



## Fall Detection in Elderly People

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### Abstract

Falls in elderly people are the second leading cause of accidental or unintentional injury deaths worldwide, according to the World Health Organization (WHO). Around 6 million people die as a result of fatal falls, with 80 percent of them coming from low- and middle-income countries. 37.3 million Elderly people suffer severe falls that necessitate medical attention. In rural and remote areas, the lack of multispecialty healthcare infrastructure and specialized medical experts necessitates low-cost, quick, and skilled infrastructure/expert independent solutions for early fall detection mechanisms. The essential factors which are worked and discussed in the studies on the identification of incidents & procedures or movements associated with the sudden falling activities in the ageing people or senior people are identified in this review, which may provide support to the future research on the same subject. However, other parts of this study and literature, which includes the sample size to be investigated, targeted users or specific age having users under our study, and methods for obtaining information regarding every application, have yet to reach consensus.

**Keywords:** fall detection, wearable devices, cloud computing, framework, Sensors

### 1. Introduction

Activity of “Falls” which is second highest & foremost source of accidental or sudden falling injury deaths globally in the ageing with specific age ranged people, as per the World Health Organization (WHO). A study says that around six million individuals die as a consequence of the activity of fatal falls, with eighty percent of them coming from low- and middle-income countries. 37.3 million Elderly people suffer severe falls that necessitate medical attention. In rural and remote areas, the lack of multispecialty healthcare infrastructure and specialized medical experts necessitates low-cost, quick, and skilled infrastructure/expert independent solutions for early fall detection mechanisms. As a result, the proposed work aims to reduce the number of elderly people who fall and suffer serious injuries as a result of those falls. The system which is proposed in the articles is the elderly person has a wearable sensor known as the accelerometer and another one which is gyroscope sensor for measuring acceleration and angular velocity. The study is based on five articles that talk about geriatric fall detection systems. Summaries generated for all five articles which gives an overview of the research work described in the articles.

Because of modern advancements, life expectancy has improved by five years since 2000. According to the World Health Organization (WHO), the present worldwide population of older people which is (8.5%) will grow by 20% by 2050, making up twenty percent of the world's population. There are many countries that are implementing the healthy ageing policies in response to all of these changes, with the intention of helping elderly people lead active, independent lifestyles. One of the most challenging challenges is ensuring that the elderly age actively and healthily, but there is also great opportunity for society in the next decades.

Objective of the article is to explore more possibilities to for a smart system and inexpensive system which is the need of healthcare clinics and for elderly people where their caretakers can get alert on any fall incident. A robust system for the detection falling would identify a incident of fall and alert the appropriate authorities.

With the advent of new technologies in our daily lives, it is critical that this technology be utilized to assist the elderly. Accidental activity of falls poses a significant risk and continuous threat to the elderly people. As a result, the focus of this research is on technologies that can help the elderly. Wearable, audio, and video-based fall detection systems are among these technologies. This paper reviews the literature on fall detection algorithms that use those three branches, as well as the numerous sensors that they utilize. When it comes to wearable technology, it is inexpensive and accurate, but it is inconvenient. On the other hand, audio-based technology is handier and less expensive than video-based technology. However as compared to the video-based technology and wearable based technology, technology based on audio devices is more difficult to apply for a solution. The technology based on video is precise and simple to implement. Video-based technology is now the most expensive of the three options, and it is also prone to occlusion. However, because of its versatility, this technology is projected to be the best of the three as homes become smarter and camera prices continue to fall.

In the healthcare industry, fall detection is a serious issue particularly aimed at the aged persons which are higher likely than others to sudden act of fall. 50% of the injuries related to hospitalization are in the people over the age of 65 or over. Devices offered in the commercial market for the detection or sensing of act of sudden fall are not even high priced and difficult to afford but also requires periodic subscription charges as well for the same service.

In recent years, a variety of alternative technologies for the programmed recognition of the action of falls have emerged. Some people feel the body hitting the ground after a fall or the faller's nearly horizontal posture. Accelerometers are used in most used sensor for the sensing of action of fall in such systems to detect the jerk or shock which the human physique receives when it hits. For instance, as part of a primary fall-detection system, a small sticky sensing patching that could be applied on the sacrum was developed. Smartphones with various integrated sensors, like the accelerometers & the gyroscopes, are widely carried by the elderly. As a result, by analyzing data from these sensors, it is now able to detect falls. Sensors of this type are adaptable and, for all intents and purposes, work anyplace. Elderly individuals are normally uncomfortable with having wearable sensors linked to their body, but carrying a smartphone would be quite straightforward to persuade them. Fall detection systems based on smartphones have been extensively researched. Previous studies have used data from smartphone sensors to detect falls using algorithms with decision for based on threshold.

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Although same kind of algorithm which is based on threshold used for the judgement are easy to construct and require less processing, choosing the best threshold values requires making a trade-off amongst the number of falls that aren't detected (false negatives) and the number of everyday activities that are mistakenly classified as falls (false positives). Finding appropriate threshold values that guarantee uniform execution across the board is difficult.

The "long lay," which entails lasting on the pounded for extended stages of period until aid reaches, is a hazardous consequence of falling. The "long lie" can cause major health problems such as hypothermia, pneumonia and dehydration, so which can result in death within six months of a fall in many cases. As a result, an elderly person's quality of life and independence might be significantly impacted by a fall that is not treated promptly. IoT solutions that help detect falls and warn emergency personnel in a timely manner are a social need in this scenario. Several strategies for detecting senior falls have been proposed so far. According to the sensor technology utilized, such solutions are divided into three categories which are a system based on non-wearable devices, another one is the systems which is based on wearables, and fusion or the system which is based on hybrid systems is the third category.

Artificial neural networks (ANNs) and support vector machines (SVMs), two techniques of machine learning, have recently been used to categorize falls from routine activities. The results are adequate, but using models based on deep learning to analyze the enormous data collected from mobile sensors can have more significant outcomes.

Another system which is a hybrid or mixture of deep learning model with framework of MEFD, integrating a network of convolutional neurons and a long short-term memory also called LSTM network is a deep and even bottomless model. CNN can be used to extract local representative features from a smartphone's accelerometer sensor, and LSTM can be used to learn the dependencies between the features retrieved from the sensor data. To avoid overfitting, the dropout strategy can be used to ignore some neurons at random during training. Due to the variety and limitations of cellphones, the suggested algorithm undergoes training offline before being transmitted to them for live, actual time detection of fall.

The most affordable and widely used sort of fall detector is a wearable one. They were chosen because of their inexpensive cost and great precision. Wearable devices have two distinct advantages: high accuracy and location independence because they move with the monitored individual. As a result, the elderly are not forced to be at a specific location. However, there are certain issues about the technique. Short battery life and discomfort are two of these problems. As a result, the elderly may forget to recharge the device, and other people may find it too painful to wear. The largest disadvantage, however, is that the device may not be worn at all.

This paper describes the development and evaluation of a threshold-based technology that's able to autonomously differentiate between a fall event and an ADL using triaxle accelerometers. Young, healthy participants who performed simulated falls and elderly persons going about their regular lives in their own homes provided the accelerometer data. The forces placed on the body during a fall and collision with the ground are larger than those experienced during routine daily exercise.

As a result, the proposed work aims to reduce the number of elderly people who fall and suffer serious injuries as a result of those falls. The proposed systems in the given articles is, the elderly person has a wearable accelerometer and gyroscope sensor for measuring acceleration and angular velocity.

## 2. Literature Review

Several review papers on fall detection have been published in the previous decade that cover various facets of the subject, including classification algorithms, sensor kinds, and particular feature engineering methods. We assess significant review publications on fall detection in this area, highlighting their research focus, contributions, and limitations.

The article named "A Real-Time Patient Monitoring Framework for Fall Detection" Ajerla et al., (2019) presented the framework on edge computation that uses actual timing based monitoring and less expensive wearable smart devices having sensors to detect falls automatically. Elderly persons who are particularly vulnerable to collapsing can receive better care and emergency assistance thanks to detection of fall. Long short-term memory (LSTM) model is used in the article work where model of LSTM detected fall with 99 percent accuracy. (In sequence prediction tasks, Long Short-Term Memory is proficient of learning the order dependency or the dependence in sequential form.) The Long short-term memory-LSTM fall detection model is used in this study to monitor relevant patient activity and identify the activity of fall using the architecture of an edge computing. In the article, MbientLab's MetaMotionR wireless wearable sensor modules which are smart devices and those are utilized to track human behavior specifically any specific activity or movement and deliver the real-time live or run time streaming data to the devices an edge device. According to the working of the article, using the technique of multi-stream data with various efficient sensors results in higher and practically usable performance. Article describes Fall Detection Using Machine Learning and working with edge computing framework. Authors presented an edge computing framework for real-time fall detection in this paper. Smartphones are frequently used to detect falls. Smartphones are easily damaged and expensive to replace in the event of a fall. As a result, a less expensive option would be preferred. Article used MbientLab's MetaMotionR sensors, which were inexpensive. Portable data was collected on a peripheral such as a laptop using Apache Flink to pre-process the data before sending it to the next level of analysis when the value exceeded a certain threshold. The data was analyzed with TensorFlow at this specific level with a pre-trained Long Short-Term Memory - LSTM model and also used to classify the data as falling or classify the data for not falling.

To validate the performance and general functionality of edge computing framework, several experiments conducted, as shown in the given table. Authors collected real-time activity and fall data from human volunteers and incorporated it into the system to detect a fall. The data was obtained with the use of an accelerometer in the MbientLab device MetaMotionR. The four forms of falls were described. To avoid any unwanted injury, a yoga mat was use. Table 1 contains information on the experimental subjects (Ajerla et al., 2019).

Fall monitoring is still a developing field, with new technologies being introduced on a regular basis. The research includes several classifications for fall monitoring, but the majority of them are for monitoring in general, that is, for systems that use

video, audio, and environmental sensors an overview of the literature is offered, with a focus on wearable sensor devices which are smart devices and the monitoring systems they use.

**Table 1: Details of the experimental subjects**

Experiment	Subjects	Age	Height	Weight	Falls
1	1	22	168	65	20
2	1	22	168	65	20
3	6	22-40	150-171	55-73	24

The models of the Fall detection specifically include an effective and efficient fall detection system that analyses the sensor's unprocessed or raw format data to detect the activity of fall. Two of the most extensively used sensors for fall detection, threshold monitoring, and predictive analytics based on machine learning have been constructed using data acquired from accelerometers and gyroscopes. When monitored data values surpass predefined threshold values, a fall is identified using threshold-based algorithms. Machine learning techniques, on the other hand, examine data and attempt to uncover hidden patterns in order to classify it.

Many research investigations rely on the system of automatic detection of human activity in uncontrolled contexts. Non-invasive activity recognition systems may help in the continuous monitoring of the elderly and patients in order to improve their safety and provide better insight into their health status. Fall detection is a specific subject in his research domain that has sparked a lot of attention among scientists; it is approached using a variety of methodological and technological approaches (Fortino & Gravina, 2015).

The number of sensors, their location on the body, and the system's accuracy are the primary concerns of a fall detection system based on wearable devices. On the one hand, additional sensors will provide the system with more data, increasing the chances of improved accuracy. A more sophisticated system, on the other hand, results in higher economic expenses and comfort difficulties; users want to be able to utilize such systems flawlessly and to perform their daily lives without interruptions (Fortino & Gravina, 2015).

In this paper, we introduce the Smart Wristlet, a revolutionary wearable sensor system that can detect falls for up to 24 hours. We built a machine-perception based fall detection method in Smart Wristlet to ensure its reliability and usability. This algorithm is referred to as Fall Perception in the rest of this research. Smart Wristlet achieves a fall detection precision of 93 percent, which is 3 percent greater than conventional approaches, thanks to the high efficiency and accuracy of Fall Perception. In addition, recollection has improved by 9%. More crucially, the battery life is increased by more than 30% by decreasing the computational complexity and sensor data. These gains are obviously critical for ensuring long-term and uninterrupted mHealth services in real-world applications. Smart Wristlet, for example, may track a user's activities and activate the airbags to protect him if a fall event is detected using pop-up airbags on the user's body. Furthermore, automated remote emergency alerting for elderly falls is critical, as the elderly are often unable to call for aid when they fall and become hurt (Li et al., 2014).

Smart Wristlet mHealth system is a novel wearable sensor system built for senior care, according to the design criteria. Most importantly, Smart Wristlet is made to detect users' behaviors without being intrusive. Smart Wristlet is suitable for both inpatients and outpatients because of this functionality. Sensors placed in a wristlet collect necessary user data in this mHealth system. The movement metrics as well as physiological data are monitored using these implanted sensors. The Smart Wristlet system's design and hardware foundation make it a formidable tool for user activity analysis and health monitoring (Li et al., 2014).

The Mobile Enabled Fall Detection (MEFD) framework is introduced in this article (Hassan et al., 2019), which describe detecting elderly people's falls and allows family members and caretakers to assist them by quickly finding location of them. A fall is defined as an event in which a person falls rapidly and without control from a higher to a lower level. For (Hassan et al., 2019) linked home healthcare for senior persons, accurate and real-time fall detection is critical. The authors demonstrated a smartphone-based fall detection framework that detects falls by automatically and continuously monitoring data supplied by the smartphone's sensors. A hybrid deep learning model for real-time online fall detection that was trained offline using the MobiAct dataset. The suggested system can identify falls and non-falls with greater precision than current systems, according to test results. The authors hoped to add other sensor data, such as cardiac information before and after falling, and GPS data in the future to follow people's activities, according to the article (Hassan et al., 2019).

For the notification and alert one of two sorts of alerts generated to recognize the results are positive for fall activity.

- A point for wireless access medium which are usually installed and available at homes sends out an interior sound alert to family members.
- A hospital or caregiver receives an outdoor SMS alert from a mobile network base station. (Hassan et al., 2019).

This paper [3] describes a comprehensive communication system for monitoring elderly people by accessing their electrocardiogram (ECG) and accelerometer data via a cloud-based server at any time via a mobile application, ensuring that they are safe. Monitoring elderly people who live alone is a growing problem that caregivers want to solve because many elderly people are at risk of falling. Serious consequences may occur if immediate assistance is not provided. The system described in this paper has been accomplished by placing a Multi-core Processing Unit at the elderly's side that acts as a gateway and monitors signals from a wearable sensing device. It will use Machine Learning algorithms to classify ECG and accelerometer data, stream the data on demand, alert caregivers via a mobile app, and store the data in a database for further analysis in the event of a fall. The Extended Nearest Neighbor learning algorithm had a 95% accuracy in fall detection (Al-Kababji et al., 2019).

Real-time monitoring and detection of falls in the elderly has been a critical issue for years and require prompt medical intervention. This necessitates the creation of a fall detection and management system that can provide prompt medical

assistance when needed. This study very well presents a 3-axis sensor of Accelerometer-based IoT based activity of the fall detection monitoring system and an alarm system for the elderly people. If timely medical intervention is not provided, injuries caused by falls in the elderly can be fatal. As a result, this article aims to create a system that can detect falls and notify medical professionals when someone is in such a critical distress. The system suggested in this article is for fall recognition, and it uses a wearable device with a sensor and storage capacity on a cloud data storage, utilizing a board based on IoT, to continually capture data of an aging patient's acceleration. Article working is also to access the stored data, an android application designed for the medical expert to examine the fall in the elderly patient and provide the desired assistance by sending intimation to relevant resources, if needed. An accelerometer threshold-based technique was utilized to gather data of sensor and set the fall sensing threshold. A thorough algorithm has been created to recognize falls based on reality. Simulation is also used for evaluation and the article shares simulation results (Gupta et al., 2020). Action of accidental falls and its moments, such as fractures of bone, are a significant risk, particularly for the senior citizens who live alone or live far away and always and require quick assistance. Activity of falling is the sixth most happening cause of death in those persons which are over the age of 65 as according to a survey. Furthermore, it is the second most prevalent cause of mortality for the persons aged 65 to 75, and it is the more and most common cause of death for those aged 75 and up. As a result, research into automatically detecting falls at home has exploded and enables many researchers to work on this most sensitive issue of the society (Li et al., 2014). Researchers in this paper are much more motivated to build healthcare systems for the purpose to protect the safety of elderly persons at home by the growing population of older people, especially in this era for those which have rich and advanced economies. Mobile robots, on the other hand, can offer a cost-effective solution to the healthcare issue. Furthermore, combining modern technologies like the Kinect sensor system with the robotics system could open up new avenues for developing intelligent systems that could be used to monitor the senior citizens and sound an alarm if harmful occurrences which are like falling down occurs or which are identified. Falls and its effects pose a significant concern, particularly for older persons who live alone and which definitely require rapid assistance. The Kinect sensor system is utilized in this project and study to create a mobile robot system that can be helpful in tracking a user of the system and detect when user gets fallen due to any reason. When an activity of a fall is observed, the mobile robot system is also well equipped with a GSM based cell phone, which is utilized to send an SMS message which is a GSM based notification and also able to perform an emergency call to the people associated with the fallen person (Li et al., 2019).

The purpose of the selected article/paper has been defined by the writers (Wagner et al., 2019) that it is to make available a narrative evaluation of existing technology for monitoring that can be used at home by older individuals. There is often a need for older individuals living freely in the community to strike a balance between risk and safety. The desire to maintain independence is evaluated against the danger of damage during regular activities. To be safe, the older adult may become more cautious in his or her everyday activities, yet living alone poses problems that are often concerning to both the individual and his or her family or caregiver. The authors go on to note that more Americans are living longer lives, and recent surveys suggest that most seniors desire to live as independently as possible in their own homes for as long as they can. This necessitates effective monitoring, and technology has a lot to offer in this regard. The study claims that in recent years, progress has been made in tracking the mobility and activity of elderly persons in their homes. This technology will benefit the elderly because it will allow them to remain in their homes as long as feasible. Wearable technology, which combines computer or electronic technology with clothing or accessories, as well as discreet monitoring, are fast-growing industries. Several applications of this technology could help detect falls and improve overall safety. Furthermore, continual monitoring of an older adult's precise motions or activity might detect variations in daily activity levels, which could signal a change in medical state. A review of current literature is used to provide a complete explanation of the development of this technology. Although many gadgets are still in development, the future of this technology may give an added level of protection and security for elderly people in their homes (Wagner et al., 2019).

### 3. Method

Based on the Google Scholar search engine recommendation, a systematic review data was collected and reviewed. The following are the steps that will guide through this review:

#### 3.1. Search strategy

A literature search in search engine turned up possibly pertinent papers about the investigation of fall relevant events (includes examples like: fall detection, fall detection in elderly, fall detection using IoT or evaluation or forecasting of fall risk) in the senior population using inertial sensors. The following search strings were used to retrieve desired results: ("accelerometer sensor" or "inertial / kinematic sensors" or "sensor of gyroscope" or "IOT in fall detection") and ("fall" or "the fall detection" or "risk of fall") and ("elderly in fall detection" or "sensors on fall detection" or "activity sensor"). The retrieval of previously recognized to be important documents was used to validate this search string.

#### 3.2. Criteria of Selection

Articles that met all of the following criteria were taken into consideration for this analysis or study:

- Articles included in Open access;
- Comprehensive/Complete, original publications that were published between the period of August, 2002 and June, 2019 in journals with peer-review in English, as well as some other languages were also tried, by writers or researchers who are sufficiently equipped to comprehend debates and documents based on scientific and technological parameters.

#### 3.3. Criteria of Exclusion

- Papers without participants or intended users proper and required age specification.
- Majorly information from Review papers.

#### 3.4. Data analysis and article assessment of quality

The different mind developed queries were examined to help with data analysis:

**Sensors:** We were interested in the sorts of sensors that were employed, the data acquisition sample rates, and the position/site of the sensing tools/devices on the user's body during signal collecting. In order to achieve the goal of signal processing, analysis, and recognition, we examined the most popular types of data (pre)processing, analysis, and recognition approaches used in articles. This depends on the objective of the investigation, which can be a categorization scheme, a statistical examination of signal qualities, or something else entirely. We separated them into the category of feature extraction and learning from data including machine learning subcategories of signal processing. Because of our interest in older populations, the features of the sample/example analyzed through the certain shortlisted studies or papers are an important consideration. We were particularly interested in shaping if the collected samples were made up of strong or fragile old age people. Tests: It's crucial to identify which functional or activity-based tests were used in conjunction with the practice of feelers to extract the participants' walking patterns given the variety of signal-gathering settings. Finally, a type of job investigated in the publications is of tremendous interest. Fall incident detection, classification of falling users, and evaluation or forecasting of fall risk are the three primary areas of applications we identified.

#### 4. Results

Six publications were manually inserted after the search approach, which retrieved information from 60 papers and was explored in other databases. 40 items were still being evaluated after duplicate articles were culled from various sources. After comparing the abstracts to the qualifications, 20 papers were discarded, leaving 20 for full-text reading. 20 publications were chosen as a result of this review. Year of publication: Figure 1 shows the chronological dispersal of these publications examined in this evaluation. Our observation is that their distribution over time shows no clear pattern or trend. Summary of papers particular for the review: The articles that were picked for the review are listed below: The articles that were picked for examination in this review are summarized in Table 2, together with information about the author, year of publication, sensor type (including the sampling rate that was used in Hz), and data collecting tests. We go over each of the data analysis questions in more detail in the sections that follow. Year of publication: Figure 1 depicts the order in which the papers considered for this evaluation or in-depth analysis were published. We see that the distribution of these publications across time shows no discernible pattern or trend. However, it was apparent that there were more papers released in 2019 than in years before when compared to those years. (See Figure 1).

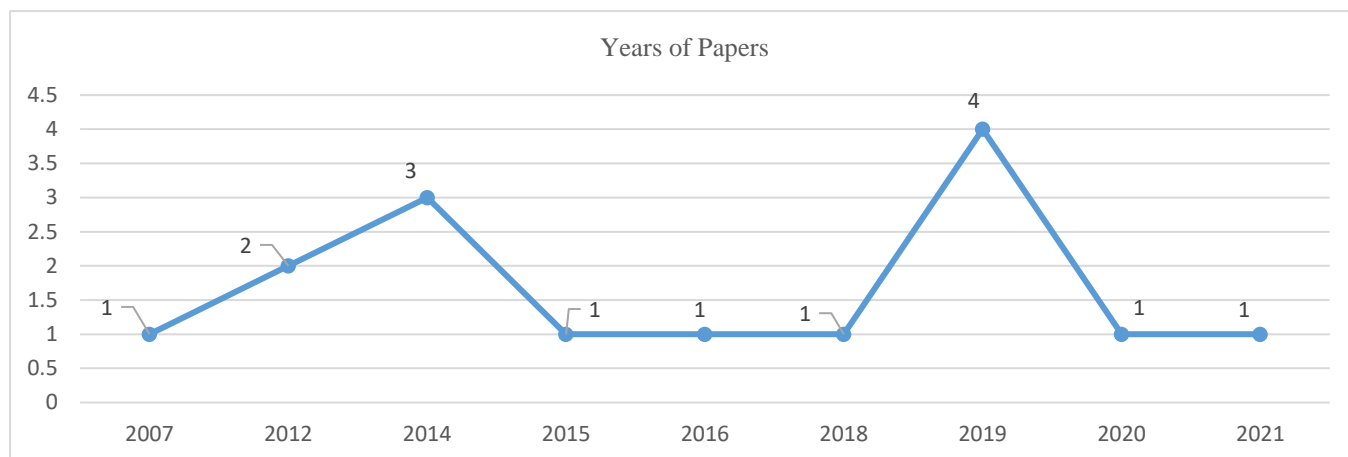
**Table 1: Articles Selected**

Autor	Application	Sensor	Hz	Tests
Ajerla et al. (2019)	Fall Detection	Accelerometer	200	ADL
Mohammad et al. (2019)	Fall Detection	accelerometer, gyroscope, accelerometer, orientation	100	ADL
Kababji et al. (2019)	Fall and ECG Monitoring	ECG, Accelerometer	40	Functional
Yacchirema et al. (2018)	Fall Detection	accelerometer, gyroscope	200	ADL
Akash et al. (2020)	Fall Detection	accelerometer, gyroscope	40	ADL
Zhinan et al. (2014)	Fall Perception	accelerometer, gyroscope, compass, Pulse	40	ADL
<u>Nirmalya</u> et al. (2021)	Fall Detection	accelerometer, gyroscope	20	Functional
Zaid et al. (2014)	Fall Detection	Kinect	100	ADL, Functional
Giancarlo et al. (2015)	Fall Detection	accelerometer, gyroscope, barometer	40	Functional
Tirza et al. (2019)	Fall Detection	accelerometer, gyroscope, barometer	100	ADL
Moeness et al. (2016)	Fall Detection	Accelerometer	200	ADL
Omar et al. (2014)	Fall Detection	accelerometers, oscilloscopes, Video	50	ADL
Philippe et al.	Fall Detection	Accelerometer	40	Functional
Roberto et al. (2012)	Fall Detection	Accelerometer	100	ADL
Wagner et al. (2017)	Fall Detection	accelerometers, oscilloscopes	50	Functional

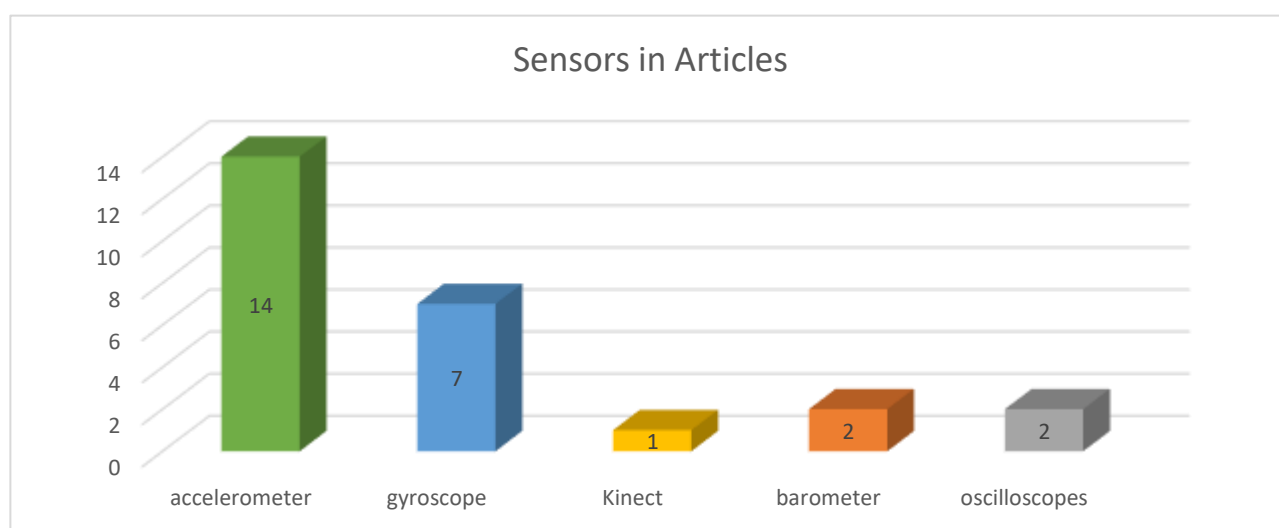
##### 4.1. Sensors

The base sensors including the most important accelerometer and the gyroscope, others as well which are magnetometer, and barometer were found in articles as techniques of tracking movement caused by changes in velocity or body patterns in the retrieved data. It's worth noting that some articles (Hassan et al., 2019; Gupta et al., 2020; Fortino & Gravina, 2015; Yacchirema et al., 2018) captured motion signals using a combination of two or more sensors. In the majority of the publications, the accelerometer was chosen (See Figure. 2).

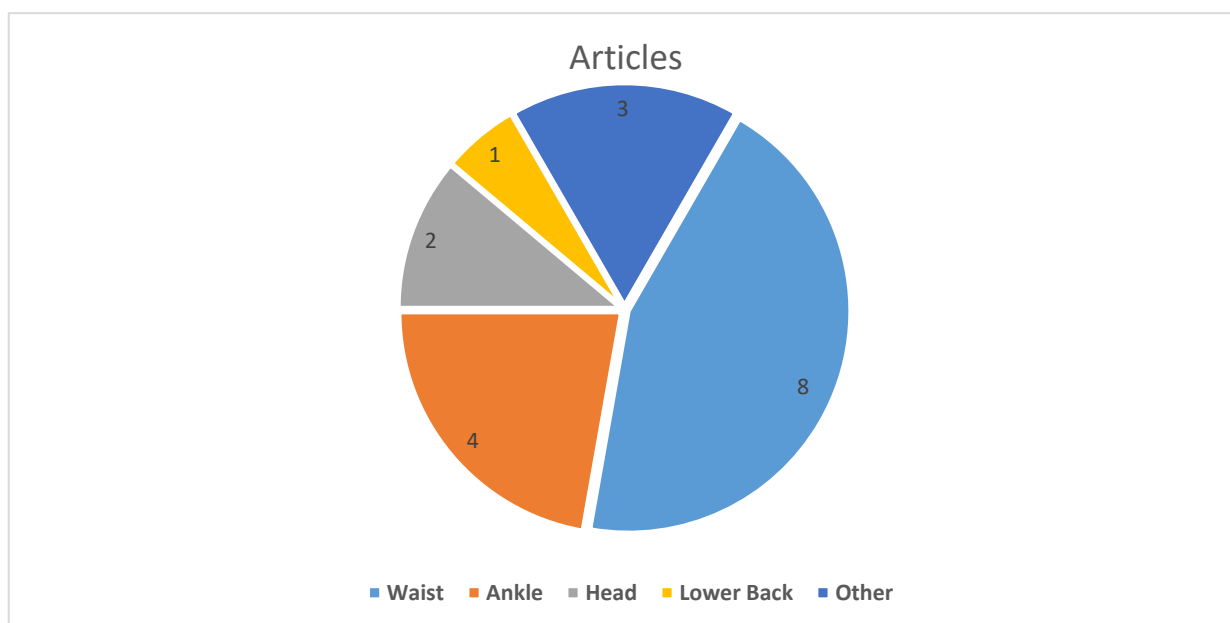
Aside from including the different types of activity sensors, another key aspect of the experiment was the location of the sensors on the participant's body. Figure 3 shows that the waist region was used in eight articles and the ankle region in four. The "other" group includes placements such the pelvis, thorax, and thigh that were less regularly employed. Some articles made use of a mix of sensors in various regions of the body.



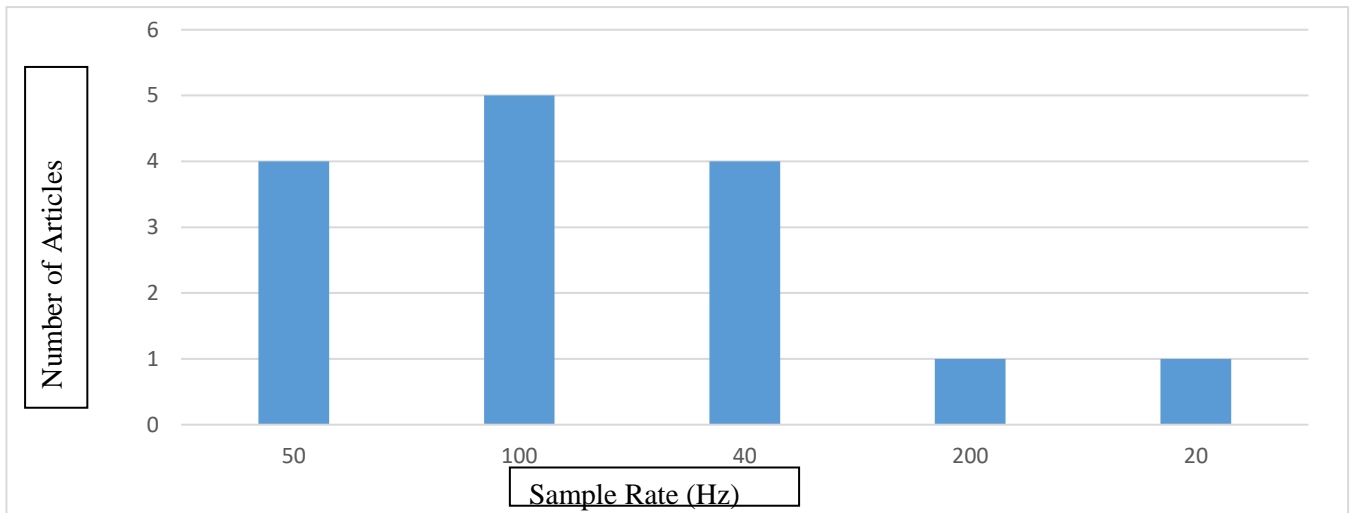
**Figure 2: years of publications**



**Figure 1: Type of Sensors**



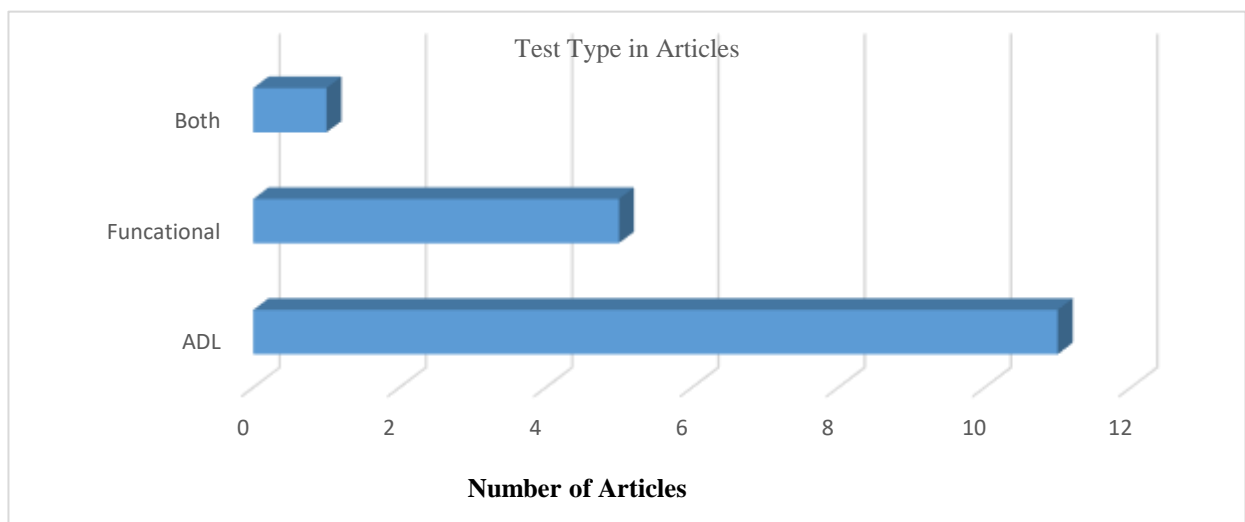
**Figure 3: Body Regions for sensors**



**Figure 4: Sampling Rate (Hz) used in number of Articles**



**Figure 5: Signal Processing Type**



**Figure 6: Test types to extract gait characteristics**

## 4.2. Sampling rate

In the following section, our effort pursued to identify the sample percentage that is most frequently employed or utilized for capturing signals in a particular sort of investigation. It's important to note that two of the rates in publications (Al-Kababji et al., 2019) are related to the gyroscope at this point (40 Hz), as only these study papers used this device exclusively. Accelerometers, which have been shown to be the most often utilized equipment for fall studies, are the subject of the remaining sample rates. Figure 4 displays a bar plot of the sampling rate data with a range of 20 to 200 Hz. In the publications, frequencies between 40 and 100 Hz were most frequently used.

## 4.3. Signal processing

The extraction of features from accelerometer signals and machine learning techniques were found to be the two main and most important categories of data processing features used in picked and preferred studies. Research that compares features just using statistical tests are categorized as "feature extraction," while research that incorporate computational or artificial cleverness techniques on features are referred to as "machine learning." All such papers utilizing machine learning is referenced. (See Figure 5)

## 4.4. Tests and scales

In relation to the sensor tests used to extract the patterns, particular functional evaluations were applied in 9 of the 15 articles. On the other hand, regular activities like climbing and descending stairs were used in 6 studies to track daily routine activities over the course of several days using a sensor (See Figure 6).

# 5. Discussion

When thinking about fall research strategies, the sensing tool called accelerometer, which was at waist based worn and lumbar as well, was foremost frequently used sensor setup to record gait data. Although machine learning techniques are growing in popularity, methodologies which straight away compares the properties taken out from sensing accelerometry data are generally the most commonly utilized in signal processing.

The investigations also employed data from the sensors of accelerometer, sensor gyroscope, and others like magnetometer, and barometer. 80.2% of articles utilized the accelerometer and gyroscope combined, while 79% of articles used the accelerometer and the sensor of barometer.

The fallouts showed that the region based on waist and the lumbar were the maximum often used. With a 99.96% sensitivity rate, the waist area is regarded to be the best location for detecting falls. The lumbar and waist, which are near to the center of mass, perform better than other locations at predicting the likelihood of falling. Although the authors (Thakur & Han, 2021) did not consider to include the waist part of the body as one of them, they found that the waist-specific area of hip was the most frequently employed for fall sensing. The most typical sensor site was shown to be in the lumbar region.

The way of gathering indications throughout tests of function, in restricted or unregulated routine activities of life, is crucial for the fall investigation. Clinical technology should take unrestricted acquisition into consideration, even though employing functional testing and regulated activities may allow for a more precise interpretation of the data. However, these occurrences complicated the interpretation of the data because the researchers had limited control over how the sensing tool/device was employed. Tests of functional are obvious candidates for identifying falls or maintaining the body balance issues, but some of them are actually made up of regular tasks. For instance, the scheduled Up and Go evaluation requires the participant to get up from a chair, walk, turn, and sit down; consequently, analyzing signals from this test can more accurately represent the individual's gait characteristics. This could explain why researchers frequently this and related exams or assessments.

We expected to see more and more papers on fall detection, as this has been the theme of previous research. The reduced number of fall detection publications can be explained by looking at the excluded studies, which typically feature a sample of young individuals. Simulated falls were used in many of the studies. The authors of those research say that fall simulation poses a risk to the elderly, which is why they didn't use an older adult's sample. The articles that dealt with fall detection tracked activities for days, with inadvertent or simulated falls collected in the participants' daily living situations. Only one study ( Mohamed et al., 2014) employed simulated falls to record the signals.

## 5.1. Limitations

This review's restriction could be attributed to the databases used for article searches. We drew on three datasets that we believe are relevant to the study's subject. There are additional publications in the literature about fall event identification that did not meet the review's eligibility requirements. They were excluded because they have been published in many conferences or have been indexed in numerous databases.

Lack of a meta-analysis was another problem. The variety of the study design made it impossible to categorize the data for this kind of analysis.

# 6. Conclusion

We were able to see some standardization in research on the identification of events linked to collapse like serious issue of falls in the age of elderly based on the findings of this systematic review, as well as validate earlier data in the correlated literature. The accelerometer was the most commonly used sensor to collect the gait indications to be analyzed, with a sample rate of 50–100 Hz and the most popular locations of use being the waist and lumbar. In terms of signal processing, the methods that rely solely on comparing properties retrieved from accelerometer data which are still the utmost popular, but on the other side the methods of machine learning are becoming more popular.

This study gives great support to identify the key factors that should be well addressed in researches and studies on the activity recognition of events which are associated to falls particularly in the people of ageing age and provides aid for identification of gaps in future research on the subject.

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