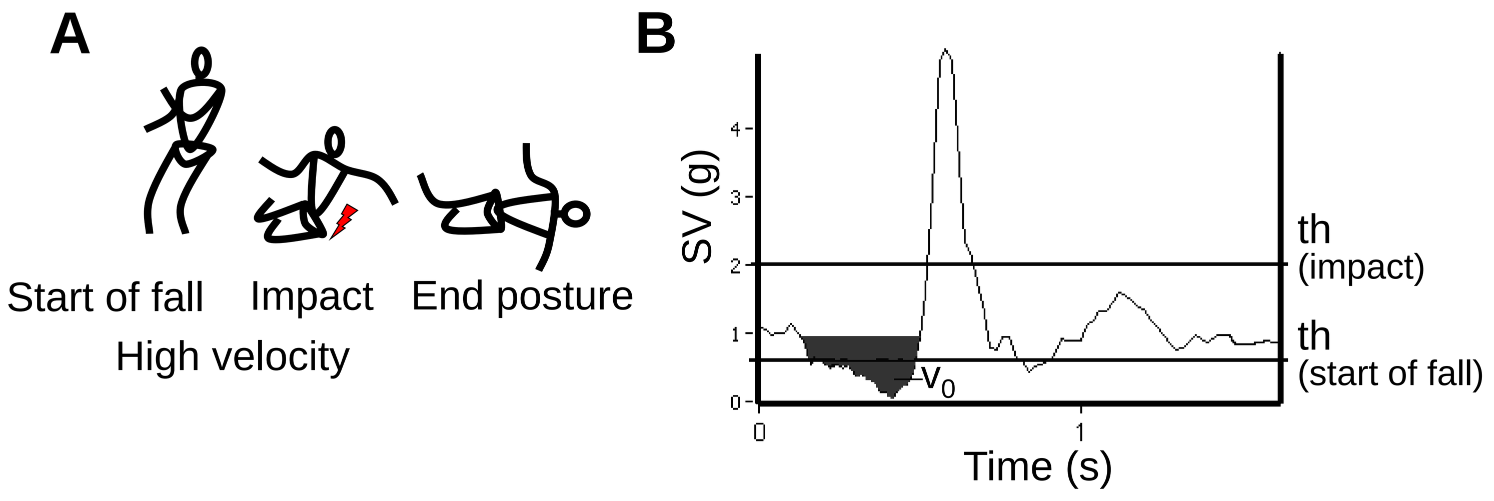


**Figure 2.** Fall phases (A) were detected from acceleration signal (B). The start of a fall is detected from 3D sum vector SV (threshold, th=0.6g), velocity $v_0$ (th=0.7 $ms^{-1}$) was integrated, and impact was detected from different parameters based on predetermined thresholds.

## Results

The best fall detection sensitivity was achieved with algorithm 1 using sum vector SV, detecting 97.5% of the test falls (Table 1). All forward falls, lateral falls, and falls from a bed were detected, while some backward falls remained undetected, mostly because of end posture was not detected as horizontal. The criterion of start of the fall phase was fulfilled in 95% of the test falls. The biggest difference in fall detection sensitivity between algorithms 1 and 2 was found in falls from a bed. The most complex fall detection method, algorithm 3, detected from 77% to 78% of falls. In 80% of all test falls, velocity toward the ground exceeded the predetermined threshold. Algorithm 3 was not able to detect falls from a bed.

**Table 1.** Sensitivity (%) and specificity (%) of fall detection algorithms

| | | *Algorithm 1* | | *Algorithm 2* | | *Algorithm 3* | |
|---|---|---|---|---|---|---|---|
| | n | SV | Z | SV | Z | SV | Z |
| F, syncope | 40 | 100.0 | 100.0 | 100.0 | 100.0 | 85.0 | 85.0 |
| F, trip | 40 | 100.0 | 100.0 | 100.0 | 100.0 | 95.0 | 95.0 |
| B, sit | 40 | 95.0 | 90.0 | 92.5 | 87.5 | 82.5 | 80.0 |
| B, straight | 40 | 90.0 | 90.0 | 90.0 | 90.0 | 90.0 | 90.0 |
| L | 40 | 100.0 | 97.5 | 100.0 | 97.5 | 100.0 | 97.5 |
| From Bed | 40 | 100.0 | 95.0 | 72.5 | 67.5 | 17.5 | 15.0 |
| Total falls | 240 | 97.5 | 95.4 | 92.5 | 90.4 | 78.3 | 77.1 |
| ADL | 164 | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 |

F = forward, B = backward, L = lateral

Specificity, as determined from ADL samples, was 100% for all algorithms, indicating no false fall alarms. The results of this study have been published[3].

## Conclusions

To conclude, the fall detection concept tested here provides an effective method for automatic fall detection. The method can discriminate various types of falls from activities of daily living, with a sensitivity of 97.5% and a specificity of 100%. This concept has been implemented into wireless fall detector prototype and is currently being validated in long-term (6-9 months) test in real-life environment (residential home) with reasonable number of end-users (older adults) in Finland and in Sweden. During this study also the effect of using automatic fall detection system on care work is studied.

## References

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3. Kangas M., Vikman I. Wiklander J., Lindgren P., Nyberg L., and Jämsä, T. (2009) Sensitivity and specificity of fall detection in people aged 40 years and over. Gait Posture 29: 571-574.