Clinical Benefits of an Exergame-Based Multicomponent Training Program Using “WarioWare: Move It!” for Older Adults in Rural Long-Term Care Facilities

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Abstract

Background: Cognitive impairment is prevalent among older adults and frequently misdiagnosed or diagnosed late, increasingly drawing attention as a significant health issue in aging populations. Compared to community-dwelling individuals, cognitive impairments are more common among residents of long-term care facilities (LTCFs). These facilities face challenges implementing organized exercise programs due to a shortage of professional caregivers and limited resources. Additionally, older adults may lose interest in repetitive interventions over time. “WarioWare: Move It!” by Nintendo, a novel exergame that combines aerobic exercise, body coordination, balance training, and cognitive tasks, provides an immersive experience to enhance motivation and reduce staff intervention, presenting a potential solution.

Objective: This study aims to assess the clinical effectiveness of an exergame-based training program delivered via “WarioWare: Move It!” in improving physical flexibility, joint range of motion, motor coordination, hand dexterity, and cognitive function in elderly residents of LTCFs.

Methods: The training program was conducted across multiple rural LTCFs in Shanxi Province, involving participants aged 65 and older. Participants were randomly assigned to either the intervention group (receiving the “WarioWare: Move It!” intervention) or the control group (receiving standard care). The intervention involved motion-sensing actions and postures (such as waving, jumping, arm swinging, rotating, and mimicking object movements) using the Joy-Con controllers for 60 minutes twice a week over 12 weeks. Primary outcome measures were derived from a battery of clinical tests, including the Sit and Reach test (the distance between the hands and toes when reaching forward), Shoulder Flexibility test (the distance between hands clasped behind the back), Trunk Rotation Flexibility test (the angle of the waist rotation to each side), Shoulder Range of Motion test (the angles of shoulder flexion, extension, abduction, and adduction), Elbow Range of Motion test (the angle of elbow flexion), Figure-of-Eight Walk test (completion time), Standing Balance test (balance duration), Hand Dexterity test (the number of blocks moved by the dominant hand in one minute), and Cognitive Function tests (e.g., Cognitive Abilities Screening Instrument, the Chinese version of the Mini-Mental State Examination, and the Montreal Cognitive Assessment). Statistical analysis was performed using mixed ANOVA, with time as the within-subject factor and intervention group as the between-subject factor, to assess the training effects on the various outcome measures.

Results: A total of 232 participants were recruited and randomly assigned to the intervention group, including 18 (56%) with mild dementia, 9 (50%) with moderate dementia, and 89 (49%) with mild cognitive impairment. The mixed ANOVA results revealed significant group × time interactions across several physical flexibility assessments. Specifically, the remaining distance between the hands and toes during the forward bend showed a significant interaction ($F = 8.484$, $P < 0.001$, $?^2 = 0.098$), as did the distance between the hands clasped behind the back ($F = 3.666$, $P = 0.035$, $?^2 = 0.045$) and the angle formed by the trunk during left and right waist rotation ($F = 17.353$, $P < 0.001$, $?^2 = 0.182$). Significant group × time interactions were also observed for forward flexion ($F = 17.655$, $P < 0.001$, $?^2 = 0.185$) and abduction ($F = 6.281$, $P = 0.004$, $?^2 = 0.075$) of the shoulder joint, as well as for elbow flexion ($F = 17.353$, $P < 0.001$, $?^2 = 0.041$). Similarly, a significant group × time interaction was found for the time taken to complete the Figure of Eight Walk test ($F = 11.846$, $P < 0.001$, $?^2 = 0.132$). Additionally, a significant group × time interaction in the number of blocks moved within one minute ($F = 4.016$, $P = 0.022$, $?^2 = 0.049$). Lastly, all scale scores exhibited significant group × time interactions (all $P < 0.001$), with effect sizes of 0.145 for the Cognitive Abilities Screening Instrument, 0.406 for the Mini-Mental State Examination, and 0.169 for the Montreal Cognitive Assessment.

Conclusions: The “WarioWare: Move It!” intervention significantly improved physical flexibility, joint range of motion, motor coordination, hand dexterity, and cognitive function in older adults with mild cognitive impairment or dementia residing in rural LTCFs. The intervention offers an innovative and feasible approach for promoting elderly health in resource-limited settings, demonstrating potential for widespread application in similar environments.

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Clinical Benefits of an Exergame-Based Multicomponent Training Program Using “WarioWare: Move It!” for Older Adults in Rural Long-Term Care Facilities

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Abstract

Background: Cognitive impairment is prevalent among older adults and frequently misdiagnosed or diagnosed late, increasingly drawing attention as a significant health issue in aging populations. Compared to community-dwelling individuals, cognitive impairments are more common among residents of long-term care facilities (LTCFs). These facilities face challenges implementing organized exercise programs due to a shortage of professional caregivers and limited resources. Additionally, older adults may lose interest in repetitive interventions over time. “WarioWare: Move It!” by Nintendo, a novel exergame that combines aerobic exercise, body coordination, balance training, and cognitive tasks, provides an immersive experience to enhance motivation and reduce staff intervention, presenting a potential solution.

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Instrument, the Chinese version of the Mini-Mental State Examination, and the Montreal Cognitive Assessment). Statistical analysis was performed using mixed ANOVA, with time as the within-subject factor and intervention group as the between-subject factor, to assess the training effects on the various outcome measures.

Results: A total of 232 participants were recruited and randomly assigned to the intervention group, including 18 (56%) with mild dementia, 9 (50%) with moderate dementia, and 89 (49%) with mild cognitive impairment. The mixed ANOVA results revealed significant group × time interactions across several physical flexibility assessments. Specifically, the remaining distance between the hands and toes during the forward bend showed a significant interaction ($F = 8.484$, $P < 0.001$, $\eta^2 = 0.098$), as did the distance between the hands clasped behind the back ($F = 3.666$, $P = 0.035$, $\eta^2 = 0.045$) and the angle formed by the trunk during left and right waist rotation ($F = 17.353$, $P < 0.001$, $\eta^2 = 0.182$). Significant group × time interactions were also observed for forward flexion ($F = 17.655$, $P < 0.001$, $\eta^2 = 0.185$) and abduction ($F = 6.281$, $P = 0.004$, $\eta^2 = 0.075$) of the shoulder joint, as well as for elbow flexion ($F = 17.353$, $P < 0.001$, $\eta^2 = 0.041$). Similarly, a significant group × time interaction was found for the time taken to complete the Figure of Eight Walk test ($F = 11.846$, $P < 0.001$, $\eta^2 = 0.132$). Additionally, a significant group × time interaction in the number of blocks moved within one minute ($F = 4.016$, $P = 0.022$, $\eta^2 = 0.049$). Lastly, all scale scores exhibited significant group × time interactions (all $P < 0.001$), with effect sizes of 0.145 for the Cognitive Abilities Screening Instrument, 0.406 for the Mini-Mental State Examination, and 0.169 for the Montreal Cognitive Assessment.

Conclusion: The “WarioWare: Move It!” intervention significantly improved physical flexibility, joint range of motion, motor coordination, hand dexterity, and cognitive function in older adults with mild cognitive impairment or dementia residing in rural LTCFs. The intervention offers an innovative and feasible approach for promoting elderly health in resource-limited settings, demonstrating potential for widespread application in similar environments.

Keywords: exergame; mild cognitive impairment; dementia; long-term care facilities; multicomponent training

Introduction

Background

Mild cognitive impairment (MCI) and dementia exhibit high prevalence rates among the global elderly population, with new cases projected to increase due to population aging [1,2]. MCI is considered an intermediary stage between age-related cognitive decline and dementia, with studies indicating that approximately 5% to 13% of individuals with MCI progress to dementia each year [3]. The progression is influenced by multiple risk factors, including age, family history, and lifestyle choices, underscoring the critical importance of early intervention and preventive strategies in reducing the incidence of dementia. Dementia, a neurodegenerative disorder with multifactorial etiology, is characterized by the progressive degeneration of brain neurons, resulting in cognitive deficits across several domains, such as complex attention, memory, learning ability, perceptual-motor skills, social cognition, and language ability [4]. Due to its multifactorial nature, no effective cure for dementia currently exists, which not only leads to a significant decline in patients' quality of life but also imposes a substantial economic and social burden on families, caregivers, and healthcare systems [5]. Consequently, early prevention of dementia and maintenance of cognitive function are of particular importance in the elderly population.

In recent years, exergaming, an innovative intervention that integrates physical activity with gaming, has increasingly been introduced into training and rehabilitation programs for the elderly population [6,7]. By combining interactive experiences with immersive virtual environments, exergames encourage active participation among older adults, enhancing cognitive function while alleviating the monotony of traditional exercise forms. Studies indicate that many commercial gaming systems (such as Wii and Kinect) and custom-developed virtual reality games significantly stimulate cognitive abilities, especially in improving memory, attention, and executive function [8,9]. Exergames create an engaging, gamified environment for elderly users, which can improve participation rates and adherence to training. The game-based training approach not only effectively stimulates cognitive function but also provides a convenient exercise pathway for older adults with mobility impairments who may be reluctant or unable to engage in regular outdoor physical activities, thus overcoming barriers such as adverse weather or limited accessibility [10,11].

Despite the promising outcomes of exergaming for urban older populations, its adoption in rural LTCFs remains challenging due to limited healthcare and social resources [12]. In these settings, shortages of trained caregivers and limited equipment hinder the effective implementation of structured exercise programs, limiting seniors' access to sustained, systematic rehabilitation. Additionally, older adults often experience boredom with repetitive exercise routines. They may lack intrinsic motivation, especially when deprived of novel experiences, which can diminish interest and compromise the long-term effectiveness of training [13]. Therefore, exploring and evaluating exergaming systems that are feasible for rural LTCFs and capable of fostering high engagement could serve as a viable approach to enhancing cognitive and physical health among older adults in these communities.

Objectives

Despite the demonstrated clinical benefits of exergames for community-dwelling older adults [14,15], their effectiveness within LTCFs remains insufficiently explored. Current research primarily focuses on improvements in health-related quality of life, cognitive function, and overall functional status [16-19], with relatively few assessments targeting specific physical functions, such as flexibility, joint mobility, motor coordination, and hand dexterity. However, these physical capabilities are crucial for the independence of older adults. For instance, limited flexibility can hinder daily activities, directly impacting self-care abilities and increasing dependency on others [20,21]. A reduction in joint mobility is often associated with joint stiffness and pain, restricting the range of motion and diminishing overall physical function, limiting the living space and activity radius of elderly individuals [22]. Motor coordination is critical in balance maintenance and complex movements, where diminished coordination heightens the risk of falls [23]. Falls can have severe consequences for older adults, including fractures, prolonged immobility, or even accelerated frailty, substantially reducing the quality of life [24-26]. Hand dexterity also underpins the self-sufficiency of older adults. Loss of fine motor skills, such as gripping, pinching, and writing, can restrict their ability to perform daily tasks and participate socially, potentially leading to psychological distress [27].

The Nintendo exergame “WarioWare: Move It!” integrates twelve distinct movement modes, offering not only aerobic, coordination, and balance training but also cognitive exercises that engage memory, attention, and logical reasoning. The game’s difficulty can be flexibly adjusted to match users’ needs, ensuring optimal training effects at appropriate challenge levels. Despite its evident potential, comprehensive empirical studies are still required to substantiate its benefits fully. Therefore, this study conducted a 12-week longitudinal user study to examine the feasibility and potential clinical utility of “WarioWare: Move It!” for elderly populations in rural LTCFs. Furthermore, this research provides valuable insights and references for geriatric rehabilitation professionals and human-computer interaction researchers interested in designing exergame-based interventions for elderly care.

Methods

Ethical Considerations

This study was conducted according to the Declaration of Helsinki and received approval from the Biomedical Ethics Review Committee of Taiyuan University of Technology (Approval No. 20230641). It was also registered with the Chinese Clinical Trial Registry (Registration No. ChiCTR2400092790). Prior to their involvement, all participants provided written informed consent. Eligible elderly participants received USD 10 compensation for their participation.

Participants

In this study, we recruited 232 participants (32 patients with mild dementia, 18 with moderate dementia, and 182 with mild cognitive impairment) from LTCFs, such as rural daycare centers and nursing homes in Shanxi Province, China. Participant selection followed a purposive sampling method [28], with the entire recruitment process rigorously supervised by experienced neurologists. Inclusion criteria were as follows: (1) normal or corrected-to-normal hearing and vision; (2) age over 65; (3) residence in a senior care facility or a minimum stay of one month in such a facility; (4) completion of the Global Deterioration Scale (GDS), the Chinese version of the Mini-Mental State Examination (MMSE), and the Chinese version of the Montreal Cognitive Assessment (MoCA), with the capacity to communicate effectively; (5) ability to engage in moderate physical activity without physical disability; (6) absence of severe depressive symptoms or other neurological disorders (e.g., stroke, dizziness, epilepsy); and (7) provision of informed consent by the participant or their guardian.

All participants underwent comprehensive medical evaluations conducted by experienced neurologists, including a thorough medical history, physical examination, neuroimaging studies (either brain magnetic resonance imaging or computed tomography), and cognitive function assessments. Neurologists assessed participants' cognitive function using the GDS score, classifying the severity of dementia symptoms accordingly. Among the participants with dementia, the average GDS score was 3.7, with an average duration of dementia symptoms spanning 3.15 years. Cognitive function in the 182 MCI patients was evaluated using the MoCA, with scores consistently below 26. Furthermore, neuroimaging revealed no other structural abnormalities in any participant that could contribute to cognitive impairment.

Table 1. Clinical and demographic characteristics of participants randomly assigned to the intervention and control groups (n=232).

Characteristics	Intervention group (n=116)	Control group (n=116)	P value
Age(y), mean(SD)	73.03(4.431)	72.70(4.958)	0.587
Gender, n(%)			0.427
Woman	68(58.6)	62(53.4)	
Man	48(41.4)	54(46.6)	
Hand preference, n(%)			0.677
Left	12(10.3)	14(12.1)	
Right	104(89.7)	102(87.9)	
Exercise habit, n (%)			0.431
Yes	62(53.4)	60(51.7)	
No	54(46.6)	56(48.3)	
Education years, mean(SD)	6.53(3.037)	6.31(2.994)	0.572
Hours of sleep, mean (SD)	6.44(1.239)	6.42(1.259)	0.916

Smart device use years, mean (SD)	4.59(1.658)	4.35(1.741)	0.281

Randomization and Blinding

To eliminate selection bias, enhance the internal validity of the research findings, and ensure scientific rigor and reliability, this study employs a stringent randomized grouping method to assign participants to either the intervention or control group. The randomization process follows the strict steps outlined below:

1. All eligible participants are assigned a unique identification number to maintain anonymity.

2. Identification numbers are recorded on slips of paper, which are then sealed in opaque envelopes to ensure a double-anonymized grouping process.

3. The numbered envelopes are placed in an opaque container and thoroughly mixed to guarantee complete randomness in selection.

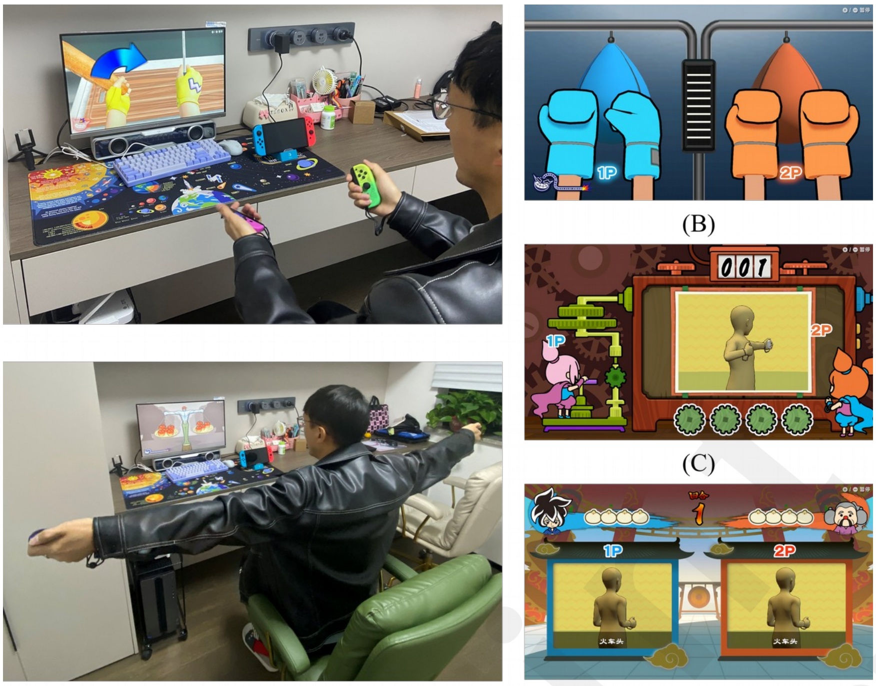
4. Researchers wear blindfolds to prevent prior knowledge of envelope contents and randomly draw a single envelope.

5. The selection process is repeated until 116 envelopes are chosen to form the intervention group, with the remaining participants allocated to the control group.

After random assignment at a 1:1 ratio, the intervention group received a 12-week training regimen, while the control group continued with standard care provided by LTCFs. Both groups maintained equivalent activity durations. Table 1 summarizes the clinical and demographic characteristics of participants allocated to the intervention and control groups.

Intervention Group Training Program

The training program for the intervention group utilized the Nintendo Switch game “WarioWare: Move It,” as depicted in Figure 1. Participants engaged with the game through Joy-Con controllers, completing rapid micro-games designed to meet specific movement-oriented objectives. Each game session lasted approximately five seconds, requiring participants to quickly adapt to various physical actions and postures, such as waving, jumping, swinging arms, rotating, and mimicking object movements. The game’s dynamic structure provides an engaging experience that promotes physical coordination, reaction speed, upper and lower limb strength, and hand-eye coordination through diverse movement patterns. Switching between tasks compels players to adjust to varying motion demands swiftly, enhancing physical agility while strengthening attention-shifting and quick decision-making skills.



(A) (B) (C) (D)

Figure 1. Training scenarios and gameplay modes of the Nintendo Switch "WarioWare: Move It" exergame. (A) Participant engaging in a gameplay scenario; (B) Competitive mode; (C) Cooperative mode; (D) Versus mode.

The "WarioWare: Move It" training program was administered twice weekly, with each session lasting 60 minutes over 12 weeks. Each session comprised three 10-minute gaming segments, interspersed with rest periods of 1 to 5 minutes to sustain participant engagement and mitigate mental fatigue. During training, staff provided tailored support and dynamically adjusted program parameters based on individual performance, modifying task content, intensity, duration, and physical demands as necessary.

Control Group Standard Care Program

The standard care program for the control group is grounded in routine practices of long-term care facilities, aiming to sustain and enhance the physical and mental well-being of elderly residents through structured group activities. These activities encompass tailored fitness exercises, horticultural therapy, and sedentary group engagements for older adults. The fitness exercises are adapted to meet the varying physical conditions of participants, ensuring a safe and comfortable environment that promotes moderate physical activity. Horticultural therapy involves hands-on planting and tending to plants, stimulating the senses, and fostering emotional regulation, contributing to improved psychological health. Sedentary activities, such as tabletop games, emphasize social interaction and cognitive maintenance by promoting a relaxed social environment that helps participants remain cognitively engaged. A professional therapist leads each session to ensure that participants receive adequate guidance and support throughout the activities. The program is conducted twice a week, with each session lasting 60 minutes over 12 weeks.

Outcomes Measured

All participants underwent three assessments at distinct time points. The initial assessment occurred at baseline prior to randomization. Subsequent evaluations were conducted at the end of 12 weeks (post-test) and six months after the intervention concluded (after 6 months). The primary outcomes of this study focus on detecting intervention effects using indicators related to physical flexibility, joint range of motion, motor coordination, hand dexterity and cognitive abilities, as detailed below.

In this study, physical flexibility assessments involve several standardized tests. First, the Sit and Reach test measures the participant's ability to stretch forward while seated with legs extended and heels fixed [29, 30]. The farthest distance reached with outstretched hands toward the toes is recorded, with the gap between the fingertips and toes serving as the flexibility index. The Shoulder Flexibility test assesses flexibility by measuring the distance between the hands when clasped behind the back [31-32]. Participants with higher flexibility achieve either easy hand clasping or shorter hand-to-hand distance. The Trunk Rotation Flexibility test requires participants to stand with feet together, and arms extended forward, rotating the torso left and right around the waist [33]. The maximum angle reached on each side indicates flexibility, with more prominent angles signifying greater flexibility.

The joint range of motion reflects the extent of freedom a joint possesses within a specified range of movement. Observing changes in the range of motion across different directions in the intervention group makes it possible to determine whether significant improvements occur in particular directions (e.g., flexion or internal rotation), thus providing targeted feedback for the intervention. This study's joint range of motion assessments includes shoulder and elbow range of motion tests. The Shoulder Range of Motion test measures the maximum range in four directions (e.g., flexion, extension, abduction, and adduction) [34,35]. In contrast, the Elbow Range of Motion test assesses the degree of elbow flexion [36].

Additionally, this study evaluates motor coordination, defined as the body's ability to synchronize various parts during complex physical tasks. The assessment methods include the Figure of Eight Walk [37, 38] and Standing Balance test [39, 40]. In the Figure of Eight Walk test, participants are instructed to walk in a figure-eight pattern around two markers placed on the ground, covering a total distance of 10 meters. The time taken to complete this task is recorded as a measure of coordination. The Standing Balance test requires participants to stand with their feet together, and their eyes closed, aiming to maintain balance, with the duration of balance maintained being measured as an indicator of stability.

Similarly, hand dexterity reflects an individual’s coordination, agility, and reaction speed in performing fine motor tasks, particularly when required to complete repetitive, high-precision tasks within a limited timeframe. Hand dexterity was assessed using the Box Block test [41, 42], where participants were instructed to use their dominant hand to transfer blocks from one compartment to another within a wooden box over 60 seconds, recording the total number of transfers completed within the specified time. Finally, cognitive function was evaluated using the Cognitive Abilities Screening Instrument (CASI) [43], as well as the Chinese versions of the MMSE [44] and MoCA scales [45]. Detailed measurement procedures are provided in Multimedia Appendix 1.

Statistical Analysis

Statistical analysis was conducted using SPSS for Windows (version 21.0; IBM Corp.). Continuous variables were represented by means and standard deviations, while categorical variables were expressed as frequencies and percentages. Before each analysis, normality and homogeneity of variance were preliminarily assessed. For variables conforming to a normal distribution, we applied two-tailed t-tests (for continuous variables) and chi-square tests (for categorical variables) to determine the significance of differences between groups. The statistical significance level for all tests was set at $P<.05$.

To assess the impact of the intervention on outcomes across different time points, we performed a mixed ANOVA, with time as a within-subject factor and the intervention as a between-subject factor. Effect sizes were calculated using eta squared (η^2), which ranges from 0 to 1, to quantify the strength of the intervention's influence. Generally, higher η^2 values indicate a more significant proportion of variance in the dependent variable explained by the intervention, thus reflecting a more substantial intervention effect. Specifically, for any significant interactions or main effects, Bonferroni correction was employed for post-hoc evaluations.

Results

Baseline Performance of the Intervention and Control Groups

This study assessed baseline performance for both the intervention and control groups before the intervention began. The evaluation covered multiple domains, including physical flexibility, joint mobility, balance, coordination, and cognitive abilities. As shown in Table 2, no significant differences were observed between the two groups across these various assessments ($P>0.05$), indicating that participants exhibited relatively comparable physical function and cognitive status before the intervention.

Comparison of Physical Function Outcomes between Intervention and Control Groups

In assessing physical flexibility, the Sit and Reach test results indicated a significant reduction in the distance between participants' hands and toes over time ($F=35.682$, $P<0.001$). Additionally, a significant group x time interaction effect was observed ($F=8.484$, $P<0.001$), demonstrating that the intervention group exhibited a markedly more significant flexibility improvement than the control group. A similar trend was observed in the Shoulder Flexibility test, where the distance between participants' hands positioned behind the back showed a significant time effect ($F=16.511$, $P<0.001$) and a significant group x time interaction effect ($F=3.666$, $P=0.035$). Additionally, in the Trunk Rotation Flexibility test, the intervention group exhibited a significant increase in rotational range, with a significant interaction effect ($F=17.353$, $P<0.001$) and a moderate-to-small effect size ($\eta^2=0.182$). Post hoc analysis demonstrated that physical flexibility indicators in the intervention group showed substantial improvement from baseline to the end of the intervention and remained consistently enhanced up to six months post-intervention, indicating the durability and stability of the intervention effects.

Furthermore, the joint range of motion was assessed by comparing participants' maximal range of motion in four directions (e.g., shoulder flexion, extension, abduction, and adduction). Results indicated a significant increase over time in shoulder flexion ($F=35.315$, $P<0.001$) and abduction ($F=4.499$, $P=0.016$) among participants. Further analysis revealed a significant interaction effect between group x time, with those receiving the intervention demonstrating more pronounced improvements in shoulder flexion ($F=17.655$, $P<0.001$) and abduction ($F=6.281$, $P=0.004$), suggesting a positive impact of the intervention on enhancing range of motion in specific directions. Additionally, the Elbow Range of Motion test showed a significant increase in elbow flexion over time ($F=9.261$, $P<0.001$), along with a significant group by time interaction effect ($F=17.353$, $P<0.001$) and a small effect size ($\eta^2=0.041$). These effects may be related to the nature of the intervention tasks (e.g., simulated swimming, skiing, and flying), emphasizing shoulder flexion, abduction, and elbow flexion, thereby enhancing the range of motion more substantially in these directions.

Subsequently, in the assessment of motor coordination, the Figure of Eight Walk and Standing Balance test were utilized to evaluate participants' functional performance based on time metrics. The Figure of Eight Walk test measured walking coordination by recording completion time, with shorter times indicating better coordination. The Standing Balance test assessed static balance ability by recording how participants could maintain balance while standing with their eyes closed, with longer durations indicating better balance. Post-hoc analysis revealed a significant time effect in the completion time of the Figure of Eight Walk test ($F=36.038$, $P<0.001$), as well as a significant group × time interaction effect ($F=11.846$, $P<0.001$), suggesting that the intervention group showed a notably more significant improvement in walking speed and motor coordination than the control group. Similarly, results from the Standing Balance test demonstrated a significant increase over time in participants' balance duration with eyes closed (F=9.059, P<0.001), indicating a positive impact of the intervention on static balance ability.

Finally, the Box Block test, utilized to assess hand dexterity, revealed a significant increase in the number of blocks transferred by participants within one minute over time (F=18.648, P<0.001). Additionally, a significant group-by-time interaction effect was observed (F=4.016, P=0.022), indicating that the intervention group demonstrated a substantially greater improvement in hand dexterity than the control group.

Comparison of Cognitive Function Outcomes between Intervention and Control Groups

This study assessed cognitive function by examining changes in performance on cognitive scales (e.g., CASI, MMSE, MoCA) between the intervention and control groups. In the CASI assessment, participants' scores significantly increased over time (F=21.427, P<0.001), with a notable group x time interaction effect (F=13.226, P<0.001), suggesting a positive impact of the intervention on cognitive function. A similar pattern was observed in both the MMSE and MoCA assessments. For the MMSE, scores significantly improved over time, with a strong time effect (F=94.552, P<0.001) and a significant group x time interaction effect (F=53.244, P<0.001), supporting the pronounced cognitive improvement within the intervention group. Likewise, MoCA scores demonstrated a significant time effect (F=52.563, P<0.001) and a group x time interaction effect (F=15.882, P<0.001), reinforcing the intervention's effectiveness in enhancing various aspects of cognitive function. Notably, the effect sizes (η^2) for the group x time interaction effects across the three scales were 0.145 for CASI, 0.406 for MMSE, and 0.169 for MoCA. The relatively larger effect size for MMSE suggests its higher sensitivity in detecting the intervention's impact on cognitive outcomes.

Table 2. Data of measurement outcomes at baseline, post-test, and after 6 months post-intervention.

Tests			Baseline Mean (SD)	Post-test Mean (SD)	After 6 months Mean (SD)	F test	P value	Effect size (η^2)
Sit and Reach Test	Control group		24.92(7.826)	24.28(7.345)	24.00(8.092)	0.908[a]; 0.297[b]; 0.541[c]		
	Intervention group		24.73(7.534)	22.50(7.776)	22.93(7.570)			
	2-way ANOVA	Time	—[d]	—	—	35.682	<.001	0.314
		Group×time	—	—	—	8.484	<.001	0.098
Shoulder Flexibility Test	Control group		18.83(6.029)	18.18(5.728)	17.90(5.368)	0.785; 0.143; 0.285		
	Intervention group		18.45(6.193)	16.30(5.608)	16.62(5.227)			
	2-way ANOVA	Time	—	—	—	16.511	<.001	0.175
		Group×time	—	—	—	3.666	0.035	0.045
Trunk	Control group		103.80(19.824)	104.43(18.548)	104.05(18.026)	0.961; 0.170; 0.300		

Rotation Flexibility Test	Intervention group	103.57(21.260)	110.65(21.546)	108.60(20.853)			
	2-way ANOVA Time	—	—	—	24.011	<.001	0.235
	2-way ANOVA Group×time	—	—	—	17.353	<.001	0.182
Shoulder Range of Motion Test[e]	Control group	139.70(12.584)	141.43(14.113)	140.92(13.312)	0.945; 0.010; 0.013		
	Intervention group	139.53(9.814)	148.73(10.370)	147.20(8.115)			
	2-way ANOVA Time	—	—	—	36.315	<.001	0.318
	2-way ANOVA Group×time	—	—	—	17.655	<.001	0.185
Shoulder Range of Motion Test[f]	Control group	114.23(12.853)	115.50(13.091)	116.00(12.922)	0.971; 0.830; 0.823		
	Intervention group	114.32(11.952)	116.10(11.790)	115.40(10.916)			
	2-way ANOVA Time	—	—	—	3.164	0.055	0.039
	2-way ANOVA Group×time	—	—	—	0.395	0.635	0.005
Shoulder Range of Motion Test[g]	Control group	30.88(5.774)	30.78(5.347)	31.05(5.164)	0.943; 0.180; 0.881		
	Intervention group	30.78(6.612)	32.70(7.244)	31.25(6.648)			
	2-way ANOVA Time	—	—	—	4.499	0.016	0.055
	2-way ANOVA Group×time	—	—	—	6.281	0.004	0.075
Shoulder Range of Motion Test[h]	Control group	22.15(4.481)	22.70(4.084)	22.48(4.403)	0.867; 0.897; 0.919		
	Intervention group	22.33(4.811)	22.82(4.551)	22.58(4.314)			
	2-way ANOVA Time	—	—	—	1.774	0.177	0.022
	2-way ANOVA Group×time	—	—	—	0.009	0.984	0.001
Elbow Range of Motion Test	Control group	125.88(9.067)	126.60(8.796)	126.10(9.353)	0.698; 0.536; 0.770		
	Intervention group	125.07(9.300)	127.85(9.181)	126.67(8.113)			
	2-way ANOVA Time	—	—	—	9.261	0.001	0.106
	2-way ANOVA Group×time	—	—	—	3.298	0.049	0.041
Figure of Eight Walk Test	Control group	45.65(8.438)	44.57(8.054)	45.40(7.585)	0.838; 0.092; 0.233		
	Intervention group	45.25(9.012)	41.35(8.845)	43.22(8.577)			
	2-way ANOVA Time	—	—	—	36.038	<.001	0.316
	2-way ANOVA Group×time	—	—	—	11.846	<.001	0.132
Standing Balance Test	Control group	19.17(6.417)	19.77(6.463)	20.05(6.089)	0.870; 0.364; 0.686		
	Intervention group	19.40(5.848)	21.00(5.505)	20.57(5.449)			
	2-way ANOVA Time	—	—	—	9.059	<.001	0.104
	2-way ANOVA Group×time	—	—	—	1.579	0.212	0.020
Box and	Control group	12.38(3.484)	12.83(3.869)	13.15(2.992)	0.975; 0.327; 0.793		

block Test	Intervention group		12.35(3.759)	13.73(4.285)	13.35(3.766)		
	2-way ANOVA	Time	—	—	—	18.648	<.001	0.193
		Group×time	—	—	—	4.016	0.022	0.049
Cognitive Abilities Screening Instrument	Control group		71.48(5.782)	71.88(6.223)	71.98(6.327)	0.985; 0.017; 0.207		
	Intervention group		71.45(6.093)	75.07(5.535)	73.67(5.599)			
	2-way ANOVA	Time	—	—	—	21.427	<.001	0.216
		Group×time	—	—	—	13.226	<.001	0.145
Chinese Version of the MMSE Scale	Control group		23.88(2.980)	24.30(3.115)	24.25(2.994)	0.540; 0.007; 0.006		
	Intervention group		23.40(3.868)	26.28(3.313)	26.15(3.068)			
	2-way ANOVA	Time	—	—	—	94.552	<.001	0.548
		Group×time	—	—	—	53.244	<.001	0.406
Chinese Version of the MoCA Scale	Control group		21.95(4.579)	22.48(4.279)	22.73(4.057)	0.722; 0.142; 0.199		
	Intervention group		21.60(4.187)	23.80(3.695)	23.88(3.878)			
	2-way ANOVA	Time	—	—	—	52.563	<.001	0.403
		Group×time	—	—	—	15.882	<.001	0.169

[a]A t-test was applied for continuous variables at baseline for control and intervention groups.

[b]A t-test was applied for continuous variables post-test for control and intervention groups.

[c]A t-test was applied for continuous variables after 6 months post-intervention for control and intervention groups.

[d]Not applicable.

[e]The maximum range of motion of the shoulder joint in flexion.

[f]The maximum range of motion of the shoulder joint in extension.

[g]The maximum range of motion of the shoulder joint in abduction.

[h]The maximum range of motion of the shoulder joint in adduction.

Discussion

Advantages of "WarioWare: Move It!" in Physical and Cognitive Rehabilitation for Older Adults

To our knowledge, this is the first study to evaluate the clinical effectiveness of a gaming intervention on a range of functional outcomes, including physical flexibility, joint mobility, motor coordination, hand dexterity, and cognitive status. "WarioWare: Move It!" integrates elements of aerobic exercise, physical coordination, balance training, and cognitive engagement into a motion-based game, enhanced by real-time feedback mechanisms. The immersive setting encourages active participation among older adults, which is particularly valuable in LTCFs in rural areas, where limited medical and social resources present challenges to implementing structured exercise programs. Therefore, we explored the application value of “WarioWare: Move It!” in systematic rehabilitation, focusing on its feasibility in improving elderly participation and promoting functional recovery. The findings reveal that elderly participants in LTCFs who received the “WarioWare: Move It!” intervention showed significantly improved flexibility, joint mobility, hand dexterity, and cognitive function compared to a standard care control group. It highlights the potential of “WarioWare: Move It!” as an innovative therapeutic strategy, offering an accessible and well-accepted rehabilitation approach that may help mitigate age-related declines in physical function within long-term care settings.

Additionally, this study innovatively incorporates “WarioWare: Move It!” to develop a motion intervention program based on exergames. Similar to other exergames, it employs role-playing game mechanics and immersive scene design to foster participant engagement through a playful approach [46, 47]. The program offers visual feedback (via screen display) and tactile feedback (through the Joy-Con controller) while incorporating diverse movement postures and randomly varied actions, thus extending beyond traditional exergames limited to fingertip control. Notably, “WarioWare: Move It!” presents a multi-component training scheme that combines aerobic exercise, body coordination, balance training, and cognitive stimulation to enhance participants' cardiorespiratory endurance, balance, flexibility, and cognitive functions. Prior studies have demonstrated that such multi-component exergaming provides substantial benefits to physical and cognitive functions in community-dwelling older adults due to its accessibility, cost-effectiveness, and time efficiency, earning broad acceptance [48-50]. Consistent with these findings, this study observed that “WarioWare: Move It!” led to marked improvements in participants' physical abilities (e.g., coordination, balance, and flexibility) and cognitive capacities (e.g., executive function, attention, and memory).

One unique aspect of the exergame provided by “WarioWare: Move It!” lies in its ability to automatically set an initial difficulty level at each stage and progressively adjust this based on the player's performance. As players become more familiar with specific game scenarios and movement patterns, the system increases the challenge by gradually increasing the frequency of the required actions, thus prompting players to achieve efficient coordination between body and mind within a short time frame. Such dynamic adaptability enhances the game's appeal and imposes higher demands on participants' reaction speed, coordination, and focus.

Another fascinating aspect of “WarioWare: Move It!” is its thoughtful inclusion of three distinct multiplayer modes, each tailored to meet the preferences of different types of players. In addition to a robust single-player training mode, the game introduces competitive, cooperative, and duel modes to enrich social interactions and enhance player engagement and immersion. First, the competitive mode enables players to compete in specific tasks, with victory determined by scoring or task completion speed, fostering a sense of challenge and achievement. Next, the cooperative mode emphasizes teamwork, encouraging players to complete tasks together, thus strengthening team dynamics and promoting social cohesion. Finally, the duel mode focuses on direct player-versus-player confrontations, offering immediate feedback and creating an intense, engaging battle experience. Overall, these multiplayer interaction modes diversify the game's social and interactive dimensions and offer varied engagement pathways for different player types, thereby boosting player loyalty and satisfaction.

Implications of Multidimensional Improvements in Functional Performance among Older Adults

In this study, we investigated whether early improvement trends in body coordination and flexibility could be identified in older adults during training. Age-related declines in muscle elasticity and neuromuscular control typically negatively affect coordination and flexibility in older adults [51]. Unlike younger individuals, older adults tend to benefit from training primarily through adaptive changes in the neuromuscular system, improving motor control, postural stability, and coordination rather than relying solely on muscle hypertrophy or strength gains [52, 53]. Our findings indicated that, after a 12-week training period, the remaining distance between fingertips and toes during the Sit and Reach test, as well as the distance between hands during the Shoulder Flexibility test, were significantly reduced, indicating a positive effect of the intervention on enhancing both lower and upper limb flexibility. In addition, the trunk rotation angle in both directions significantly increased, further demonstrating the improvement in trunk rotation capacity and overall coordination. Although short-term enhancements in muscle mass may be challenging to detect, neuromuscular adaptations have already positively impacted functional performance in the early stages. In other words, through dynamic contextualized training, older adults experienced enhanced neuromuscular control and motor flexibility, leading to faster, observable improvements in coordination and flexibility.

We also observed a significant improvement in participants' range of motion in specific directions of the shoulder joint, such as flexion and abduction. These movements are crucial for many daily activities, like dressing and reaching, and their enhancement directly impacts functional performance and independence in older adults' everyday lives [54]. The direction-specific improvement is primarily attributed to the contextualized exercises embedded within the intervention (e.g., swimming, flying, and skiing simulations), emphasizing functional relevance and practical application, thereby fostering adaptations in the associated muscle groups and neuromuscular pathways. Additionally, the elbow joint demonstrated a significant group x time interaction effect in flexion angle, reflecting the rapid adaptability of the neuromuscular system during the short-term intervention. Compared to muscle hypertrophy, older adults are more likely to improve motor control and joint flexibility through neuromuscular adaptations in the short term [55, 56], leading to prioritized enhancements in specific directions for the shoulder and elbow joints.

Although the gamified intervention primarily targeted upper limb and trunk movements, a significant increase in walking speed was observed, indicating the potential benefits of diverse game-based training for gait-related abilities. Walking involves coordinated lower limb and trunk movements, gait control, balance adjustment, and core stability [57, 58]. In this study, game interventions (e.g., racing, skiing, flying, and archery) not only required upper limb and trunk movements, but also challenged balance and center of gravity control through dynamic postures (e.g., leaning forward, reaching forward, lateral shifting). The multifaceted posture control and center of gravity shifting training facilitated improvements in postural stability, balance perception, and neuromuscular coordination, ultimately enhancing gait performance. Moreover, the intervention group significantly reduced completion time for the Figure of Eight Walk test, indicating improved stability and turn control during dynamic gait tasks. Likewise, increased duration in the Standing Balance test reflects improved balance, suggesting that the intervention significantly enhanced participants' neuromuscular control in dynamic and balance tasks. Although the training did not directly target lower limb gait, the center-of-gravity adjustments, posture transitions, and full-body coordination exercises embedded within the games significantly improved gait performance.

The “WarioWare: Move It!” intervention demonstrated significant efficacy in enhancing fine motor control and flexibility of the hands. During the intervention, participants performed hand movement tasks with the Joy-Con controller, such as simulating a tug-of-war, making rock-paper-scissors gestures, and quickly catching a flying disc. These tasks required precise hand adjustments across various contexts, emphasizing independent finger movement and wrist flexibility. Additionally, the intervention group showed a notable increase in the number of blocks transferred within one minute, alongside a significant group x time interaction effect. These contextualized hand-movement training facilitated improvements in fine finger control and wrist flexibility among older adults, with implications for daily tasks requiring fine motor skills, such as grasping objects, handling utensils, and using tools.

Finally, this study observed significant improvements in participants' cognitive performance across various assessment tools (e.g., CASI, MMSE, and MoCA). Existing research indicates that gamified interventions have a therapeutic impact on the cognitive functions of older adults [59, 60]. In this study, the gamified environment provided multidimensional stimulation through visual, auditory, and tactile cues, along with task-based prompts and real-time feedback, consistently presenting participants with spatial and logical challenges. Immersion in such virtual scenarios contributed not only to attentional recovery and stress reduction but also played a positive role in cognitive rehabilitation and enhancement [61]. Moreover, the nature of gamified training, which requires participants to make quick decisions in dynamic scenarios, stimulated executive functioning and response capabilities [62]. Notably, the design features of “WarioWare: Move It!” integrated aerobic exercise, coordination, and balance training alongside cognitive tasks involving memory, attention, and logical reasoning. These multi-layered cognitive stimulations created a comprehensive training environment, promoting broad activation of brain functions. Therefore, the notable improvements observed in brain health assessments post-intervention were anticipated, highlighting the significant role of gamified interventions in cognitive rehabilitation and enhancement for older adults.

Insights for Rehabilitation Professionals and Human Computer Interaction Researchers in Elderly Care

This study offers a new perspective for rehabilitation professionals working with elderly populations, focusing on three key areas: (1) Integrating multi-component training with physical function restoration. “WarioWare: Move It!” effectively combines aerobic exercise, body coordination, balance, and cognitive stimulation within a structured platform that facilitates multifunctional training through various dynamic activities. (2) Enhancing adherence through practicality and enjoyment. The game's intuitive visual feedback and goal-achievement mechanisms significantly boost older adults' motivation to engage in rehabilitation exercises. By incorporating immersive scenarios, real-time feedback, and progressively challenging tasks, “WarioWare: Move It!” fosters a sense of accomplishment and interactive enjoyment, promoting experiential learning and substantially improving adherence. (3) Practical application of targeted physical function training. Through contextualized and interactive movement design, “WarioWare: Move It!” incorporates actions frequently performed in daily life (e.g., shoulder flexion and abduction, gait balance, and hand movements) within gameplay to enhance specific physical functions (e.g., joint mobility and flexibility).

This study offers valuable insights for researchers in the human-computer interaction field, specifically in designing elderly-friendly interactive systems. Specifically, it highlights three key areas: (1) Dynamic adaptive design for elderly-friendly interventions. The dynamic adaptability of the system in “WarioWare: Move It!” gradually guides participants toward higher levels of physical and cognitive demands, facilitating synchronized improvements in both domains within a safe and comfortable experience. (2) Multisensory feedback and enhanced interaction. The Intervention successfully integrates multisensory stimulation through visual and tactile feedback (via the Joy-Con controllers) and task cues, enhancing the immersive experience and improving the brain's responsiveness through multimodal input. (3) Rehabilitation Benefits of Multiple Social Interaction Modes. The social interaction modes within the exergames, including competition, cooperation, and versus challenges, demonstrate significant rehabilitation value. The competitive mode fosters players' achievement motivation, the cooperative mode strengthens teamwork awareness, and the versus mode provides immediate feedback. These social interaction modes enrich the player's social experience and, through interpersonal interaction, fulfil the psychological and emotional needs of elderly participants, thereby further optimizing rehabilitation outcomes.

Limitations and Future Work

Our study has several limitations. First, although the sample size exceeds the requirements for statistical analysis, it remains relatively small. Second, despite the exergames have positively affected specific physical and cognitive functions, they cannot fully replace traditional rehabilitation methods (e.g., physical or cognitive-behavioural therapy). Future intervention designs could consider integrating exergames with conventional rehabilitation techniques, creating a more diversified and comprehensive rehabilitation plan to meet the broader needs of older adults. Third, the social interaction features of “WarioWare: Move It!” (such as competition, cooperation, and rivalry) enhance rehabilitation outcomes. However, preferences for competition or collaborative modes may vary among older adults, particularly those who are more introverted or have lower social engagement, making these modes less appealing to some. Future game iterations could incorporate personalized social interaction options to ensure each participant receives an optimal experience, boosting engagement. Finally, due to the small sample size, subgroup analyses were not conducted to identify whether certain subgroups would benefit more from the intervention. Future research should aim to recruit larger samples to explore the responses of patients with varying degrees of dementia to the intervention.

Conclusions

The “WarioWare: Move It!” training program significantly improves physical flexibility, joint range of motion, motor coordination, hand dexterity, and cognitive function among older adults in rural LTCFs. The intervention offers a novel approach to providing supportive health care in resource-limited settings. Specifically, for patients with mild cognitive impairment or dementia, the intervention not only aids in delaying functional decline but also enhances cognitive function and quality of daily living through multisensory stimulation and dynamic interaction. Furthermore, the incorporation of exergames marks an innovative shift in elderly care models, offering a novel, low-demand intervention method that effectively addresses the shortcomings of traditional care approaches. These findings support the integration of exergames into routine care practices and provide a viable, technology-driven solution to address the challenges of aging health in institutional care settings worldwide.

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Data availability

The data used in the study is not publicly available, but the data used and/ or analyzed during the current study are available from the corresponding author on reasonable request.

Conflicts of Interest

The authors declare no competing interests.

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Supplementary Files

Multimedia Appendixes

Untitled.
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