# Indoors Wi-Fi fall Detector Buckle for the Elderly

**Maykon Christian Meneghel[1]*, Percy Nohama[1, 2], Guilherme Nunes Nogueira Neto[1, 2]**

[1]*Graduate Program on Health Technology, Pontifical Catholic University of Paraná, Curitiba, 80215-901, Brazil*
[2]*Rehabilitation Engineering Laboratory, Pontifical Catholic University of Paraná, Curitiba, 80215-901, Brazil*

*Corresponding author: E-mail: maykon.meneghel@pucpr.edu.br

DOI: 10.5185/amp.2019.1450
www.vbripress.com/amp

## Abstract

Accidental falls may occur in the elderly, especially older than 65 years. Among the intrinsic factors that corroborate this fatality are the physiological changes resulting from the aging process. Factors such as inadequate lighting, uneven ground, or some obstacles along the way also contribute to falls. The literature indicates most falls occur in the domestic environment. In some cases, falls can cause serious injuries, such as bone fractures and head injuries. In these cases, intervention time to treat a person who has fallen is crucial. In this study, we developed a Wi-Fi fall detector buckle to be used indoors at waist height by the elderly. For testing purposes, we assumed a simple detection threshold that identifies a fall whenever the absolute value recorded by the accelerometer is greater than 2.3 g and the angle formed between the y-axis and the vertical sagittal axis of the buckle device is greater than 60°. The device is functional, adjustable, flexible and inexpensive. It is functional because it can differentiate falls from ADL with 84.1% accuracy, adjustable because it allows to change the fall detection threshold, flexible for including new detection algorithms and cheap because it uses components available in abundance in the market. Copyright © VBRI Press.

**Keywords:** Fall detector, Wi-Fi, elderly.

## Introduction

Falls suffered by the elderly people represent a serious public health problem. And they tend to be more often in people over 65 years old [**1-3**]. That is because the aging process results in physiological changes in the neurological, visual, cardiovascular and musculoskeletal systems [**4**]. In addition to aging, specific diseases and the use of medications also contribute to the occurrence of falls among the elderly [**5**].

Medicine has evolved to slow the aging process by making older people less susceptible to falls [**6**]. Treatment with vitamin D and calcium supplementation [**7**] and trainings with balance and strength exercises [**8**] have been proven to be effective in reducing the amount of falls in the elderly population.

In addition to the intrinsic factors aforementioned, some extrinsic factors such as inadequate lighting, a folded rug, an uneven ground or an obstacle on the path, corroborate to the occurrence of falls [**9**]. Furthermore, most falls occur in indoor environments [**10**].

When a fall event occurs, the elderly person may have difficulties to get back in one's feet and may remain immobile at the fall location for a long period until the rescuer arrives. In such cases, if the elderly person had a head fracture or a vital organ perforated during the fall, the delay in medical assistance can be deadly [**11**].

In order to circumvent this problem, rehabilitation engineering has invested in sensors and fall detection algorithms to warn whenever a fall event is identified [**12-21**]. Detection algorithms range from complex algorithms [**12**, **13**, **20**] to simple threshold detection algorithms [**14-19**, **21**].

Detection systems are categorized into two main types [**18**]: context sensitive sensors and portable devices. Context sensitive sensors use vision-based methods [**12**], infrared sensor arrays attached to the wall [**13**] and even ultrasonic sensors placed on the ceiling and on the wall of a room [**14**]. Portable devices usually use accelerometer sensors attached to the body [**15-21**]. All systems have shown satisfactory results in detecting falls in the elderly.

However, most context sensitive sensors are difficult to manipulate, requiring more than one device to be installed [**14**] and work only at previously installed places [**12**]. Most of the time, the portable devices are incorporated in wearable systems [**22**]. Wearable systems, although requiring constant use by the elderly, they have a greater acceptance, provided they are discrete [**23**].

Smart Wearable Systems (SWS) enable to connect point-to-point sensors and actuators in real time to be used in a non-invasive mode, combining a real life environment with the subject physical and cognitive abilities for those who wear them, providing continuous health, mobility and mental state monitoring [**24**].

For this paper, we designed and developed a wireless fall detector, using the Wi-Fi communication protocol (802.11b / g / n), which was later embedded in a belt buckle. The belt is a common accessory and it is present in the daily life of an elderly person. The fall detector buckle is a SWS that monitors the gravitational acceleration components, at the waist height, in real time, with a sampling frequency of 1 kHz and also interacts with a remote database whenever a fall is identified.

### *Background*

Most of the falls occur indoors, being more frequent in bathrooms, bedrooms and kitchens [**10**]. The main factors that justify these occurrences are: inadequate lighting, carpets, low chairs, soft chairs, uneven surfaces, raised floors, slippery surfaces and electric cables on the way [**25**].

In addition to injuries, a fall can lead to medical consequences such as psychological difficulties and social isolation [**4**]. The fall worsens the loss of confidence, causing the elderly to reduce the activities of daily living (ADL), resulting on the reduction of life quality [**26**-**28**]. The fear of repeated falls may lead the elderly subject to a progressive restriction of mobility and lifestyle [**29**].

Fall detection devices help the elderly to become more confident in performing the ADL, in addition, the SWS create intelligent environments that contribute to a remote health care [**24**].

## Materials

In order to build a fall detection device to be used in indoor environments, we chose the ESP-8266 microcontroller with integrated Wi-Fi communication from Espressif Systems and an MPU-6050 accelerometer sensor from IvenSense to make the acceleration reading.

For prototyping purposes, we used the GY-521 module, manufactured by Shenzhen Yilingtai Technology, containing an MPU-6050 accelerometer with a gyroscope and a built-in temperature sensor. Both devices are low-cost and can be easily found in the market.

We use a threshold detection algorithm [**18**, **19**], which determines a fall event whenever the absolute value of the gravitational acceleration modulus is greater than or equal to 2.3 and the Euler angle formed between the y-axis and the vertical sagittal axis is greater than or equal to 60°.

We performed 28 fall events [**15**] to verify the percentage of true positives (when the sensor identifies a fall) and 35 other ADL to verify the percentage of true negatives (when there was no fall and the sensor did not identify it). The true percentage demonstrates how much the sensor get it correctly when it is supposed to get it truth, analyzed separately in two groups of activities: falls and ADL.

To ensure that the device can be more widely accepted by the elderly, we embedded the fall detector into a belt buckle. The Wi-Fi fall detection buckle monitors the gravitational acceleration and when a fall is identified, the device forwards a message to a database allocated on a remote server.

### *Communication architecture*

**Fig. 1** illustrates the communication architecture of the developed project. The microcontroller (MCU) reads the accelerometer and gyroscope sensors through the $I^2C$ bus every 1 ms. Embedded in the MCU is the simple threshold fall detection algorithm [**18**, **19**], whenever a fall is identified the device forwards an alarm message to the database, structured in SQL.

There is an alarm table, in the SQL database, for each individual registered, the alert messages are sent for this table whenever a falling event is identified. The database can be accessed remotely by the device through port number 443, using security credentials (user, password and IP device) and token authentication.

Hence, only the devices previously allowed for remote access from the server can communicate with the database, making communication secure and free of any data interceptions.

In order to achieve communication between the fall detector and the database, both must be connected to the internet.

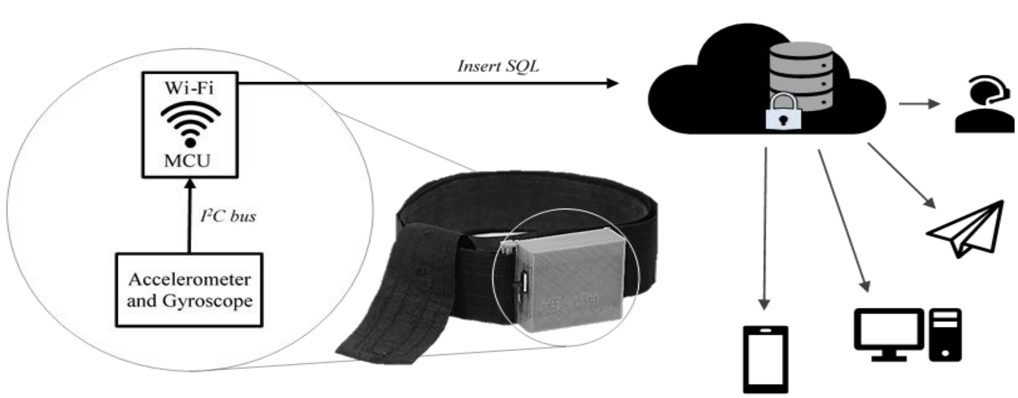


**Fig. 1.** Communication architecture of the WiFi fall detector buckle. The device has an embedded firmware that reads the accelerometer and gyroscope sensors and when a fall is detected an alert is sent (by SQL commands) to a database allocated on a remote server.

### *Device hardware*

The electronic circuit of the developed device has (1) a power supply, responsible for regulating the voltage to be supplied to the MCU, (2) the MCU circuit and (3) an MPU-6050 accelerometer sensor, already integrated in the GY-521 module, as previously mentioned.

The working voltage of the entire circuit is 3.3 V, which drains roughly 92 mA. The circuit is powered by a rechargeable Lithium-ion BL-5C battery, manufactured by NOKIA, with a capacity of 1020 mAh at a voltage of 3.7V. In this way, the instrument can keep working for about 11 h. However, in order to avoid battery variation with each discharge, we have included a Lithium battery charger module with a TP-4056 integrated circuit (NanJing Top Power ASIC), to recharge the battery through a micro USB port. With this, the system's battery may be recharged during sleep and used indoors during the whole day.

With this electronic circuit is possible to write a new firmware into the MCU's memory through the serial ports, without any further hardware changes.

A sliding switch was inserted to connect the battery on the voltage regulator input to turn the device on and off.

### *Device firmware*

When the device is initialized, the setup phase occurs first. In this phase, the MCU configures the $I^2C$ bus, establishing a communication with the MPU-6050 sensor, then establishes Wi-Fi communication with a known internet network and, at last, communicates with the database in SQL, which is available remotely on a web server.

After the setup phase, the MCU enters in an infinite loop such as illustrated in **Fig. 2**. At each time instant, the MCU performs the reading of the acceleration and gyro registers on the MPU-6050 by the $I^2C$ bus and performs the calculation to identify the occurrence of fall, based on the threshold detection algorithm.

If the absolute value of the gravity acceleration magnitude is greater than or equal to 2.3 g and the Euler angle formed between the y-axis and the vertical sagittal axis is greater than 60°, a fall message is sent through SQL commands to the database and then the system returns to the acceleration and gyro data reading.

The orientation of the fall detector, based on the MPU-6050 coordinates, is shown in **Fig. 3**. The Euler angle formed between the y-axis and the vertical sagittal axis is nothing more than the rotation around the x-axis. Clinically, it represents hip extension and flexion movements.

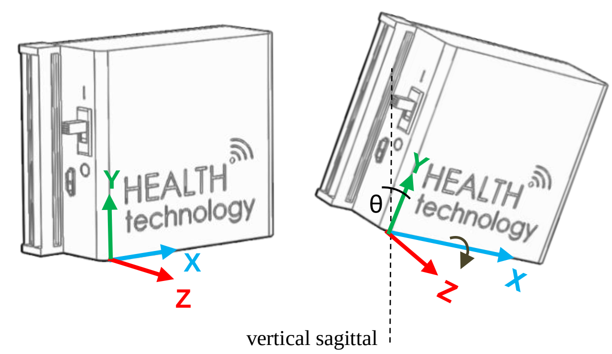


**Fig. 3.** Axial orientation of the buckle device.

## Experiments and Validation

### *Subject*

The experiments were carried out by one of the authors (28 years old, 85 kg, waist height 100 cm). All the tasks performed in the experiments had real impacts in real scenarios, even though the falls were cushioned by a 135 mm thick foam mattress.

### *Methods*

To carry out the experiments, 35 ADL performed indoors and 28 different possible ways in which the elderly may fall, also indoors [**15**], were first defined.

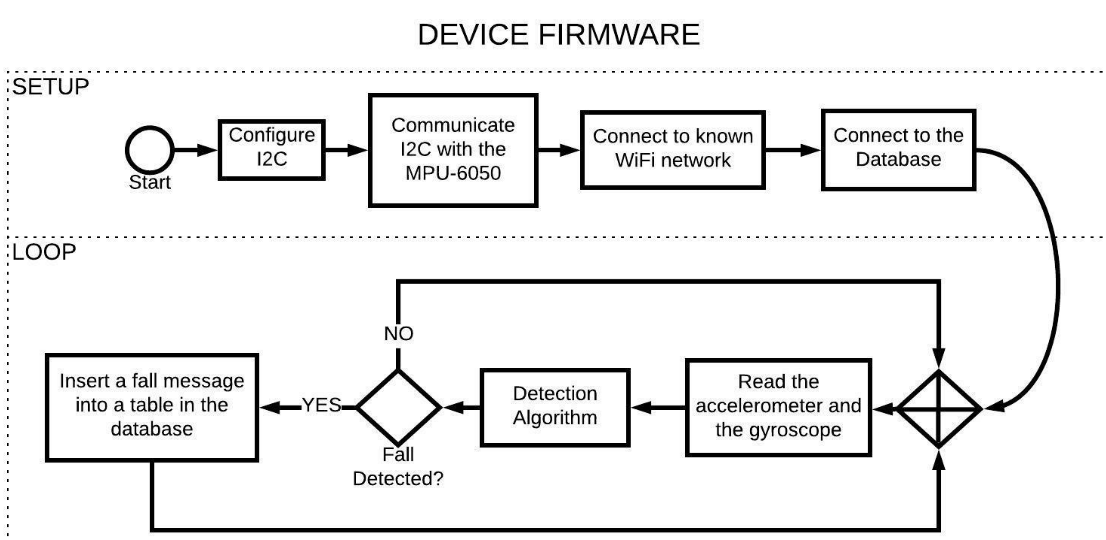


**Fig. 2.** Buckle device flowchart.

A total of 63 simulations were performed, in four different rooms of an apartment (bathroom, bedroom, living room and kitchen) taking note of the beginning and end time of each activity in a synchronized clock with the time from the remote database. In this way, each simulation could be easily identified by the time on the fall records table.

### *Data analysis*

**Table 1** was used to quantify the buckle device precision, which classifies an event, based on whether the fall occurred (or not), regarding the buckle device (not) detection. A true negative (TN) refers to a non-detection when there was no fall. On the other hand, a false positive (FP) occurs when the device detects a fall that actually did not happen. A false negative (FN) happens when the device does not detect an evident fall and a true positive (TP) is when the system manages to detect a fall, when it happened effectively.

**Table 1.** Classification of events by detection.

| | | **EVENTS** | |
|---|---|---|---|
| | | **ADL** | **FALL** |
| **BUCKLE DEVICE** | **Not detected** | True Negative | False Negative |
| | **Detected** | False Positive | True Positive |

The buckle device sensitivity, specificity and accuracy are defined by the equations 1, 2 and 3 respectively [**15**, **30**].

$$Sensitivity = \frac{TP}{TP+FN} \quad (1)$$

$$Specificity = \frac{TN}{TN+FP} \quad (2)$$

$$Accuracy = \frac{TP+TN}{TP+FP+TN+FN} \quad (3)$$

What determines the sensitivity of the Wi-Fi fall detector buckle device in identifying falls is the percentage of TP. And the percentage of TN determines the specificity for not detecting a fall during the ADL. In this way, we can verify the accuracy of the buckle sensor in distinguishing accidental falls from ADL.

## Results and discussions

As a result, it is shown in **Fig. 4** the buckle device as it was designed **(Fig. 4a)** and after manufacturing **(Fig. 4b)**.

The fall detection logs can be found in **Table 2**. In the first column, it shows time and date of fall occurrence. In the second column appears the identification of the fall detection device. Finally, in the third column is presented the identified fall warning message.

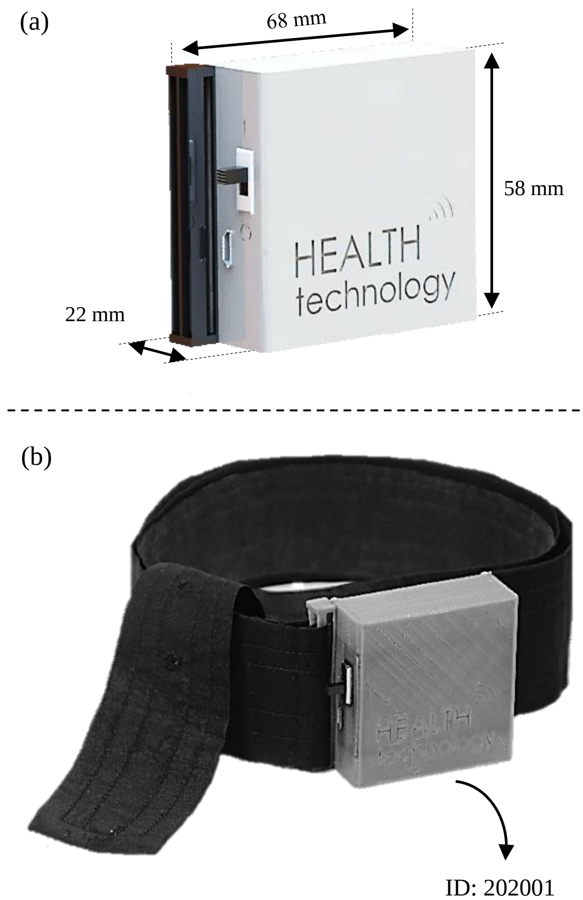


**Fig. 4.** WiFi fall detector buckle device shown in a 3D design **(a)** and after manufacturing it **(b)**. The only two interaction interfaces with the elderly are a sliding button to turn on and off and a micro USB input to power the battery.

From the Wi-Fi fall detector buckle device reliability results (**Fig. 5)**, one can notice that there were 6 FP for the ADL out of a total of 35 activities and 24 TP out of a total of 28 fall activities. Therefore, the buckle device has 85.7% sensitivity, 82.8% specificity and 84.1% accuracy.

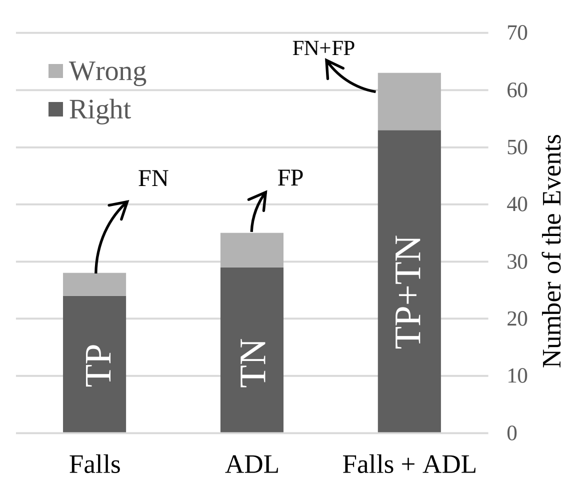


**Fig. 5.** Reliability results of the buckle device.

**Table 2.** Fall detection records on the database.

| Time Stamp | Device ID | Message | Mapped Events |
|---|---|---|---|
| 2018-08-08 13:42:40 | 202001 | Fall Detected! | ADL19 |
| 2018-08-08 13:45:19 | 202001 | Fall Detected! | ADL20 |
| 2018-08-08 13:49:37 | 202001 | Fall Detected! | ADL21 |
| 2018-08-08 18:56:51 | 202001 | Fall Detected! | ADL10 |
| 2018-08-08 18:57:05 | 202001 | Fall Detected! | ADL12 |
| 2018-08-12 19:07:22 | 202001 | Fall Detected! | ADL35 |
| 2018-08-19 16:28:59 | 202001 | Fall Detected! | FALL01 |
| 2018-08-19 16:41:18 | 202001 | Fall Detected! | FALL02 |
| 2018-08-19 16:43:03 | 202001 | Fall Detected! | FALL03 |
| 2018-08-19 16:45:53 | 202001 | Fall Detected! | FALL04 |
| 2018-08-19 16:47:02 | 202001 | Fall Detected! | FALL05 |
| 2018-08-19 16:49:08 | 202001 | Fall Detected! | FALL06 |
| 2018-08-19 16:50:51 | 202001 | Fall Detected! | FALL07 |
| 2018-08-19 16:51:57 | 202001 | Fall Detected! | FALL08 |
| 2018-08-19 16:52:34 | 202001 | Fall Detected! | FALL09 |
| 2018-08-19 16:53:54 | 202001 | Fall Detected! | FALL10 |
| 2018-08-19 16:54:02 | 202001 | Fall Detected! | FALL11 |
| 2018-08-19 16:55:54 | 202001 | Fall Detected! | FALL12 |
| 2018-08-19 16:56:30 | 202001 | Fall Detected! | FALL17 |
| 2018-08-19 16:57:38 | 202001 | Fall Detected! | FALL18 |
| 2018-08-19 17:00:16 | 202001 | Fall Detected! | FALL19 |
| 2018-08-19 17:01:34 | 202001 | Fall Detected! | FALL20 |
| 2018-08-19 17:02:49 | 202001 | Fall Detected! | FALL21 |
| 2018-08-19 18:39:26 | 202001 | Fall Detected! | FALL22 |
| 2018-08-19 18:41:45 | 202001 | Fall Detected! | FALL23 |
| 2018-08-19 18:43:24 | 202001 | Fall Detected! | FALL24 |
| 2018-08-19 18:45:00 | 202001 | Fall Detected! | FALL25 |
| 2018-08-19 18:48:12 | 202001 | Fall Detected! | FALL26 |
| 2018-08-19 18:49:18 | 202001 | Fall Detected! | FALL27 |
| 2018-08-19 18:55:20 | 202001 | Fall Detected! | FALL28 |

We had designed and developed a Wi-Fi fall detector buckle device with 84.1% of accuracy in distinguishing falls from ADL.

With this biomedical instrument, a new longitudinal study may be explored in the future in nursing home residents to evaluate the efficacy of the buckle device in a real scenario.

The Wi-Fi fall detector instrument was designed to be used at waist height, where the detection accuracy appears to be greater [**22**, **31**], but nothing prevents it from being used in another position in the body of an elderly person.

For some activities, the proposed threshold was not suitable, however, the device interface allows new fall detection algorithms to be implemented without any hardware changes, making it flexible to receive artificial intelligence algorithms [**32**], for example.

Initially, we had assumed the same detection threshold as adopted by Lim et al. (2014) [**18**], but it was necessary to adjust the absolute value from 2.5 g to 2.3 g and the angle from 65° to 60° to improve the accuracy of the buckle device. Our results of sensitivity, specificity and accuracy were, on average (12.26 ± 1.05) % lower than appointed by Lim et al. (2014), this may be related to the number of events measured and the number of subjects studied.

Fall detection devices have already been widely discussed in the literature [**12-21**]. The main contribution of this paper is the development of an innovative, efficient, adjustable, flexible, wearable and cheap device. We also demonstrated that by implementing a simple threshold detection algorithm, which evaluates the impact of the fall and hip extension and flexion angles, it was possible to distinguish accidental falls from ADL with an accuracy of 84.1%. The WiFi fall detector buckle monitors the gravitational acceleration and whenever a fall is identified the device forwards an alert message to a database allocated on a remote server. The fall detector buckle is an Internet of Things (IoT) device belonging to smart wearable systems that can provide more confidence and security to the elderly in carrying out the activities of the daily living.

## Conclusion

The fall detection system developed is functional, adjustable, flexible and inexpensive. It is functional because it can differentiate falls from ADL with 84.1% accuracy and it sends a help request (SOS message) whenever the detection threshold is exceeded, adjustable because it allows to change the fall detection threshold, flexible for allowing to include new detection algorithms. And finally, financially feasible, since the total cost of all project components was less than $ 25.

This device can be considered a smart wearable system of easy adhesion by the elderly, able to provide independence in the performance of ADL and, consequently, increasing life quality of those who wear it.

## Acknowledgements

The authors would like to thank Fundação Araucária de Apoio ao Desenvolvimento Científico e Tecnológico do Estado do Paraná (FA) and Conselho Nacional de Desenvolvimento Científico e Tecnológico (CNPq) for scholarships and financial resources.

## Author's contributions

M.C. Meneghel participated of the system's design and implementation, tested and wrote the manuscript draft. P. Nohama participated of the device conception, essays definition, data analysis, manuscript draft and aticle final version. G. N. Nogueira Neto contributed to the final version of the manuscript. Authors have no competing financial interests.

## Supporting information

Supporting informations are available from VBRI Press.

### References

1. Tamura, T.; Yoshimura, T.; Sekine, M.; Uchida, M.; Tanaka, O.; *IEEE T. Inf. Technol. B.*, **2009**, *13*, 910.
2. Tinetti, M. E.; Speechley, M.; *New Engl. J. Med.*, **1989**, *320*, 1055.
3. Hausdorff, J. M.; Rios, D. A.; Edelberg, H. K.; *Arch. Phys. Med. Rehab.*, **2001**, *82*, 1050.
4. Graafmans, W. C.; Ooms, M. E.; Hofstee, H. M. A.; Bezemer, P. D.; Bouter, L. M.; Lips, P.; *Am. J. Epidemiol.*, **1996**, *143*, 1129.
5. Woolcott, J. C.; Richardson, K. J.; Wiens, M. O.; Patel, B.; Marin, J.; Khan, K. M.; Marra, C. A.; *Arch. Intern. Med.*, **2009**, *169*, 1952.
6. Kannus, P.; Sievänen, H.; Palvanen, M.; Järvinen, T.; Parkkari, J.; *Lancet*, **2005,** 366(9500), 1885.
7. Lee, A.; Lee, K.-W.; Khang, P.; *Permanente Journal*, **2013**, *17*, 37.
8. Kachhwaha, R.; *International Journal of Health Sciences and Research*, **2018**, *8*, 104.
9. Berg, R. L.; Cassells, J. S. Falls in older persons: risk factors and prevention, in The second fifty years: Promoting health and preventing disability, National Academies Press: USA, **1992**, pp. 263-290.
10. Akyol, A. D.; *Int. Nurs. Rev.*, **2007**, *54*, 191.
11. Shany, T.; Redmond, S. J.; Narayanan, M. R.; Lovell, N. H.; *IEEE Sens. J.*, **2012**, *12*, 658.
12. Rougier, C.; Meunier, J.; St-Arnaud, A.; Rousseau, J.; *IEEE T. Circ. Syst. Vid.*, **2011**, *21*, 611.
13. Fan, X.; Zhang, H.; Leung, C.; Shen, Z. Fall Detection with Unobtrusive Infrared Array Sensors, in Multisensor Fusion and Integration for Intelligent Systems, **2017**, pp. 253-267.
14. Nadee, C.; Chamnongthai, K. Ultrasonic array sensors for monitoring of human fall detection, in 12th International Conference on Electrical Engineering/Electronics, Computer, Telecommunications and Information Technology (ECTI-CON), **2015**, pp. 1-4.
15. Montanini, L.; Del Campo, A.; Perla, D.; Spinsante, S.; Gambi, E.; *IEEE Sens. J.*, **2018**, *18*, 1233.
16. Xia, Y.; Wu, Y.; Zhang, B.; Li, Z.; He, N.; Li, S.; *J. Nanosci. Nanotechno.*, **2015**, *15*, 4367.
17. Zheng, J.; Zhang, G.; Wu, T.; Design of automatic fall detector for elderly based on triaxial accelerometer, in Bioinformatics and Biomedical Engineering, 2009. ICBBE 2009. 3rd International Conference on, **2009**, pp. 1-4.
18. Lim, D.; Park, C.; Kim, N. H.; Kim, S.-H.; Yu, Y. S.; *J. Appl. Math.*, **2014**, 2014, 8.
19. López, A.; Pérez, D.; Ferrero, F. J.; Postolache, O.; A Real-Time Algorithm to Detect Falls in the Elderly, in 2018 IEEE International Symposium on Medical Measurements and Applications (MeMeA), **2018**, pp. 1-5.
20. Yuwono, M.; Moulton, B. D.; Su, S. W.; Celler, B. G.; Nguyen, H. T.; *Biomed. Eng. Online*, **2012**, *11*, 9.
21. Jung, S.; Hong, S.; Kim, J.; Lee, S.; Hyeon, T.; Lee, M.; Kim, D.-H.; *Sci Rep*, **2015**, *5*, 17081.
22. Igual, R.; Medrano, C.; Plaza, I.; *Biomed. Eng. Online*, **2013**, *12*, 66.
23. Gövercin, M.; Költzsch, Y.; Meis, M.; Wegel, S.; Gietzelt, M.; Spehr, J.; Winkelbach, S.; Marschollek, M.; Steinhagen-Thiessen, E.; *Informatics for Heath and Social Care*, **2010**, *35*, 177.
24. Chan, M.; Estève, D.; Fourniols, J. Y.; Escriba, C.; Campo, E.; *Artif. Intell. Med.*, **2012**, *56*, 137.
25. Fuller, G. F. Falls in the elderly, *Am. Fam. Physician*, **2000**, *61*, 2159.
26. Evans, D.; Hodgkinson, B.; Lambert, L.; Wood, J.; *Int. J. Nurs. Pract.*, **2001**, *7*, 38.
27. Myers, H.; Nikoletti, S.; *Int. J. Nurs. Pract.*, **2003**, *9*, 158.
28. Oliver, D.; Daly, F.; Martin, F. C.; McMurdo, M. E. T.; *Age Ageing*, **2004**, *33*, 122.
29. Prudham, D.; Evans, J. G.; *Age Ageing*, **1981**, *10*, 141.
30. Lara, O. D.; Labrador, M. A.; *IEEE Commun. Surv. Tut.*, **2013**, *15*, 1192.
31. Kangas, M.; Konttila, A.; Lindgren, P.; Winblad, I.; Jämsä, T.; *Gait Posture*, **2008**, *28*, 285.
32. Lin, C. C.; Yang, C. Y.; Zhou, Z.; Wu, S.; *Int. J. Distrib. Sens. N.*, **2018**, *14*, 1.

# SUPPORTING INFORMATION

*Experimental setup*

| EVENTS | | | |
|---|---|---|---|
| **ADL ID** | **ADL** | **FALL ID** | **FALL** |
| ADL01 | Sit on a chair slowly | FALL01 | The subject is standing, falls backwards, finishing lying, and remains on the ground |
| ADL02 | Get up from a chair slowly | FALL02 | The subject is standing, falls backwards, finishing lying, stays on the ground for a while and then gets up again |
| ADL03 | Sit and get up from a chair slowly | FALL03 | The subject walks, falls backwards, finishing lying, and remains on the ground |
| ADL04 | Sit on a chair quickly | FALL04 | The subject walks, falls backwards, finishing lying, stays on the ground for a while and then gets up again |
| ADL05 | Get up from a chair quickly | FALL05 | The subject is standing, falls backwards, finishing sitting, and remains on the ground |
| ADL06 | Sit and get up from a chair quickly | FALL06 | The subject is standing, falls backwards, finishing sitting, stays on the ground for a while and then gets up again |
| ADL07 | Sit on a couch slowly | FALL07 | The subject walks, falls backwards, finishing sitting, and remains on the ground |
| ADL08 | Get up from a couch slowly | FALL08 | The subject walks, falls backwards, finishing sitting, stays on the ground for a while and then gets up again |
| ADL09 | Sit and get up from a couch slowly | FALL09 | The subject is standing, falls forwards, finishing lying, and remains on the ground |
| ADL10 | Sit on a couch quickly | FALL10 | The subject is standing, falls forwards, finishing lying, stays on the ground for a while and then gets up again |
| ADL11 | Get up from a couch quickly | FALL11 | The subject walks, falls forwards, finishing lying, and remains on the ground |
| ADL12 | Sit and get up from a couch quickly | FALL12 | The subject walks, falls forwards, finishing lying, stays on the ground for a while and then gets up again |
| ADL13 | Pick up an object from the floor with squatting slowly | FALL13 | The subject is standing, falls forwards on the knees, grabbing a chair, and remains on the ground |
| ADL14 | Pick up an object from the floor with squatting quickly | FALL14 | The subject is standing, falls forwards on the knees, grabbing a chair, stays on the ground for a while and then gets up again |
| ADL15 | Tilt the trunk slowly without bending the knees | FALL15 | The subject walks, falls forwards on the knees, grabbing a chair, and remains on the ground |
| ADL16 | Tilt the trunk slowly bending the knees | FALL16 | The subject walks, falls forwards on the knees, grabbing a chair, stays on the ground for a while and then gets up again |
| ADL17 | Tilt the trunk quickly without bending the knees | FALL17 | The subject is standing, falls forwards on the knees, and remains on the ground |
| ADL18 | Tilt the trunk quickly bending the knees | FALL18 | The subject is standing, falls forwards on the knees, stays on the ground for a while and then gets up |
| ADL19 | Jump with greater impact on the soles of the foot | FALL19 | The subject walks, falls forwards on the knees, and remains on the ground |
| ADL20 | Jump with greater impact at the tips of the toes | FALL20 | The subject walks, falls forwards on the knees, stays on the ground for a while and then gets up again |
| ADL21 | Jump with greater impact at the tips of the heel | FALL21 | The subject is standing, falls on the left side, and remains on the ground |
| ADL22 | Lie on bed slowly | FALL22 | The subject is standing, falls on the left side, stays on the ground for a while and then gets up again |
| ADL23 | Get up from bed slowly | FALL23 | The subject walks, falls on the left side, and remains on the ground |
| ADL24 | Lie and get up from bed slowly | FALL24 | The subject walks, falls on the left side, stays on the ground for a while and then gets up again |
| ADL25 | Lie on bed quickly | FALL25 | The subject is standing, falls on the right side, and remains on the ground |
| ADL26 | Get up from bed quickly | FALL26 | The subject is standing, falls on the right side, stays on the ground for a while and then gets up again |
| ADL27 | Lie and get up from bed quickly | FALL27 | The subject walks, falls on the right side, and remains on the ground |
| ADL28 | Bump into a table | FALL28 | The subject walks, falls on the right side, stays on the ground for a while and then gets up again |
| ADL29 | Bump into a chair | | |
| ADL30 | Bump into a wall | | |
| ADL31 | Bump into a doors | | |
| ADL32 | Climb a ladder slowly | | |
| ADL33 | Get down from a ladder slowly | | |
| ADL34 | Climb a ladder quickly | | |
| ADL35 | Get down from a ladder quickly | | |