

# Internet of things gerontechnology for fall prevention in older adults: an integrative review

Gerontecnologias e internet das coisas para prevenção de quedas em idosos: revisão integrativa  
Gerontecnologías y internet de las cosas para prevención de caídas en adultos mayores: revisión integradora

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## Abstract

**Objective:** To identify in the literature the Internet of Things gerontechnology developed to prevent accidents by falls in older adults.

**Methods:** This integrative review was carried out from January to May 2020. Articles without period or language restriction with individuals aged 60 years or older addressing the use of Internet of Things gerontechnology for fall prevention were included. Duplicate articles were excluded. The search was performed by the PIE strategy (Population, Intervention, Effect/Assessment), resulting in the question: "What Internet of Things gerontechnology developed for accident prevention by falls in older adults available in the literature?". It was performed in the MEDLINE/PubMed, LILACS, CINAHL, Scopus and Web of Science databases. Year, type of study, country, professionals involved, outcome, development site and classification in Internet of Things gerontechnology and prototypes were identified.

**Results:** Twenty-three Internet of Things gerontechnology were identified. The years 2018 and 2019 had higher numbers of publications. There was a predominance of descriptive studies by computer science professionals and engineers and developed in Europe, Asia, North America and Oceania. Eight Internet of Things gerontechnology and 15 prototypes were found, seven sensors, five devices, three serious games and systems, two robots and one exergames, virtual reality and application. Most gerontechnology sought to improve mobility and balance, five of which were developed in the hospital and home environments, respectively.

**Conclusion:** The Internet of Things gerontechnology can be used as resources to assist in fall prevention and strengthening functional capacity. However, future research is needed to analyze the effectiveness of this type of technology for fall prevention in older adults.

## Resumo

**Objetivo:** Identificar na literatura as gerontecnologias Internet das Coisas desenvolvidas para prevenção de acidentes por quedas em idosos.

**Métodos:** Revisão integrativa, realizada de janeiro a maio de 2020. Foram critérios de inclusão artigos, sem restrição de período ou idioma com indivíduos de 60 anos ou mais, que abordem a utilização de gerontecnologia Internet das Coisas para prevenção de quedas. Excluíram-se artigos duplicados. A busca foi realizada pela estratégia PIE (População, Intervenção, Efeito/Avaliação), resultando na pergunta: "Quais as gerontecnologias Internet das Coisas desenvolvidas para prevenção de acidentes por quedas em idosos disponíveis na literatura?". Foi realizada nas bases de dados MEDLINE/PubMed, LILACS, CINAHL, *Scopus* e *Web of Science*. Identificaram-se ano, tipo de estudo, país, profissionais envolvidos, desfecho, local de desenvolvimento e classificação em gerontecnologia Internet das Coisas e protótipos.

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Conflicts of interest: nothing to declare.

**Resultados:** Identificaram-se 23 gerontecnologias Internet das Coisas. Os anos de 2018 e 2019 apresentaram maiores números de publicações. Ocorreu predominância de estudos descritivos, por profissionais da ciência da computação e engenheiros e desenvolvidos na Europa, Ásia, América do Norte e Oceania. Encontraram-se oito gerontecnologias Internet das Coisas e 15 protótipos, sendo sete sensores, cinco dispositivos, três jogos sérios e sistemas, dois robôs e um *exergames*, realidade virtual e aplicativo. A maioria das gerontecnologias buscava melhora da mobilidade e equilíbrio, sendo cinco desenvolvidas em ambiente hospitalar e domiciliar, respectivamente.

**Conclusão:** As gerontecnologias Internet das Coisas podem ser utilizadas como recursos para auxiliar na prevenção de quedas e no fortalecimento da capacidade funcional. Todavia, fazem-se necessárias pesquisas futuras para analisar a eficácia deste tipo de tecnologia para prevenção de quedas em idosos.

## Resumen

**Objetivo:** Identificar en la literatura las gerontecnologías internet de las cosas desarrolladas para la prevención accidentes por caídas en adultos mayores.

**Métodos:** Revisión integradora, realizada de enero a mayo de 2020. Los criterios de inclusión fueron artículos, sin restricción de período o idioma, con individuos de 60 años o más, que abordaran la utilización de gerontecnologías internet de las cosas para la prevención de caídas. Se excluyeron artículos duplicados. La búsqueda fue realizada mediante la estrategia PIE (población, intervención, efecto/evaluación), que dio como resultado la pregunta "¿Cuáles son las gerontecnologías internet de las cosas desarrolladas para la prevención de accidentes por caídas en adultos mayores disponibles en la literatura?". Se realizó en las bases de datos MEDLINE/PubMed, LILACS, CINAHL, *Scopus* y *Web of Science*. Se identificó el año, tipo de estudio, país, profesionales involucrados, resultado, lugar de desarrollo y clasificación en gerontecnologías internet de las cosas.

**Resultados:** Se identificaron 23 gerontecnologías internet de las cosas. Los años 2018 y 2019 presentaron mayores números de publicaciones. Hubo predominancia de estudios descriptivos, por profesionales de ciencias de la comunicación e ingenieros y desarrollados en Europa, Asia, América del Norte y Oceanía. Se encontraron ocho gerontecnologías internet de las cosas y 15 prototipos, de los cuales siete eran sensores, cinco dispositivos, tres juegos serios y sistemas, dos robots y un *exergames*, realidad virtual y aplicación. La mayoría de los gerontecnologías buscaba una mejora de la movilidad y el equilibrio, de las cuales cinco fueron desarrolladas en ambiente hospitalario y domiciliario.

**Conclusión:** Las gerontecnologías internet de las cosas pueden ser utilizadas como recurso para ayudar en la prevención de caídas y en el fortalecimiento de la capacidad funcional. Sin embargo, es necesario llevar a cabo estudios futuros para analizar la eficacia de este tipo de tecnología para la prevención de caídas en adultos mayores.

## Introduction

With the aging of the world population, the need to support the elderly public becomes imperative to support the demands inherent in the aging process. Today they reveal profound and constant changes in which technology has been part of everyone's daily life.

In this sense, the development of technologies specifically aimed at older adults has its greatest exponent in gerontechnology, since it seeks to provide answers to two main trends: the increase of the elderly population and the growing technological advance.<sup>(1)</sup> The term gerontechnology appeared in the 1970s and was conceived by engineers, designers and gerontologists.<sup>(2)</sup> It has international and national representation through the International Society for Gerontechnology and the Brazilian Society of Gerontechnology, entities that bring together professionals for the development of technologies aimed at older adults.

Gerontechnology is the study of technology associated with aging to adapt technological resources to health, housing, mobility, communication, leisure, among others, in order to maintain in older

adults their physical and cognitive skills, making them more autonomous and independent, essential conditions to ensure their functional capacity.<sup>(3)</sup>

As a technological innovation capable of contributing to Gerontechnology, there is the Internet of Things (IoT), as it allows physical objects to see, hear, think, perform tasks, share information, process data, capture environmental variables and external changes over a wireless network, which communicates using the Internet,<sup>(4)</sup> incorporating devices, sensors, systems, applications, etc., to provide more complete monitoring and greater care for older adults.

IoT can be used in several areas, however the health area is singled out as one of the most benefited, as IoT solutions can be applied with wearables and smart home in order to assist in healthcare, which enables the emergence of Ambient Assisted Living (AAL).<sup>(5)</sup> Thus, IoT can revolutionize the prevention of problems and injuries that can be avoided with real-time monitoring.

Therefore, gerontechnology with IoT solution can help maintain health and prevent harm to older adults. Accidents caused by falls are highlighted as the most relevant injury in the elderly population.

Approximately one in three older adults falls once a year<sup>(6)</sup> and the chance of falling increases with age, especially after age 80,<sup>(7,8)</sup> characterizing as a leading cause of morbidity and mortality for older adults in the world.<sup>(9)</sup>

A fall is defined as an unexpected change in position that takes the individual to a lower level and results in a risk of hospitalization or even death.<sup>(10)</sup> In addition to the risk of hospitalization or even death, falls have a high economic cost and a significant impact on the use of health services.<sup>(11)</sup>

Thus, investigating IoT gerontechnology in order to know the technological options available to prevent or reduce recurrent falls is relevant and necessary. These technologies can promote innovation, expansion and improvement of healthcare, improving the quality of life of older adults, their families and caregivers, also allowing changes in healthcare professionals' practice, especially nurses.

From this perspective, this study aimed to identify in the literature IoT gerontechnology developed for the prevention of accidents caused by falls in older adults.

## Methods

This is an integrative review, which followed the steps as follows: 1) Choice of research question; 2) Definition of inclusion and exclusion criteria for studies; 3) Sample selection; 4) Inclusion of selected studies; 5) Analysis of results, identifying differences and conflicts; 6) Discussion of data.<sup>(12)</sup> This study adopted the EQUATOR network guidelines and followed the the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) recommendations.<sup>(13)</sup>

The search was defined using the PIE strategy<sup>(14)</sup> (Population, Intervention, Effect/Assessment). Thus, the population of interest is older adults, the IoT intervention is gerontechnology and the assessment is accident prevention by falls, resulting in the following question: "Which IoT gerontechnology developed for the prevention of accidents from falls in older adults is available in the literature?"

Articles without period or language restrictions were included with individuals aged 60 years or

more, which address the use of IoT for fall prevention. Duplicate articles were excluded. The collection period was from January to May 2020. Database search was carried out through online access and independently by two researchers.

The search was carried out in the following databases: Medical Literature Analysis and Retrieval System Online/National Library of Medicine (MEDLINE/PubMed), Latin American and Caribbean Literature in Health Sciences (LILACS), Cumulative Index to Nursing and Allied Health Literature (CINAHL), Scopus and Web of Science.

To expand the search, natural language terms, uncontrolled descriptors and controlled descriptors from the health terminology of the Health Sciences Descriptors (DeCS) were adopted. Chart 1 brings the search terms and strategy in the databases.

**Chart 1.** Components of the PIE strategy, search terms and strategy, and databases

Component	Search terms		Search strategy	Databases
	Uncontrolled descriptors	Controlled descriptors		
P: Population	Elderly; Old; Elder; Aging	Aged	(Gerontechnology OR Technology OR Internet of Things)	MEDLINE/PubMed LILACS CINAHL Web of Science SCOPUS
I: Intervention	Gerontechnology	Technology; Internet of Things	AND (Elderly OR Old OR Elder OR Aged OR Aging)	
E: Effect/Assessment	Prevention	Accidents Fall	AND Prevention AND Accidents Fall;	

The title and summary of all the articles screened were read; then, a thorough reading of selected articles was performed and those were chosen to make up the final sample, and a summary table was elaborated with the following information for the analysis of technologies: author, place of use, year of publication, country of development, type of study, main conclusions, professionals involved, funding agency, description, outcome, specification regarding sensors, serious games, exergames, devices, virtual reality, robots, applications and classification in IoT gerontechnology or IoT gerontechnology prototypes.

It is noteworthy that sensors are devices sensitive to some form of interaction with the environment that collect information about a physical measure that needs to be measured. They are classified as thermal, pressure, wearable, speed, position, acceleration, among others.<sup>(15)</sup>

Serious games: virtual games for educational and health promotion purposes, but they can possess the general principles of games, like fun and entertainment.<sup>(16)</sup>

Exergames: these require the movement of the entire body of the individual associated with physical exercise with video game.<sup>(17)</sup>

Devices: objects that are related to a set of rules, words that relate to each other and can influence people's behavior.<sup>(18)</sup>

Virtual reality: described as an advanced user interface, having as features the visualization and movement in three-dimensional environments.<sup>(19)</sup>

Robot: machine that performs repeating tasks and requires high precision.<sup>(20)</sup>

Applications: Toolset designed to perform specific actions.<sup>(21)</sup>

For the classification of IoT gerontechnology and IoT gerontechnology prototypes, the following essential elements for the functionality of an IoT were taken into account: connectivity, sensing and processing.<sup>(4)</sup> Therefore, studies presenting the three elements were considered IoT gerontechnology and studies that presented at least one of these elements, IoT gerontechnology prototypes. Prototype can be characterized as a preliminary version of a new developed product.<sup>(22)</sup>

The information from the studies was systematized, categorized and analyzed.

## Results

A total of 1,873 articles were identified and, after reading titles and abstracts, 1563 articles were excluded, leaving 310 for the next stage. In this stage, a full reading was performed, after which 287 were excluded. Finally, the final sample of this review consisted of 23 studies. Figure 1 presents the process of selecting this research according to the PRISMA flowchart.

IoT gerontechnology in the literature for accident prevention by falls were published between 2008 and 2020, most in 2018 and 2019 in the following countries: Australia (3),<sup>(23-25)</sup> United States of America (3),<sup>(26-28)</sup> Thailand (2),<sup>(29,30)</sup> Germany (2),<sup>(31,32)</sup> Austria (1),<sup>(33)</sup> Sweden (1),<sup>(34)</sup> Algeria (1),<sup>(35)</sup> Canada (1),<sup>(36)</sup> South Korea (1),<sup>(37)</sup> Finland (1),<sup>(38)</sup> Japan (1),<sup>(39)</sup> Portugal (1),<sup>(40)</sup> United Kingdom (1),<sup>(41)</sup> Italy (1),<sup>(42)</sup> Serbia (1),<sup>(43)</sup> Switzerland (1)<sup>(44)</sup>, and Taiwan (1).<sup>(45)</sup>

Of the 23 IoT gerontechnology identified, six were descriptive studies,<sup>(26,27,32,36,38,40)</sup> three experimental studies,<sup>(25,29,33)</sup> a randomized clinical trial,<sup>(42)</sup>

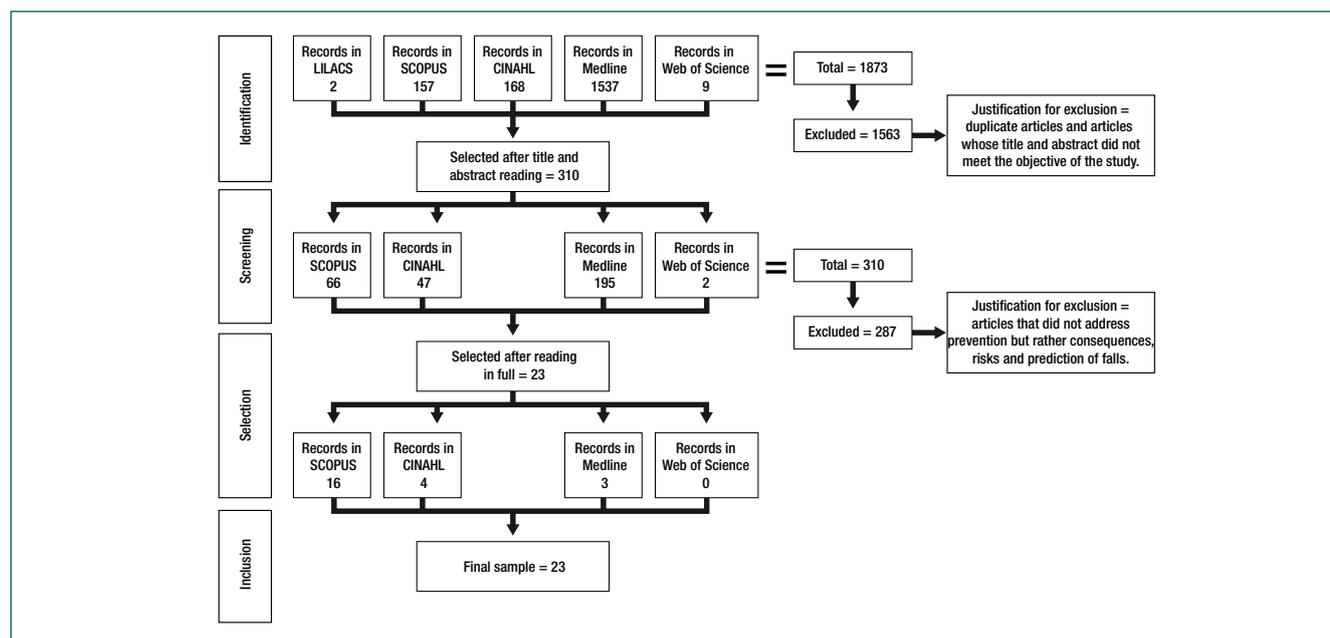


Figure 1. Flowchart of the article selection process

a quasi-experimental<sup>(30)</sup> and twelve did not report the methodology used.<sup>(23,24,28,31,34,35,37,39,41,43-45)</sup>

Regarding the authorship of studies by professional category, computer science (7),<sup>(23,26,28,31,32,34,35)</sup> engineers (4),<sup>(24,27,38,43)</sup> nurses (1)<sup>(33)</sup> and 12 articles did not inform the authors' background.<sup>(25,29,30,36,37,39,40-42,44,45)</sup>

As for the institution to promote IoT gerontechnology, ten were funded by government institutions,<sup>(27,29,33,34,36,38,40,43-45)</sup> two per non-governmental organization<sup>(23,26)</sup> and two by universities.<sup>(30,41)</sup> The other did not mention.<sup>(25,28,31,32,35,37,39,42)</sup>

Regarding IoT gerontechnology outcomes, eight were focused on mobility,<sup>(24,28,32,36,39,42-44)</sup> six, on balance,<sup>(25,27,29,30,37,40)</sup> four, on movements,<sup>(23,31,33,41)</sup> three, on object detection<sup>(26,35,45)</sup>, and one, on physical capacity.<sup>(38)</sup> However, an article did not report which outcome gerontechnology was intended for.<sup>(34)</sup>

As for the place of development, five were developed in a hospital<sup>(23,26,31-33)</sup> and homeenvironment, respectively<sup>(30,34,35,40,43)</sup> two in institutions older adults<sup>(42,44)</sup> and eleven did not mention.<sup>(24,25,27-29,36-39,41,45)</sup>

Chart 2 brings the specifications of the studies related to IoT-type gerontechnology (eight)<sup>(24,26,31-35,44)</sup> and gerontechnology prototype (15),<sup>(23,25,27-30,36-43,45)</sup> being seven sensors,<sup>(23,26,32,33,36-37,41)</sup> five devices,<sup>(25,39,42,44,45)</sup> three serious games<sup>(29,40,43)</sup> and systems,<sup>(31,34,35)</sup> two robots<sup>(27,30)</sup> and an exergame,<sup>(38)</sup> virtual reality<sup>(24)</sup> and application.<sup>(28)</sup>

## Discussion

In this research, the development of IoT gerontechnology for the prevention of accidents due to falls is highlighted, mostly published in the last two years,<sup>(24,29-31,34-38)</sup> confirming how current the theme. The predominance of studies by engineers<sup>(24,27,38,43)</sup> and computer science professionals<sup>(23,26,28,31-35)</sup> in European countries,<sup>(31-34,38,40-44)</sup> North America,<sup>(26-28,36)</sup> Asia<sup>(29,30,37,39,45)</sup> and Oceania,<sup>(23-25)</sup> proves the seriousness of the subject worldwide and reinforces the trend towards greater technological investment in developed countries.

In this sense, Australia<sup>(23-25)</sup> and the United States<sup>(26-28)</sup> presented higher productivity of IoT gerontechnology, which can be understood as a response of the country to this problem, since the falls are the leading external cause of death for older adults over 85 in this country. Search strategies for fall prevention are essential, since prevention actions can provide a reduction of 66% in its incidence.<sup>(46)</sup>

Although this review does not present Brazilian studies, data on falls in older adults are alarming. In 2018, there were 123,774 hospital admissions in the country for falls.<sup>(47)</sup> The rate of occurrence of falls ranges from 10.7 to 59.3% in older adults residing in the community and from 32.5 to 66.7% in residents of long-stay institutions for older adults.<sup>(48)</sup>

From the results of this study, it is expected that healthcare professionals, engineers and researchers are motivated and seek to develop research involving IoT gerontechnology aimed at fall prevention and disseminate their results. Research institutions, universities, governmental and non-governmental organizations and private initiative need to invest in the development of technologies aimed at the elderly population, since the increase in this population requires actions, strategies and changes in public policies, in addition to financing with notices and projects specific.

It is also noteworthy that to increase this thematic area, it is necessary to establish partnerships between technology centers and healthcare professionals, emphasizing the participation of nurses in this process. In this review, the participation of nurses was scarce. However, it is known that their expertise in care can add to the technological apparatus the development of technologies that are more sensitive to the needs of older adults.<sup>(49)</sup>

It was observed, in this study, regarding IoT gerontechnology produced in different environments, that about 30% of falls are related to the physical environment.<sup>(50)</sup> Gerontechnology produced that focused on the early detection of abnormalities in the movement of older adults and the decline of their biomechanical abilities are possible to identify locomotion impairments that can lead to falls. In this sense, specific IoT gerontechnology aimed at existing functional limitations can enable continuous improvement in func-

**Chart 2.** IoT gerontechnology and IoT gerontechnology prototypes for accident prevention by falls

IoT gerontechnology			
Year/Country/Citation	Specifications	Description	Main findings
Aidemark et al., 2019/ Sweden <sup>(24)</sup>	System- Fall management with advice, sensors and app.	Combination of preventive actions through expert advice and examples of risks, detection of fall incidents with sensors that capture body movements, visual detection of the user's movement and position, analysis of behavior patterns.	IoT-oriented home learning environment for fall prevention that makes living independently and enhanced self-understanding to make everyday life easier. Developed in a home environment.
Aljahdali et al., 2018/ Algeria <sup>(25)</sup>	System – Intelligent assistive walker device for the visually impaired and older adults.	Hardware and software device. Hardware consisting of sensor, controller and output. Software composed by the “Map” and “Find-me” apps. The information received from the sensors (position, objects and people around) are sent to commands to the controller and guide the walker to meet the needs of older adults safely.	Recognize the dangerous positions that can cause the fall. Developed in a home environment.
Jähne-Raden et al., 2019/ Germany <sup>(31)</sup>	INBED System	The wearable component attaches to older adults' upper leg in the upper half of the thigh, ideal for detecting lifting events by changing the angle of the legs without affecting comfort. In addition to the sensor, the developed system contains relay stations and a central signal processing base station to create a scalable communication network.	System supports professional care in reducing patient injuries caused by falls. Developed in a hospital environment.
Kouris et al., 2015/ Serbia <sup>(43)</sup>	Game – KINOPTIM: Game platform that provides the medical profile of each individual to develop a Personalized Clinical Decision Support System (PCDSS).	During the execution of the exercises, wearable sensors are placed on the wrists and ankles to detect movement; then, the MBI module incorporates a Decision Support System (DSS) to collect, organize and analyze the passive, active and cooperative relationships of the collected data. The DSS used in the KINOPTIM platform receives as input the medical profile of each individual to develop a Personalized Clinical Decision Support System (PCDSS).	Classifies fall risk levels and generates recommendations for physicians. Developed in a home environment.
Torres et al., 2016/ Australia <sup>(23)</sup>	Sensor - WISP battery-free wearable sensor with radio frequency identification (RFID).	Battery-free wearable sensor for use over clothing prior to the sternum, in which there is data corresponding to the movements and identification being collected in real time via RFID. Data is received at the bed and chair exit recognition stage for processing and analysis. Thus, an alert can be issued to caregivers when leaving the bed or chair.	Determining bed and chair outputs in real time is important due to the lack of methods in the literature that use batteryless sensors for fall prevention. Developed in a hospital environment.
Wolf et al., 2013/ Germany <sup>(32)</sup>	Sensor - Bed exit alarm.	Shimmer sensors available at the bedside and equipped with Bluetooth. Prototype integrates wide motion protection as a precursor to bed exit and protection from high acceleration during fall.	Reliably detects attempts to get out of bed and generates few false alarms. Developed in a hospital environment.
Ranasinghe et al., 2012/ USA <sup>(26)</sup>	Sensor - WISP: Wireless identification and detection platform through a wearable sensor.	Wireless identification and detection of the WISPs Platform (wearable device) for real-time monitoring and identification of activities: 1) RFID readers; 2) Monitoring software.	Great potential to provide a technological intervention to prevent falls in hospitals. Developed in a hospital environment.
Hilbe et al., 2010/ Austria <sup>(33)</sup>	-BUCINATOR sensor: bed exit alarm.	Air-filled pressure sensitive rails are mounted on the top edge of the bed side rail for the exit alarm system. These rails are connected with the pressure sensor. If a patient at risk of falling intends to get out of bed with the siderail in the upright or lowered position, pressure in the system increases and if a threshold level is exceeded, an electrical alarm signal is generated. The nursing staff will be informed about the risk of the situation through the public address system.	A reliable bed exit alarm system gives confidence in relatives' safety and puts less strain on the family. Developed in a hospital environment.
IoT gerontechnology prototypes			
Year/Country/Citation	Specifications	Description	Main findings
Patton et al., 2008/ USA <sup>(27)</sup>	Robot - KineAssist for gait and balance training.	Provides partial body weight support and postural control; allows movement of the trunk and pelvis; follows ground walking movements in forward, rotation, and avoidance directions; and makes it impossible for the individual to lose balance.	It can help prevent falls, as it improves gait and balance. Does not mention the location of development.
Merilampi et al., 2019/ Finland <sup>(38)</sup>	Exergame - based on a smart chair.	Developed for Android devices via Bluetooth. User movements are measured by nine pressure sensors located under the chair seat. Sensors send their data to the Android device. The exergame “smart chair” uses three categories of minigames: ski jumping, snowboarding and ball tossing. Interaction with the game environment requires the user to move their body. The snowboard minigame is designed to train postural control in a seated position. The ski jumping minigame requires greater functional skill. The ball toss game incorporates upper extremity strength and coordination.	Facilitates the delivery of fun tools in providing preventive interventions with the potential to decrease the risk of falling. Does not mention the location of development.
Prasertsakul et al., 2018/ Thailand <sup>(29)</sup>	Game - Dual Task Virtual Reality Balancing Training (DTRVBT).	Laptop and Kinect sensor. The 3D information from this sensor allows users to interact with the object in the virtual environment (Unity3D). The game requires arm movement in both vertical and horizontal directions. The player must place the object in the assigned area.	It can facilitate better postural control and contribute to fall prevention of healthy adults in the future. Does not mention the location of development.
Verrusio et al., 2017/ Italy <sup>(42)</sup>	-Human Body Posturizer (HBP) device	Device composed of articulated orthosis, with four elements that come into contact with different anatomical zones, being able to adapt to the physical characteristics of each individual. Improves the accuracy of the response, walking and posture, stimulating the prefrontal cortex (PFC), fundamental in motor control.	Useful tool for fall prevention in older adults, as it reduces risk factors in older adults with chronic conditions. Developed in a geriatric institution.
Viriyavit et al., 2020/ United Kingdom <sup>(41)</sup>	Sensor - Alarm for bed exit detection	Sensor panel equipped with two types of sensors to detect the weight applied to the bed, being installed on the left and right side of the panel. The combination of the two pairs of different types of sensors is used to detect the position of each side of the body on the bed.	It works with high accuracy in position detection and requires fewer sensors than other existing ones. Does not mention the location of development.
Raffe et al./ 2018/ Australia <sup>(24)</sup>	Virtual Reality - Kinect + HTC Vive – Simple setup that combines skeletal tracking and virtual reality.	Kinect: Track the player's body movement. HTC Vive: used for virtual reality screen.	It has the potential to increase the immersion of an experience and prevent potential falls. Does not mention the location of development.

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IoT gerontechnology prototypes			
Year/Country/Citation	Specifications	Description	Main findings
Tzung-Han et al., 2017/ Taiwan <sup>(45)</sup>	Device - Fall prevention shoes	Line laser on the side of the shoes and RGB camera on the upper part of the shoes. System sends alert according to the width and depth of the detected obstacles.	Suitable to be installed on portable devices and general product costs are acceptable Does not mention the location of development.
Di P et al., 2016/ Japan <sup>(39)</sup>	Device - Smart Cane	Robot consisting of a unidirectional mobile base, aluminum pole, minicomputer, sensor system and a laser rangefinder (LRF), used to assist older adults in walking training.	Behaves to prevent the user from being in a position to generate falls. Does not mention the location of development.
Vieira et al., 2015/ Portugal <sup>(40)</sup>	Game - based on the Berg Balance Scale (BBS) test	Game association + BBS-based motion sensor consisting of daily tasks exercises. And the sensors are used to detect movement, correctly distinguishing between activities of daily living, such as sitting or walking, from an actual fall duration.	Improves autonomy and safety, specifically for those at risk of falling. Developed in a home environment.
Maneeprrom et al., 2019/ Thailand <sup>(30)</sup>	Robot	8-inch touch screen attached to the head of a Dinsow Mini robot version M2070, where older adults watch four videos on fall prevention and choosing walking aid devices, two videos on suitable footwear, two videos on exercise and 28 voice messages about fall prevention and daily exercise reminder.	It increases knowledge about fall prevention, promotes exercise, and improves balance between physically active and at-risk older adults. Developed in a home environment.
Qiu et al., 2018 / South Korea <sup>(37)</sup>	Sensors - A set of miniature wearable inertial sensors	Inertial sensors are placed on the lower back, thighs and legs and a battery of tests performed for a multifactorial fall risk assessment is performed to identify the greatest number of risk factors presented.	Wearable inertial sensor-based systems show great promise for the assessment of fall prevention in older adults. Does not mention the location of development.
Wu et al., 2018/ Canada <sup>(36)</sup>	Sensor - Wearable sensor-based fall risk assessment program (SFRA).	SFRA consists of two core pieces: a wearable device for collecting and storing data and a mobile device for displaying fall hazard information.	Information can motivate older adults to adopt fall prevention interventions. Does not mention the location of development.
Moufawad et al., 2016/ Switzerland <sup>(44)</sup>	Instrumented-Shoes Device	The system consists of the Physilog inertia detection and data logging unit and the plantar pressure insole. Its architecture is oriented to collect real-time footwear data and perform online activity classification and characterization (eg gait analysis of locomotion periods and postural transition analysis). Data from all sensors (medial and lateral heel, lateral arch, 1st / 3rd / 5th metatarsals, hallux and remaining toes) are stored on a memory card to prevent data loss.	Assesses mobility and provides quick, personalized feedback for older adults. Developed in a geriatric institution.
Goulding et al., 2015 USA <sup>(26)</sup>	Application - Sparrow system.	Mobile application for Android connected to sensors and attached to a wheelchair that emits movement signals warning of the risk of falling.	Efficient to issue real alerts about user movement during use. Does not mention the location of development.
Qiu et al., 2013/ Australia <sup>(25)</sup>	Device - Textured Insoles	Insoles inserted into standard shoes to reduce postural sway.	Improves stability and reduces postural sway. Does not mention the location of development.

tional capacity, reducing the consequences of lack of balance in older adults.<sup>(51)</sup>

IoT gerontechnology works more effectively in the follow-up and monitoring of older adults.<sup>(52)</sup> The clinical applications of IoT Gerontechnology in the health of older adults include monitoring, diagnosis, disease prediction and treatment. For example, through IoT gerontechnology, the system or a device can detect risk warning signs for older adults and send a signal or message to caregivers and health-care professionals. This way, they can monitor their health status remotely and in real time.<sup>(53)</sup>

It is noteworthy that for the construction of IoT solutions, other technologies are needed,<sup>(54)</sup> thus requiring specialized labor, investments and partnerships in order to produce technologies according to the necessary demands.

The architecture of IoT solutions must encompass complex elements, such as connectivity, sensing and processing, which becomes a challenge for its development and implementation. Given the heterogeneity of objects, the difficulty in real-time

data transmission, instantaneous data analysis performed in pre-processing, local intelligence in low-power embedded systems, interaction between users on site, complex interfaces, portability and wearability,<sup>(32)</sup> many products are developed covering one or more elements mentioned, thus configuring themselves as prototypes.

The large amount of IoT gerontechnology with the use of sensors<sup>(23,26,32,33,36,37,41)</sup> and devices stands out.<sup>(25,39,42,44,45)</sup> The use of sensor-based alert triggering systems is a promising approach that can inform nursing staff, family members and caregivers when a patient tries to get out of bed.<sup>(55)</sup> Electronic detection sensors for bed-related patient fall prevention are becoming more and more common and are designed to detect patients who get out of bed without assistance, thus being able to avoid dangerous situations.<sup>(56)</sup> Sensors of this nature are low cost and easy to purchase, as common presence sensors, available in electronics stores, for example, can be used.

In this review, the devices were designed with the aim of improving postural stability and conse-

quently preventing falls. The devices can also provide an effective and cost-effective alternative for reducing postural sway and gait assessment in older people.<sup>(57)</sup>

IoT gerontechnology that had used robots,<sup>27,30</sup> serious games,<sup>29,40,43</sup> virtual reality<sup>24</sup> and exergames<sup>38</sup> had appeared in lesser number, for its development to perhaps involve greater raised time and costs more; however, they possess diverse possibilities of use in elder attention and care. Games, for example, offer an attractive and fun way to learn, in addition to helping to understand that technology can improve autonomy and safety, assess risk and help prevent potential falls, thus contributing to healthy aging.<sup>(15)</sup>

Thus, IoT gerontechnology can be used as important tools to aid in fall prevention and in the strengthening of functional capacity. The review results reinforce the need for interprofessional practices to better meet the needs of the elderly population.

The originality of the study is highlighted as it is a current and little explored theme in the Brazilian scenario. The method adopted allows the selection of different types of studies, which on the one hand enriches the findings, but restricts the details of them, as there is no requirement for criteria regarding the quality and strength of the evidence, thus making it impossible to provide more in-depth information regarding to the development of IoT gerontechnology, limiting the opportunity for replication by other researchers.

## Conclusion

It was evident that the period between 2018 and 2019 had the highest number of publications, especially the production in Australia. It is noteworthy the predominance of descriptive studies, engineers and computer science professionals as those who produced the most. For fall prevention, IoT gerontechnology focused on mobility and balance stands out. IoT gerontechnology was found that addressed systems, sensors, devices, serious games, exergames, robots, virtual reality and applications. As it is a topic still under development, it is necessary to future studies that seek to analyze the effectiveness of

IoT gerontechnology for fall prevention, studies that encourage discussions on cost assessment and applicability in the population. In addition to the need to establish partnerships between technology centers and healthcare professionals.

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