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Exergames to Prevent the Secondary Functional Deterioration of Older Adults during Hospitalization and Isolation Periods during the COVID-19 Pandemic

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Abstract: The COVID-19 pandemic is having an intense impact on the functional capacity of older adults, making them more vulnerable to frailty and dependency. The development of preventive and rehabilitative measures which counteract the consequences of confinement or hospitalization is an urgent need. Exergaming can promote physical activity, prevent falls, and maintain functional and cognitive capacity. However, although the use of exergames in health programs for the elderly is promising, their widespread use should not be considered without the supervision of a social health professional. Therefore, the objective of this work was to evaluate and analyze three video game consoles (Nintendo Wii®, Xbox-Kinect® and Play Station 4®) and 26 commercial exergames with the aim of identifying their usefulness for the prevention of functional deterioration. Three occupational therapists analyzed the data independently, and subsequently agreed on the results. The examination of the commercial consoles met three criteria: components, interaction channels and the type of the exergame. Each exergame was analyzed taking into account its ability to train postural control, balance, upper limb functionality and cognitive function. The results of the evaluation showed that exergames contain game activities that can be part of the rehabilitative treatment aimed at the prevention of the functional impairment of older people affected by COVID.

Keywords: virtual reality exposure therapy (VRET); exergames; rehabilitation; improve functional capacity; SARS-CoV-2; post-COVID syndrome; older adults

1. Introduction

Severe acute respiratory syndrome 2 (SARS-CoV-2) has spread worldwide, affecting more than 163 million people [1]. An estimated 80% of the mortality corresponds to people over 65 years of age. In survivors, the clinical manifestations of this new disease vary widely, from mild manifestations compatible with a common cold, to death itself. In this wide spectrum of symptoms, respiratory, cardiovascular, hepatic, olfactory–gustatory, digestive and neurological affectations stand out [2].

Surviving the acute phase means that older adults face two major threats to their functional capacity: the residual symptoms of SARS-CoV-2, also called post-COVID syndrome [3], and the consequences of a prolonged period of immobility. The former is characterized by persistent fatigue, dyspnea and neuropsychological symptoms, and it affects 35% of COVID patients treated on an outpatient basis and 87% of hospitalized patients [4]. The effects of immobility in older people are widely known, characterized by sarcopenia, cardiovascular disease, osteoporosis, intestinal problems, impaired balance and an increased risk of falls, sensory deprivation, and cognitive impairment [5].

Similarly, older people who experience periods of isolation or confinement in order to avoid infection also see their functional capacity reduced by having to exacerbate a sedentary lifestyle and considerably reduce their level of mobility and daily performance [6–8].

It is evident that the pandemic is having an intense impact on the functional capacity of older adults, making them more vulnerable to frailty and dependency. In order to preserve the autonomy and quality of life in this sector of the population, the development of preventive measures that counteract the consequences of isolation, and rehabilitation programs that combat the physical and cognitive deterioration generated by SARS-CoV-2 infection is a priority.

Technological advances can offer accessible and economical alternatives to prevent dependency and initiate rehabilitation processes in situations of home, hospital or residential isolation. Telerehabilitation services, supervised by an occupational or physical therapist [9], are a viable and safe alternative for the promotion of the performance of rehabilitation exercises at home, in a hospital room or in a residence.

An emerging technique that has proven effective in improving the functional capacity and well-being of older adults is virtual-reality–based therapy [10,11]. This type of technology has made it possible to develop virtual rehabilitation activities that add dynamism and fun to treatment sessions. The key to this type of therapy is the interaction between the person and the virtual activities, as the virtual reality system emits different types of feedback depending on the movements made: sounds that inform the participant of success or failure, images or photos of the participant and messages of achievement or encouragement.

Virtual exergames represent a low-cost and commercially accessible type of virtual reality, and they have given rise to the technique of exergaming. This term, composed of "exercise" and "gaming", has been defined as any type of video game that requires the movement of the player's entire body [12,13]. Exergaming, although it comes from the entertainment industry, is being applied to enable older people to exercise in a pleasant and enjoyable way [14,15].

Exergaming breaks with the concept of the sedentary "armchair" video game and requires movement and action from the player to interact with the different game scenarios. Due to their direct relationship with physical activity and, therefore, the promotion of health, exergames have captured clinical and scientific interest since their launch on the market as a technological tool of increasing use in day centers and nursing homes.

Active video game consoles use technology that tracks movement and projects the player's motor reaction onto the game screen. They contain attractive and multisensory game environments with a high immersive capacity (for example, driving on a circuit, going down a river in a canoe or practicing a multitude of sports with the ovation of the public), in which the interaction takes place through global body movements. In this way, the practice of physical exercise becomes a dynamic and fun activity, which breaks down the barriers of repetitive and monotonous physical exercise. The gamified approach and immersive scenarios motivate older people to acquire a greater commitment to the practice of physical and rehabilitative exercises.

The potential of exergaming to promote autonomy, prevent falls, and reverse anxiety/depressive states in aging has been widely studied in the last decade [16–18]. The therapeutic application of exergames in older people has been effective in improving balance [19–21], gait speed [22,23], lower limb strength [24] and cognitive function [25,26], all of which are predictive indicators of functional disability. The incorporation of exergames in treatment sessions generates a new rehabilitative context in which the person identifies themselves and gets involved. It allows older adults to achieve actions that are not always possible in real life, due to fragility, disability or social isolation caused by aging [27]. These characteristics make exergaming an appropriate intervention to contribute to the recovery of the baseline functional state prior to SARS-CoV-2 infection. They can also be used to combat the consequences of reduced mobility due to periods of preventive confinement [28].

However, it is necessary to consider that, although the results are promising, its generalized use in the elderly should not be promoted. Commercial exergames need to be evaluated and graduated by a therapist, who should adapt the characteristics of the game to the preventive or rehabilitative intervention according to the functional level of the user. The wide variety of exergames (walking, cycling, tennis, bowling, climbing, soccer, resistance exercises, one-legged balance, adventure, zumba, aerobics, etc.) requires an exhaustive analysis of their motor and cognitive requirements, with the objective of selecting the one best suited to the needs and capacities of the person. If the level of cognitive and motor skills of the exergame exceeds the capabilities of the person, it can be demoralizing and frustrating to fail to keep up with the video game or reach the desired scores. In addition, the limits of balance and muscle strength can be altered, causing falls or musculoskeletal injuries. Jalink [29], for example, found 38 papers in which musculoskeletal injuries of the upper limbs and neck were identified in older adults who practiced physical exercise with exergames.

This study has two objectives: (1) to describe current commercial video game systems with physical motion sensors, and (2) to select commercial exergames based on four rehabilitation criteria, i.e., maintaining and changing the position of the body, maintaining or improving balance, strengthening the functionality of the upper limbs and stimulating cognitive function. With this information, rehabilitation professionals—such as occupational therapists and physiotherapists—are able to use those exergames with gaming activities that are easily adaptable to the characteristics and needs of older adults who are at risk of becoming frailer as a result of confinement and periods of hospitalization caused by SARS-CoV-2 infection.

2. Materials and Methods

Three occupational therapists independently analyzed three video game consoles and 26 commercial exergames: 12 Nintendo exergames, ten Xbox-Kinect exergames and four Play Station exergames. The results of this evaluation were then agreed upon to produce a final result.

The analysis of the consoles was based on three criteria: the components, the interaction method and the type of exergame. The evaluation of the exergames was based on four criteria: (1) the changing and maintaining of the position of the body, (2) balance, (3) the use of the upper limbs for activities of daily living, and (4) the stimulation of cognitive functions.

2.1. Commercial Videogame Consoles

Nintendo Wii®, Xbox-Kinect® and Play Station 4® are seventh-generation consoles that allow exergaming. Their use has expanded rapidly in clinical and rehabilitation units for several reasons: ecological and challenging treatment environments, immediate multimodal feedback (visual, auditory and proprioceptive) on the level of performance, high motivation and adherence to treatment, the possibility of graduating the intervention, and the low cost of the equipment.

2.1.1. Wii Nintendo®

The Wii Nintendo® video game console was the first virtual reality video game console to be launched on the market. In 2012, it was succeeded by the Wii U®, and in 2017 by the hybrid console Nintendo Switch®. The feature that differentiated the Wii from the rest of the existing consoles at that time was its wireless controllers (the Wii Remote® and Nunchuck®). The controls contain accelerometers and infrared detection that allow the determination of their position in three-dimensional space, detecting changes in direction, speed and acceleration. They also include an internal speaker and vibration. The wireless and movement detection system, through the controller, makes it possible to participate in the game, regardless of position: sitting in a wheelchair, sitting in bed or standing with a walker. This property has favored the Wii® being used by older adults with wheelchair mobility or reduced mobility.

The Wii Balance Board (WBB)® accessory is a balance platform that incorporates a Bluetooth connection and four pressure sensors that detect weight and changes in pressure in any direction, reproducing the player's movements on the screen. WBB® has found a place in clinical practice as a portable and accessible tool for the assessment of balance and the risk of falls [30,31].

WBB®-compatible exergames are related to physical exercise, sports and entertainment. Wii Fit Plus® and Wii Ski® are the most widely used exergames in clinical research. Wii Fit® includes programs for balance exercise, fitness, yoga and aerobics.

In 2020, Nintendo renewed these accessories by designing the Ring Fit Adventures® video game for the Nintendo Switch® console, which includes aerobic exercises for strength, balance and muscle stretching. The player's movements are detected through a Pilates ring (Ring-Con®) and a strap with a controller (Joy-Con®) that is fixed on the left leg. A recent study [32] found that the energy consumption of this video game is higher than that required by other exergames such as Wii Fit or Kinect Adventures.

2.1.2. Xbox® and Kinect®

The Xbox360® is the seventh-generation console produced by Microsoft®. It was introduced in 2005 and has now been succeeded by the eighth-generation Xbox One® (2014) and Xbox Series X® console. The Xbox 360® and Xbox One® incorporate the Kinect® real-time tracking sensor. Its launch in 2010 revolutionized the world of video games, making the Xbox the first console that did not need controllers to be used. In 2013, Microsoft® introduced the Kinect 2® sensor, designed for the new Xbox One® console, which included enhancements such as greater horizontal and a 60-degree vertical field of view, increased perceived depth range, and higher resolution to differentiate the orientation of the body, including hands and fingers.

The Kinect does not require the player to hold a controller to participate in the game, but the cameras and sensors are able to recognize, capture and follow their movement, and display it on the screen, without the need for manual controllers or force platforms, unlike the Wii Nintendo®. This allows physical movements and cognitive responses to take place in a more natural and ecological way.

The Azure Kinect DK® is the latest Kinect sensor from Microsoft®. This new sensor appears to hold substantial promise for functional rehabilitation processes. It was designed to be used in life sciences, fashion, robotics and logistics. It consists of: (1) a 1-MP depth sensor with wide and narrow field of view options; (2) a 7-microphone array to capture far-field sounds and voice; (3) a 12-MP RGB video camera for an additional color sequence; (4) an accelerometer and a gyroscope; and (5) external sync connections.

Although a few adverse effects of the use of Kinect have been described, some disadvantages have also been reflected, such as the need for free space in the rehabilitation department or at home (at least 2 m), the low possibility of the graduation of the speed of the games, and the non-real correlation between the score obtained and motor recovery.

2.1.3. Sony PlayStation EyeToy® and PlayStation Move®

The PlayStation3 is the third game console of the PlayStation model from Sony Computer Entertainment®. It was first marketed in Europe in 2007, and its sales were lower than those of other consoles of the same generation, probably due to its higher cost.

The PlayStation EyeToy® and PlayStation Move® accessories are PlayStation devices for motion recognition. PlayStation Move® is the main controller of the console. It consists of inertial sensors and a sphere of motion at its end. It is handheld and glows in a full range of colors using light-emitting diodes. This light serves as an active marker and is tracked by the PlayStation EyeToy® camera, which uses computer vision and features a dual focus zoom lens for gesture recognition. It also contains a built-in microphone array for multi-directional voice tracking, echo cancellation and background noise suppression.

Studies like that of Neil [33] state that playing with the PlayStation EyeToy® generates a significantly higher activity count than the Wii®, both in healthy populations and in stroke survivors. Other works have also confirmed that the use of the PlayStation is feasible in older adults with disabilities, and in people with stroke [34,35].

The PlayStation exergames most used in clinical practice and research have been Eye Toy Games, Kung-Foo, Keep-Ups, Wishy-Washy [33,34], Goal Attack, Mr. Chef, Dig and Home Run [35,36]. Dance video games have also been combined with balance exercises in older adults [37].

3. Results

3.1. Selection, Graduation and Adaptation of Commercial Exergames to the Rehabilitation of Processes Secondary to SARS-CoV-2

Commercial exergames have the great advantage of being economically accessible and highly motivating. The richness of their graphics and visual, auditory and tactile feedback achieve an active, dynamic and engaged motor response from their players. However, the dynamism of the proposed activities and the multi-feedback emitted by the system can be overwhelming for older people who are in the subacute stage of SARS-Cov-2 infection and are experiencing neuromuscular alterations such as decreased muscle mass and the loss of strength [38,39].

Like any other rehabilitation technique, exergames need to be guided with specific therapeutic objectives that respond to structured planning. Concerns have arisen about the lack of standardized clinical guidelines and treatment protocols for the use of exergames in older people [26,40,41]. Decreased visual or auditory acuity, muscle weakness, the loss of motor dexterity, slow gait speed, or difficulty in processing simultaneous stimuli can hinder the optimal participation in exergames and generate feelings of incompetence, thus risking the loss of the benefits derived from the practice of physical exercise with virtual technology.

Considering the presence of these deficits in older people affected by prolonged periods of hospitalization or preventive confinement, we propose a classification system of exergames based on four global rehabilitation objectives: (1) change and maintain the position of the body, (2) balance, (3) the use of the upper limbs for activities of daily living, and (4) stimulation of cognitive functions. This classification system facilitates the selection of exergames based on the therapeutic objectives identified for each user.

3.1.1. Change and Maintain the Position of the Body

First of all, it is necessary to identify the position in which the exercises are performed. Some exergames can be practiced from a wheelchair and others allow the player to participate only while standing. Most exergames on the Wii® or Wii U® console allow for both positions (sitting and standing); however, the Xbox Kinect sensor has difficulty capturing precise body movements when seated.

Second, the mobility functions to be rehabilitated need to be identified. From a functional perspective, we propose to distinguish four basic functions required for the performance of activities of daily living and included in the International Classification of Functioning, Disability and Health (ICF): getting up, sitting down, bending over or changing the center of gravity of the body [42]. In order to train and improve these functions, exergames can be used that include games related to maintaining balance in different body positions, imitating postures, collecting coins or points located in different parts of the screen, or getting up/sitting down. Table 1 shows exergames containing game activities that include this classification of movements, and that can be applied to optimize functional mobility.

Table 1. Exergames to rehabilitate body position.

	Getting up/Sitting Down	Bending Over	Changing Center of Gravity
Perfect 10 (Wii Fit®)			x
Table Tilt (Wii Fit®)		x	x
Rhythm Parade (Wii Fit®)		x	x
Soccer Heading (Wii Fit®)			x
Leaks (Kinect Adventure)	x	x	x
Ski Jump (Wii Fit®)			
Zazen (Wii Fit®)			
Segway Circuit (Wii Fit®)			
Reflex Ridge (Kinect Adventure®)			
River Rush (Kinect Adventure®)	x	x	x
Super Goalkeeper (Kinect Sport®)		x	x
Crash Test Dummy (Kinect Carnival®)		x	x
Bowling (Kinect Sport®)		x	x
20,000 Leaks (Kinect Adventure®)		x	x
Squats (Ring Fit®)	x		
Bank Balance (Ring Fit®)			x

3.1.2. Balance

Changing balance is especially important for older people because it compromises the safe and efficient performance of activities of daily living and increases the risk of falls [43,44]. Equilibrium has been defined as the ability to control the center of gravity on the support base itself and in the event of unforeseen events caused by external environmental factors [45]. Four different balance training modalities have been identified: the bipodal and unipodal static balance (balance in a stable position), dynamic balance (balance when walking), proactive balance (balance to maintain the functional range) and reactive balance (compensation for the unexpected) [46,47].

There is evidence that exergames such as Wii Fit and the Wii Balance Board (WBB) are useful for the assessment of balance ability. Sato [48] found that evaluations carried out with Wii Fit exergames and slalom skiing correlated with the results of the Sensory Integration Clinical Test in the measurement of the center of pressure. Similar results were obtained when comparing the measurement of exergames with high cost posturography systems [49] and force platforms [50,51], concluding that WBB is an economic resource to evaluate the shifting of the center of pressure.

In contrast, evidence has also been found that multicomponent programs that include exergames are effective in improving the balance of older people and lowering the risk of falls [52–54]. Exergaming encourages older people to perform movements that are part of the so-called Systems Framework for Postural Control (SFPC) [55,56], such as: bending over while standing, moving the upper limbs and turning the head simultaneously, coordinating movements of the lower and upper limbs, and moving the body back and forth or perform a double task while standing. Exergames such as Wii Fit, Kinect Adventures, Kinect Sport or Kinect Carnival include game activities that motivate the performance of these types of movements in a dynamic and progressive way. Table 2 details the movements included in each of these exergames. WiiSki® has ski and snowboard variants, and is clinically used to train the shifting of the center of gravity and balance. Other Wii exergames used for the prevention or rehabilitation of functional impairment that do not require the use of WBB are: Wii Sports®, Wii Resort® or Big Brain Academy®.

Table 2. Exergames to rehabilitate balance.

	Bipodal Static Balance	Unipodal Balance	Dynamic Balance	Proactive Balance
Soccer Heading (Wii Fit®)	x			
Ski Slalom (Wii Fit®)	x		x	
Ski Jump (Wii Fit®)	x		x	
Table Tilt (Wii Fit®)	x		x	
Tightrope (Wii Fit®)	x		x	
River Rush (Wii Fit®)	x		x	x
Penguin Slide (Wii Fit®)	x		x	
Obstacle Course (Wii Fit®)	x		x	
Cycling (Wii Fit®)	x		x	
Running Plus (Wii Fit®)	x		x	
Rhythm Kung Fu (Wii Fit®)	x	x	x	
Rhythm Parade (Wii Fit®)	x		x	
Skateboard (Wii Fit®)	x		x	
20,000 Leaks (Kinect Adventure®)	x	x	x	x
Super Striker (Kinect Sport®)		x		
Soccer (Kinect Sport®)		x	x	
Table Tennis (Kinect Sport®)	x		x	x
Bowling (Kinect Sport®)	x		x	
Super Goalkeeper (Kinect Sport®)	x		x	x
Ski (Kinect sport®)	x		x	x
Track and Field (Kinect Sport®)	x		x	
Bank Balance (Ring Fit®)	x		x	x

3.1.3. Promote the Use of the Upper Limbs for the Activities of Daily Living

Upper limb functionality has been identified as an index of frailty in older people [57–59]. Periods of hospitalization and prolonged time in bed trigger the loss of muscle mass and strength in the arms, which reduces the performance of the activities of daily life—such as personal hygiene, dressing or housework—and generates high levels of dependency. Sports exercises such as tennis, table tennis, bowling, golf or basketball could help improve the mobility and muscle strength of joints such as the shoulder and elbow. Table 3 proposes different exergames to plan an exercise program aimed at restoring the functionality of the upper limbs.

Table 3. Exergames to rehabilitate upper limb functionality.

	Upper limbs Below the Shoulders	Upper Limbs Above the Shoulders
Rhythm Parade (Wii Fit®)	x	
Rhythm Kung-Fu (Wii Fit®)	x	
Golf (Wii Fit®)	x	x
Big Top Juggling (Wii Fit®)	x	x
Tilt City (Wii Fit®)	x	
Tennis (Wii Sport®)	x	
Bowling (Wii Sport®)	x	
Golf (Wii Sport®)	x	x
Boxing (Wii Sport®)	x	x
Baseball (Wii Sport®)	x	
Tennis (Kinect Sport2®)	x	
Darts (Kinect Sport2®)	x	
Table Tennis (Kinect Sport®)	x	
Super Goalkeeper (Kinect Sport®)	x	x
Beach Volleyball (Kinect Sport®)	x	x
Boxing (Kinect Sport®)	x	
Tennis (Kinect Sport®)	x	
20,000 Leaks (Kinect Adventures)	x	x
Space Pop (Kinect Adventures®)	x	x
Leaks (Kinect Sport®)	x	x
Crushing Blow (Kinect Sport®)	x	x
Robo-Wrecker (Ring Fit®)	x	
Crate Crasher (Ring Fit®)	x	
Smack Back (Ring Fit®)	x	
Bank Balance (Ring Fit®)	x	
Squattery Wheel (Ring Fit®)	x	

3.1.4. Stimulation of Cognitive Function

Recent trials have detected short-term memory deficits [60], decreased attention and disorientation [61], and the exacerbation of neuropsychiatric symptoms [62] in older patients admitted with SARS-CoV-2 infection without a prior diagnosis of dementia. In the case of people with dementia, coronavirus infection has been found to exponentially accelerate the course of the disease. A study carried out in Spain found that, during confinement, 70% of patients abandoned previous daily activities and 60% had cognitive decline reported by relatives [63].

Exergaming, by combining physical and cognitive exercise in an interactive environment, can act as a stimulating tool for cognitive function. Systematic reviews coincide in pointing out promising results on cognitive function in older people, using exergames to improve the levels of orientation, attention and executive functions [64–66]. Exergames like Brain Training®, Dr. Kawashima®, or Kinect Adventures® can be helpful in stimulating cognitive functions such as attention, concentration, sequencing and processing speed.

4. Discussion

The aim of this work was to study the potential of exergaming in the rehabilitation of older people who are in periods of confinement, or who have had SARS-CoV-2 infection.

The analysis of commercial exergames revealed their versatility in both standing and seated positions. This property is important, because it may allow the progressive planning of rehabilitative treatment. In this regard, previous studies have reported the successful adaptation of Wii exergames for people with reduced mobility and wheelchair users [67]. Moreover, Kinect exergames can improve the muscle strength needed for wheelchair propulsion [68]. It therefore seems reasonable that exergames can contribute to the rehabilitation of older people who have lost mobility after hospital admissions for Covid-19.

Regarding balance rehabilitation, certain exergames such as WiiFit® include specific activities to improve anteroposterior and lateral balance. Previous systematic reviews and meta-analyses confirmed that exergaming increases balance and prevents the risk of falls in older people [40,46,54]. In our analysis, we found that 90% of the exergames contained games with which static bipodal balance and dynamic balance could be trained. However, the functional analysis revealed that only 30% could train proactive balance, and only 18% could train unipodal balance. These results could be of interest for the design of new exergames aimed at balance rehabilitation.

The rehabilitation of upper limb functionality with virtual reality has been explored mainly in people with stroke [69,70] or multiple sclerosis [71,72]. Our analysis showed that exergaming can also be used to train upper limb mobility below and above the shoulder girdle, improving the overall functional range of elderly people. It would be interesting to explore this aspect in future research.

Finally, our analysis is not without limitations. Firstly, we did not analyze all of the exergames available on the market, although we selected the most popular and best-selling ones. Moreover, other body functions, such as specific lower limb functions, were not considered in the analytic variables, as we selected global functions related to the performance of the activities of daily living.

5. Conclusions

Older people are more likely to suffer more serious and persistent consequences from SARS-CoV-2. Low-cost virtual-reality technology, such as exergames or active video games, can be used to prevent functional impairment, or to rehabilitate motor and cognitive functions. However, it is necessary to prescribe virtual exercises based on rehabilitative criteria tailored to the symptoms in each case, which requires an individualized evaluation of the patient, taking into account the variability of symptoms and sequelae associated with SARS-CoV-2 and an exhaustive analysis of each exergame. Our proposal was based on the use of exergames from Wii and Xbox consoles to prevent and/or rehabilitate the appearance of problems associated with postural control, balance maintenance, upper limb functionality and cognitive stimulation. With this analysis, we provided relevant information to rehabilitation staff to make decisions which allow them to select the games efficiently, based on the type of exercise offered by the game, its level of challenge and the possibilities of graduation based on the therapeutic objectives.

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