Physical Functionality in Older Adults Through Interactive Digital TV Intervention

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Abstract. The geriatric population worldwide is rapidly growing, accompanied by an increase in chronic diseases and disabilities. Rehabilitation plays a crucial role in maintaining and improving independence and quality of life in this group. This study focused on determining the use of interactive digital television as a rehabilitation tool to prevent and/or reduce the risk of falls in older adults.

Functional gait tests were used to identify the type of fall risk. To evaluate the emotions while using interactive television application the Self-Assessment Manikin was used. The body composition was measured through anthropometric parameters.

After 29 exercise sessions, positive impacts on physical function and mood were observed, with significant improvements in flexibility, muscle strength, balance, and gait. These results suggest that interactive digital television could be a useful platform to improve the quality of life of older adults.

Keywords: Plex · Digital Television · Exercises · Geriatric Assessment · Anthropometric Parameters · Older Adults

1 Introduction

The aging process involves various biochemical, physiological, morphological, social, psychological, and functional changes that affect the autonomy, functional independence, and quality of life of older adults [1]. It is associated with the loss of neuromuscular function and performance, partly related to the reduction of muscle strength and power [2, 3].

Therefore, functionality in older adults is crucial for active aging programs [4]. Physical activity is fundamental to maintain a healthy lifestyle and positively affects

M. J. Abásolo et al. (Eds.): jAUTI 2023, CCIS 2140, pp. 51–65, 2024.
https://doi.org/10.1007/978-3-031-70439-0_4

overall health and well-being [5]. Evaluating the ability to perform activities of daily living (ADLs) such as climbing stairs, lifting objects, or walking is essential in geriatric assessment [6–8]. Population aging will increase health problems, especially those related to functionality [9]. The demand for physical therapy and rehabilitation services is increasing, especially among older adults [10]. Given the growing aging population, it is crucial to explore new interventions to improve physical function, prevent injuries, and reduce the risk of chronic diseases in older adults [11, 12].

Assistive technologies [1] are an important tool to address the challenges of aging, offering opportunities to improve healthcare and promote healthy lifestyles on a larger scale [5]. Furthermore, these innovative solutions [2] such as virtual reality, artificial intelligence, and telecare can overcome the limitations of access and costs associated with in-person therapy, such as geographical distance or high costs [11].

Alongside the rest of the world, Ecuador is also facing an increase in the number of older adults. This phenomenon presents significant challenges in accessing medical care [12]. In this scenario, home exercise programs can reduce frailty and fall risk, and improve the quality of life of older adults [13–15]. In current study, we have created an interactive training program that allows older adults to continue treatment at home using interactive digital television. With the tool described in this paper, individuals can perform exercises evaluated and constructed by physical therapists, complementing follow-up and evaluation of their progress.

This article presents the research results and is organized as follows: Sect. 2 describes the materials and methods used in the study. Section 3 presents the experimental findings obtained. Section 4 argues the discussion of these findings. Finally, the conclusions of the study are presented in Sect. 5.

2 Methods

2.1 Participants

The elderly who attend the Dr. Arsenio de la Torre Marcillo Gerontological Center, which has an agreement with the Catholic University of Santiago de Guayaquil, were invited to participate in the study. The aim of the study was to prevent and/or reduce the risk of falls using an interactive digital television application.

To select the participants, inclusion and exclusion criteria were defined by two of the researchers, both physiotherapists. Between May and June 2023, elderly individuals from this center were recruited, and evaluations were conducted in June 2023. All participants provided written informed consent before joining the study and were selected according to a set of detailed criteria presented in Table 1.

Initially, twenty-five elderly individuals were recruited, but only sixteen independent ones, aged between 65 and 84 years with possible mobility disorders, met the established selection criteria.

2.2 Measurement Procedures

The entire evaluation and follow-up process was carried out by physical therapy faculty members with more than five years of experience to reduce biases [1]. A medical record was created where personal data, medical, and family history were requested.

Table 1. Criteria for the selection

Inclusion	Exclusion
- Able to walk independently - Follow simple instructions - No severe cognitive disorders -Have a Smart TV with Android operating system - Internet service	-Auditory/visual impairments that prevent interaction with the Smart TV - Hemispatial neglect - Ataxia - Unresolved traumatic injuries such as fractures - Comprehensive memory impairments

Each participant (Fig. 1) underwent anthropometric measurements: weight (kg), height (cm), and body mass index (BMI). A calibrated digital scale and stadiometer were used, following established protocols, to calculate BMI using the formula weight (kg)/height $(cm)^2$ [16].

For the assessment of fall risk (Fig. 2), the following tests were applied:

i) The Tinetti scale has two domains: gait and balance. Its main objective is to detect the risk of falls. Its predictive value is higher than the value in the muscle test [17, 18]. It consists of two parts: the first is balance, which consists of nine tests: 1) sitting balance; 2) rising; 3) attempts to rise; 4) immediate balance after rising; 5) balance while standing; 6) push; 7) eyes closed; 8) 360-degree turn; and 9) sitting down. The second part, gait, consists of 7 tests: 1) initiation of gait; 2) step length and height; 3) step symmetry; 4) step continuity; 5) path; 6) trunk; and 7) walking posture. The maximum score for the gait subscale is 12, and for balance, it is 16. The sum of both scores determines the risk of falls. When the score is high, the risk of falls is lower; conversely, when it is low, the risk of falls increases [19]. The classification of fall risk was: <= 18 points, high risk of falls; between 19–24, moderate risk of falls; and >24, low risk of falls [20].
ii) The timed Get Up and Go test is an auxiliary test in the diagnosis of gait and balance disorders and their association with a determined risk of falls. The application time is 10 min, and the classification of fall risk was: >13 s, high risk of falls; between 11–13, moderate risk of falls; and <10 s, low risk of falls [21].

To evaluate emotions concerning the digital TV application, the Self-Assessment Manikin (SAM) was used, a tool that measures three emotional dimensions: pleasure, arousal, and dominance. This instrument consists of three groups of pictograms with humanoid figures, one for each dimension of emotion. Each group consists of 5 drawings and four spaces between them, allowing the subject to move within a range of 9 points per dimension [22]. Regarding the meaning of the dimensions:

– Pleasure: refers to how a person experiences emotions (smiling – angry).
– Arousal: determines the intensity or level of energy associated with the mood (calm -aroused).
– Dominance: refers to the feeling a person has about controlling their own emotions at a given moment (low or highly dominated).

a) b)

Fig. 1. Evaluation of anthropometric measurements in older adults: a) Dynamometry; b) Height measurement

a) b)

Fig. 2. Assessment of fall risk in older adults: a) Balance or gait test; c) Administering the timed Up and Go test

2.3 Intervention Protocol

A proprioceptive exercise program focused on improving strength, muscular endurance, coordination, and stability for fall prevention in older adults was implemented. The program lasted 29 sessions, divided into five phases:

- **First phase:** Socialization. A meeting was held with all older adults in the Biomechanics laboratory of the Faculty of Health Sciences at the Catholic University of Santiago de Guayaquil, Ecuador. During this meeting, the research and program were introduced.
- **Second phase:** Initial evaluation. Anthropometric measurements were taken, and the Tinetti and Timed Up and Go scales were applied.
- **Third phase:** Adaptation. A forty-minute adaptation session with the tool was conducted.
- **Fourth phase:** Intervention. This phase consisted of twenty-nine work sessions that included flexibility, muscle strengthening, and balance exercises. At the beginning of

each session, a warm-up with joint movements was performed, and at the end, static stretches of the main muscle groups were done. Each session lasted 30 min, distributed among different types of training. The first fifteen sessions were carried out in the university laboratory. During the exercise, the older adults were assisted by a physiotherapist, who provided postural corrections and feedback when necessary. At the end of the first session, the participants' emotional response was evaluated using the Self-Assessment Manikin (SAM). Instructions were given explaining the objective and how to assess the emotions of Pleasure, Excitement, and Dominance, strictly following an established protocol [23]. Subsequently, another fourteen work sessions were conducted at the participants' homes, following the protocol used during the intervention phase.

– **Fifth phase:** Final evaluation. The same data collection instruments as in the second phase were applied, and additionally, the Self-Assessment Manikin test.

Table 2 shows the rehabilitation training macrocycle, which lasted six months. It describes the different intervention phases and the corresponding training volume for each phase.

Table 2. Planning of the intervention program

Month	June				July				August				September				October				November				
# Month	1				2				3				4				5				6				
Week Number	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	
Week Start Date					1	8	15	22	29	5	12	19	28	4	11	18	25	2	9	16	23	30	6	13	Total
Week End Date					7	14	21	28	4	11	18	25	3	10	17	24	1	8	15	22	29	5	12	19	
Days W x Week						2	2	2	2	2	2	2	1			2	2	2	2	2	2	2			
Sessions x Week						2	2	2	2	2	2	2	1			2	2	2	2	2	2	2			29
Hours x Week						1	1	1	1	1	1	1	0,5			1	1	1	1	1	1	1			14,5
(1)Socialization Phase	✓																								
(2)Initial Assessment Phase	**Pre test**																								
(3)Adaptation Phase					✓																				
(4)Intervention Phase						✓	✓	✓	✓	✓	✓	✓	✓			✓	✓	✓	✓	✓	✓	✓			
(5)Final Assessment Phase																									**Post test**
																									Tot. Vol. (meso(min)
Meso Volume (min)									480											420					900
Weekly Volume (min)						60	60	60	60	60	60	60	60			60	60	60	60	60	60	60			900
(1)Adaptation Phase					100%																				
(4)Intervention Phase									100% (Institution)								100%(Spatial)								

W: weekly; Vol.: volume; hr: hour; meso: mesocycle

Source: Adaptation of the planning model of Matvéiev [24]

2.4 Intervention and Control

The participants interact with the PLEX application interface to perform the training tasks with the 9 exercise videos on smart TV screens. Priority was given to the fluidity of navigation and selection of exercise videos on the TV, as well as the ergonomic design of the Chromecast remote control. For the first fifteen work sessions with the PLEX application, we installed a 32-inch Riviera TV, model RLED-DSG32HIK5600, equipped with an Android operating system, in the biomechanics laboratory of our

institution. In collaboration with the Faculty's IT support area, configuration tests were carried out (Fig. 3).

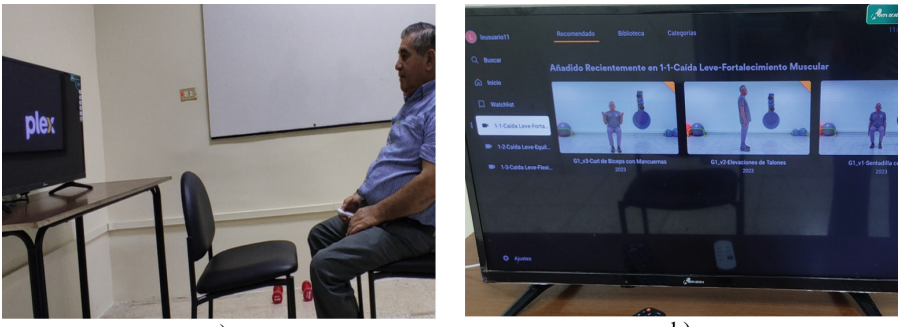
a) b)

Fig. 3. Implementation of the tool for smart TVs: a) Plex installed on the smart TV; b) User access

These tests were performed in various cases and scenarios to ensure proper access to the library of adapted and personalized exercises for each older adult, according to the diagnosis of their functional evaluation, as well as to verify the accessibility of the videos hosted on a Network Attached Storage (NAS).

Older adults received individual instructions on how to use the tool during a forty-minute adaptation session, days before starting the first fifteen rehabilitation treatment sessions (Fig. 4). Subsequently, to continue the program, Plex was installed in each individual's home in the fifteenth week, allowing them to continue with rehabilitation during the remaining fourteen sessions.

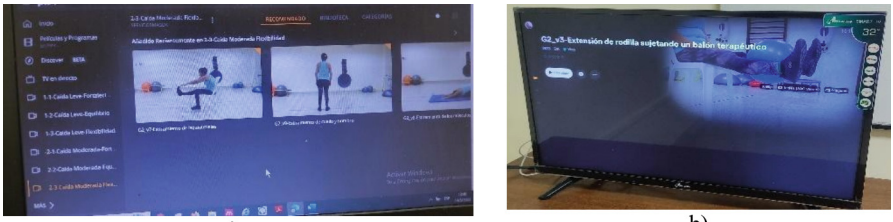
The intervention did not have direct supervision. However, telephone follow-up was carried out with the participants at the end of weeks 17 to 22 to facilitate compliance and resolve any difficulties with the tool. If difficulties were encountered with accessing the exercise video library in Plex, the possibility of additional home visits was offered. Nevertheless, this option was never required due to all participants' willingness to use the tool.



a) b)

Fig. 4. Personalized multimedia platform for smart TVs: a) Patient using Plex on smart TV; b) Access to muscle-strengthening exercises on a smart TV

The intervention consisted of 27 exercise videos, distributed into 9 categories according to the risk of falls (mild, moderate, and severe), in MP4 format with a resolution of 1920 × 1080 pixels and using the MPEG-4 video codec. To optimize understanding and learning, instructional scripts were created for the videos, prioritizing the clarity and effectiveness of the instructions (Fig. 5).



a) b)

Fig. 5. Exercise platform to prevent falls: a) Plex exercise library on smart TV; b) Smart TV showing therapy ball knee extension exercise on Plex

2.5 Exercise Design

Based on a review of scientific articles [25, 26], exercises that were effective in reducing and preventing the risk of mild, moderate, and severe falls to improve an individual's functional capacity were established. These exercises are designed to increase strength, balance, coordination, and stability in older adults, following a 30-min exercise protocol during 29 sessions, twice a week.

Exercises for mild falls are designed for situations where there is less risk of falling, such as tripping over a small object or slightly uneven ground. These may include simple actions that improve posture and balance awareness, such as standing on one leg, walking in a straight line with eyes closed, heel raises, among others, as illustrated in (Fig. 6).

Exercises for severe falls are designed for individuals who have already experienced a fall or have a high risk of falling. These exercises should be performed under the supervision of a physical therapist or healthcare professional. These may include resistance and strength training to strengthen the core and leg muscles, to reduce the risk of injuries, as shown in (Fig. 8).

Exercises for moderate falls are designed for situations where there is a greater risk of falling, such as losing balance while walking on a wet or uneven surface. Other exercises are illustrated in (Fig. 7).

3 Results

The statistical package SPSS V22 was used to obtain descriptive statistics, measures of central tendency (mean, minimum, maximum, and mode), and measures of dispersion (standard deviation, minimum, and maximum). Two non-parametric statistical tests were applied (Wilcoxon and Friedman), which are used to work with small population samples [27].

The Wilcoxon test was used to compare two related variables when the data was not normally distributed. This test was used to compare the group before and after the intervention (i.e., related samples) with the Tinetti scale and the Get Up and Go [28].

The Friedman test was used to compare three or more related variables (pleasantness, emotion, and control). This test examined the ranks of the data generated in each time period that was evaluated with the SAM test to determine if the variables share the same continuous distribution of their origin [29].

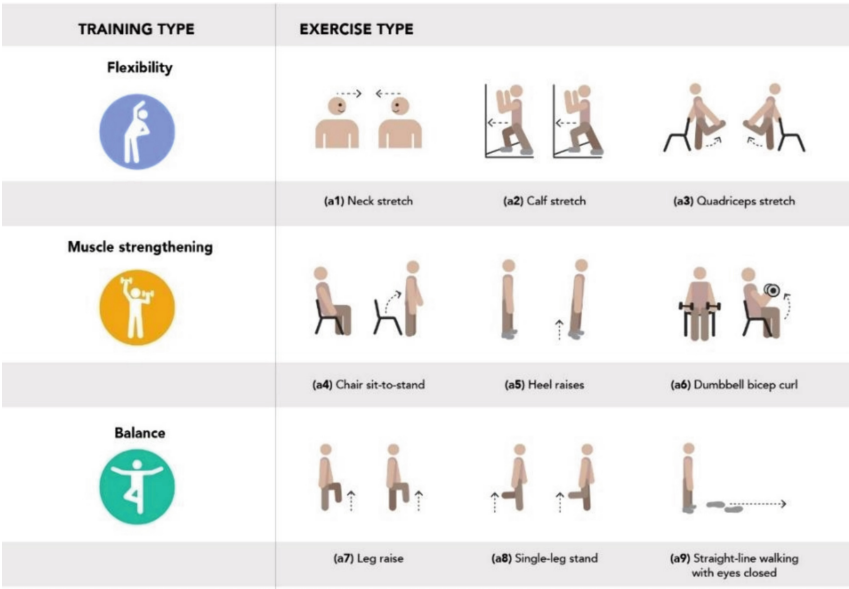


Fig. 6. Description of exercises for the patient with a mild risk of falls

A significance level of $p < 0.05$ was considered for both statistical tests. The study population initially consisted of sixteen older adults of both sexes who participated in the 15 baseline sessions conducted in the Biomechanics laboratory. However, only ten older adults continued with the exercise program in the 14 subsequent sessions scheduled at home. Therefore, the results obtained are only based on the group that completed all the routines from the first to the last session of the program.

Table 3 shows the body composition before and after using digital television for physical exercise. A reduction was observed in the values of: body weight (68.65 ± 11.87 vs 65.13 ± 12.10; $\Delta = -3.49$; $p > 0.013$), waist circumference (89.28 ± 7.22 vs 84.40 ± 7.67; $\Delta = -4.88$; $p < 0.003$), BMI (29.23 ± 3.56 vs 26.43 ± 4.31; $\Delta = -2.80$; $p > 0.007$), body fat (38.78 ± 6.71 vs 34.69 ± 7.90; $\Delta = -4.09$; $p > 0.007$) and visceral fat (1.63 ± 0.90 vs 1.63 ± 0.68; $\Delta = 0.00$; $p < 0.005$). However, an increase in lean mass was observed (64.16 ± 11.82 vs 67.30 ± 13.77; $\Delta = +3.14$; $p > 0.011$), as detailed in Table 3.

Regarding the results of Table 4 on the assessment of balance and gait using the Tinetti Scale, it was observed that the mean was 22.40 in the initial assessment and 26.20 in the

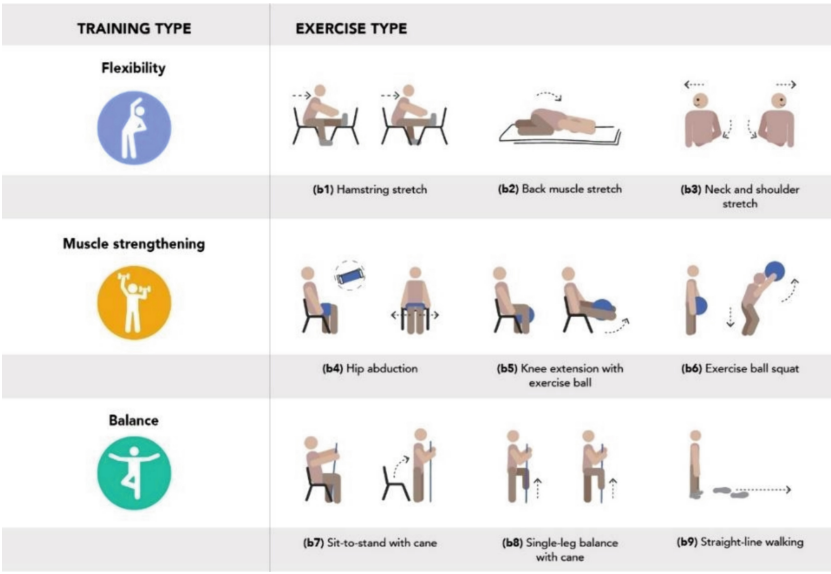


Fig. 7. Description of exercises for the patient with a moderate risk of falls

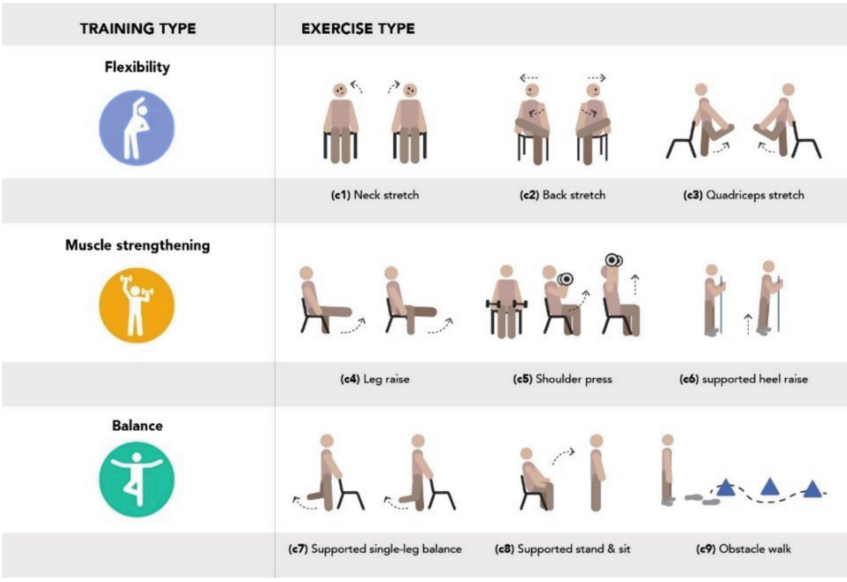


Fig. 8. Description of exercises for patients at risk of severe falls

final assessment. The standard deviation was 4.14 in the initial assessment and 2.49 in the final assessment. The minimum score recorded was 18 in the initial assessment and 22 in the final assessment, while the maximum was 28 in both assessments. In relation

to the results of the Get Up and Go test, it was observed that the mean time was 12.09 s in the initial assessment and 9.92 s in the final assessment. The standard deviation was 1.94 s in the initial assessment and 1.64 s in the final assessment. The minimum time recorded was 9.76 s in the initial assessment and 7.22 s in the final assessment, while the maximum time was 15 s in the initial assessment and 13 s in the final assessment.

Table 3. Body composition before and after using interactive digital television.

Variable	Before		After		
	Mean ± SD	Min - Max	Mean ± SD	Min - Max	P-value*
Weight (Kg)	68,65 ± 11,87	42,15–82,35	65,16 ± 12,10	40,7–78,40	0,013
Waist Circumference (cm)	89,28 ± 7,22	78–100	84,40 ± 7,67	70,2–93,30	0,003
BMI (Kg/m^2)	29,23 ± 3,56	22,80–34,28	26,43 ± 4,31	20,20–33,30	0,007
Body Fat (%)	38,78 ± 6,71	28,50–49,70	34,69 ± 7,90	18,20–45,40	0,007
Visceral Fat (%)	1,63 ± 0,90	1,20–3,70	1,63 ± 0,68	0,77–2,50	0,005
Lean Mass (%)	64,16 ± 11,82	50,30- 91,90	67,30 ± 13,77	53,50–97,60	0,011

SD: standard deviation

Table 5 presents the classification of the variable "fall" at two different time points. In the initial evaluation, it will be ensured that 40% of older adults are classified as having a severe risk of falls, 30% with a moderate risk of falls, and 30% with a mild risk of falling. However, in the final evaluation, a significant change was observed: 70% of the participants shifted to a mild risk of falls, while the remaining 30% remained at a moderate risk of falls. It is important to note that no older adults without a severe risk of falls were recorded in either evaluation. These results suggest that the interventions or treatments implemented between the initial and final evaluations have had a positive impact on reducing the risk of falls in the studied population of older adults. The hypothesis contrast test between the initial and final fall risk, performed with the Wilcoxon non-parametric test for two related samples, showed a statistical significance of $p < 0.05$. Therefore, the null hypothesis is rejected, which indicates that the use of the exercise program using the application with interactive digital television in static and dynamic balance is effective in preventing falls in older adults who participated in the study.

Table 6 shows the classification of the variable "fall" in the initial assessment. Before the intervention, it is observed that 40% of older adults were classified in the category of severe risk of falls, while 20% were at moderate risk and another 40% at mild risk of falls. This indicates an equitable distribution among the three risk levels before the intervention. After the intervention, a notable change in the distribution of older adults across different risk levels is observed. 80% of the participants shifted from being at mild risk of falls before the intervention to remaining in that category afterward. Additionally, the 20% who were at moderate risk of falls before the intervention remained in that

category afterward. However, it is important to note that no older adults were registered in the severe risk category of falls after the intervention. The hypothesis contrast test between the initial and final fall risk, performed with the Wilcoxon non-parametric test for two related samples, showed a statistical significance of $p < 0.05$. Therefore, the null hypothesis is rejected, which indicates that the use of the exercise program using the application with interactive digital television in mobility and functionality is effective in preventing falls in older adults who participated in the study.

Finally, to assess the level of satisfaction with the use of digital television through the emotional responses of the 10 older adults, statistically significant differences were observed in three stimuli: pleasure, dominance, and arousal ($p < 0.05$), using the PLEX application. Further details are provided in Table 7.

Table 4. Results of the Initial and Final Assessment of Fall Risk, according to the Tinetti Scale and Get Up and Go with the use of interactive digital television

Descriptives	Initial Tinetti Scale	Final Tinetti Scale	Initial Get Up And Go Test	Final Get Up And Go Test
Mean	22,40	26,20	12,09	9,92
Mode	18	28	15	10
SD	4,14	2,49	1,94	1,64
Minimum	18	22	9,76	7,22
Maximum	28	28	15	13

Table 5. Results of the Initial and Final Assessment with the Tinetti Scale

Score	Diagnosis	Before	After	P-value*
>24 points	Low Fall Risk	3[30]	7[70]	0,007
19–24 points	Moderate Fall Risk	3[30]	3[30]	
<+ 18 points	Severe Fall Risk	4[40]	0[0]	

Table 6. Results of the Initial and Final Assessment with the Get Up and Go Test

Score	Diagnosis	Before	After	P-value*
<10 sg	Low Fall Risk	4[40]	8[80]	0,005
11 a 13 sg	Moderate Fall Risk	2[20]	2[20]	
>13 sg	Severe Fall Risk	4[40]	0[0]	

Table 7. Results of Emotional Responses Before and After Using the Self-Assessment Manikin Test

Emotional Responses	Before		After		
	Mean ± SD	Min - Max	Mean ± SD	Min - Max	P-value*
Pleasantness Stimulus	7,20 ± 1,75	5,00–9,00	8,60 ± 0,516	8,00–9,00	0,026
Control Stimulus	7,88 ± 1,23	5,00–9,00	9,00 ± 0,00	8,00–9,00	0,016
Activation Stimulus	7,00 ± 1,33	5,00–9,00	8,70 ± 0,48	8,00–9,00	0,011

4 Discussion

The purpose of this study was to investigate how interactive digital television can be used by older adults to perform exercises to prevent or follow up on rehabilitation treatment to reduce the risk of falls.

The study focused not only on evaluating how participants manage this technology but also on measuring changes in their anthropometric measurements before and after participating in the intervention exercise programs.

A reduction was observed in body weight (3.49 kg), waist circumference (4.88 cm), BMI (2.80 kg/m^2), body fat (4.09%), and visceral fat (0.00%). However, an increase in musculoskeletal mass (3.14%) was observed.

Although studies on different technological tools and changes in body composition are limited, research conducted in older adults where the effect of physical activity programs on body composition is measured has indicated that long-term muscle strength training can be effective in improving muscle mass, functional strength, physical capacity, and reducing fat mass in older adults [30].

On the other hand, according to the study by [31], exergames, also known as digital exercise games, improve various aspects of gait in older adults. During a 12-week training program, participants engaged in interactive activities that challenged their balance and coordination. Variables related to gait (speed, cadence, time, step length, and step width) were assessed before and after training. The results showed significant improvements in walking after the training program. Additionally, positive changes in body composition were observed, with a reduction in body fat and an increase in fat-free mass after training.

Using the Self-Assessment Manikin (SAM) test in our study, we observed an increase in the emotion experienced in the dimensions of "pleasantness," "control," and "activation" before and after using the PLEX application (7.20 vs 8.60; 7.88 vs 9.00; 7.00 vs 8.70 respectively).

The results obtained in this study are similar to previous research carried out in the same population, although using different technological tools. For example, in the study "Games for a Better Life: Effects of Playing Wii Games on the Well-Being of the Elderly in a Long-Term Care Facility", the SAM was used to evaluate the health effects of older adults participating in activities with the Wii console in nursing homes. After 8 weeks of participation, an improvement in positive emotions and a decrease in negative emotions was observed [32].

In another pilot intervention study titled "Exercise Games for Subsyndromal Depression in Older Adults: A Pilot Study of a Novel Intervention" [33], which explored the use of exercise games in older adults with subclinical depressive symptoms, the SAM was also used to assess emotional state. It was found that after performing exercises with interactive games of dance, baseball, bowling, tennis, and boxing on the Xavix console, there was a significant improvement in the evaluation of pleasure and arousal according to the SAM.

5 Conclusion

This study focused on determining the use of interactive digital television as a rehabilitation tool to prevent and/or reduce the risk of falls in older adults. There were multiple significant benefits for older adults who participated in the exercise program designed for fall risk prevention, using the PLEX application interface. Firstly, a notable reduction was observed in body weight, waist circumference, body mass index (BMI), body fat, and visceral fat, while there was an increase in lean muscle mass. Additionally, the evaluations of the Tinetti Scale and the Get Up and Go test evidenced a substantial improvement in balance and gait in the participants. A key finding was the significant decrease in the risk of falls, with 70% of older adults shifting to a mild risk after the intervention.

Statistically significant differences were observed in the levels of pleasure, dominance, and emotional arousal of the participants, as measured by the Self-Assessment Manikin, suggesting an improvement in their emotional state and satisfaction with the use of interactive digital television for performing physical exercises focused on fall prevention.

However, it is crucial to acknowledge some limitations of the present study. The sample was limited to a few participants, which restricted the generalization of the results. Additionally, it focused on a population with access to technology, which may not be representative of all elderly communities. Future research should expand the sample size, consider greater demographic diversity, and conduct comparative studies that evaluate different technological and traditional interventions, as well as their long-term effects on fall prevention and quality of life improvement.

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