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Impact of Physical and Smart Cognitive Games on Cognitive Performance in Older Adults: A Randomized Controlled Trial

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Abstract

Background Age-related cognitive decline is a major public health challenge with significant implications for independence and quality of life. Non-pharmacological strategies, including game-based cognitive interventions, have gained increasing attention. This study aimed to compare the effects of physical cognitive games and smart cognitive games on cognitive performance in older adults.

Methods This parallel-group randomized controlled trial was conducted among 60 community-dwelling older adults (≥ 60 years) during the winter and spring of 2025 in Aran and Bidgol. Iran. Participants were randomly allocated to a physical cognitive games group, a smart cognitive games group, and a control group (n = 20 per group). Intervention groups participated in 40-minute sessions twice weekly for 15 sessions, while the control group received usual care. Cognitive performance was assessed using the Wechsler Adult Intelligence Scale. Data were analyzed using parametric and non-parametric tests in IBM SPSS Statistics version 27.

Results Both intervention groups demonstrated significant improvements in overall cognitive performance compared with the control group. Physical cognitive games showed relatively greater improvements in logical memory, visual memory, and associative learning (all $P < 0.001$), whereas smart cognitive games demonstrated stronger effects on mental control and digit memory (both $P < 0.001$). Significant group × time interactions were observed across these cognitive domains.

Conclusion Both physical and smart cognitive games were associated with improvements in cognitive performance among older adults. The differential domain-specific effects suggest that combining or tailoring these interventions may represent a feasible non-pharmacological strategy for supporting cognitive health in community settings. Further research with larger samples and long-term follow-up is warranted.

Trial registration: ClinicalTrials.gov: IRCT20250825066982N1. 20/11/2025; (https://irct.behdasht.gov.ir/trial/86352/pdf)

Introduction

Globally, people can now expect to live longer, and most countries are experiencing a rapid increase in both the number and proportion of older adults (1). Iran is no exception to this trend, with the proportion of adults aged 65 years and older projected to rise substantially between 2016 and 2030. Population projections further indicate that by 2050, approximately one in every four members of an average Iranian household will be an older adult (2). With advancing age, decline in cognitive function represents one of the most critical public health challenges (3). Age-related cognitive changes commonly affect attention, executive function, processing speed, and working memory (4). The extent of cognitive changes associated with normal aging is highly variable yet clinically significant (5), as it can profoundly affect multiple aspects of older adults' daily functioning and quality of life. Cognitive decline is associated with increased disability, chronic medical conditions (6), mood disorders and depression (7), as well as

elevated risks of falls and neurodegenerative diseases (8), ultimately contributing to higher hospitalization rates and mortality (9). Importantly, pathological cognitive changes often begin several years before the onset of overt clinical symptoms. Mild cognitive impairment (MCI) is commonly regarded as an intermediate stage between normal aging and dementia, with approximately 5–13% of individuals with MCI progressing to dementia annually. Given the absence of definitive treatments for dementia and the growing burden imposed on individuals, families, and healthcare systems, primary prevention strategies and preservation of cognitive function have become essential priorities in aging societies.

According to the World Health Organization, non-pharmacological strategies to maintain cognitive health are a global public health priority (World Health Organization. Risk reduction of cognitive decline and dementia: WHO guidelines. Geneva: WHO; 2019). Among these, one of the most promising strategies involves rehabilitation exercises such as physical and cognitive activities (10). Recent systematic reviews and meta-analyses have reported that game-based physical interventions such as exergames can improve cognitive outcomes in older adults, particularly in executive function and global cognition (11). However, these reviews also highlight substantial heterogeneity in intervention design, cognitive outcome measures, and overall study quality, which complicates the interpretation and synthesis of findings. Importantly, Direct head-to-head randomized comparisons for physical game-based and smart cognitive game interventions remain scarce. This paucity of direct comparisons limits conclusions regarding their relative effectiveness, as well as guidance for practical implementation in specific cultural settings (12).

Evidence suggests that recreational and game-based physical interventions can improve cognitive domains such as episodic and working memory, processing speed, and executive function, and may contribute to dementia risk reduction (13, 14). Physical cognitive games have also been associated with improvements in functional performance and balance in older adults (15–17). However, limitations including accessibility barriers, individual differences, and implementation costs may restrict participation, highlighting the need for feasible and scalable approaches (18).

Advances in technology have facilitated the development of digital cognitive games as scalable and potentially cost-effective interventions (19). Smartphone- and computer-based cognitive training programs have demonstrated improvements in working memory, attention, processing speed, and executive functions in older adults (19–22). Their adaptability and ease of access represent practical advantages (20, 21). Nevertheless, barriers such as limited digital literacy, motor slowing, and short intervention duration may reduce effectiveness and adherence in older populations (22, 23).

Despite growing evidence supporting both physical and technology-based cognitive games, few randomized controlled trials have directly compared their effects on cognitive function in older adults, particularly within Middle Eastern populations. Moreover, variability in intervention content, intensity, and delivery format makes it difficult to determine whether combined physical-cognitive engagement offers advantages over technology-based cognitive training alone. Furthermore, culturally adapted Persian-

language cognitive game interventions remain limited. Therefore, this randomized controlled trial aimed to compare the effects of physical and smart cognitive games on cognitive function among Iranian older adults. We hypothesized that both physical and smart cognitive game interventions would lead to significant improvements in overall cognitive function, with potentially different effects across specific cognitive domains. The findings may inform community-based eldercare programs and guide the development of culturally appropriate non-pharmacological interventions.

Methods

Ethical Considerations

This study was conducted in accordance with the Declaration of Helsinki and approved by the Ethics Committee of Qom University of Medical Sciences (Approval No. IR.MUQ.REC.1404.013). Following institutional approval, retired teachers aged 60 years and older were invited to participate. Before enrollment, the study objectives, procedures, and participation requirements were explained to all participants. Written informed consent was obtained from all participants prior to enrollment. Participation was voluntary, and participants were informed of their right to withdraw at any time without penalty. The confidentiality and privacy of participants' information were maintained throughout the study.

Participants

A total of 60 participants were recruited from the Retired Teachers' Association during the winter and spring of 2025 in Aran and Bidgol. Convenience sampling was employed for participant selection. The required sample size was estimated using G*Power 3.1 software based on a medium effect size (f = 0.25) for repeated measures ANOVA, a significance level of 0.05, and 80% power. A total of 60 participants (20 per group) was determined to be sufficient to detect significant differences between groups. Inclusion criteria were as follows: normal or corrected-to-normal hearing and vision; age ≥ 60 years; adequate cognitive ability to understand the interview and provide reliable responses, as determined by a brief researcher-administered cognitive screening; membership in the Retired Teachers' Association; ability to attend in-person sessions; effective communication skills; literacy (reading and writing); ability to learn the games; no use of psychotropic medications affecting alertness; no history of substance or alcohol abuse; absence of severe depression or other neurological disorders (e.g., stroke, vertigo, epilepsy); and no concurrent cognitive-enhancing interventions. Participants were excluded if they initiated new psychotropic medications affecting alertness, developed substance or alcohol abuse, began other cognitive interventions, or missed three or more intervention sessions. Our reporting follows the CONSORT checklist (24) as far as applicable. Figure 1 demonstrates the flow chart for the study.

Table 1 summarizes the clinical and demographic characteristics of participants assigned to the intervention and control groups.

Randomization and Blinding

Participants were randomly assigned to three groups of 20 individuals each (physical cognitive games, smart cognitive games, and control) using a randomization list generated with R software by an independent coordinator who was not involved in participant recruitment, intervention delivery, or outcome assessment. Allocation concealment was maintained using sequentially numbered, opaque, sealed envelopes, which were opened only after participant enrollment and assignment. Participants in the two intervention groups engaged in physical or smart cognitive games. All sessions were conducted in a quiet room at the Retired Teachers' Association in Aran and Bidgol. Prior to the intervention, trained evaluators instructed participants on the correct execution of the games to ensure safety and adherence. To minimize bias, outcome assessors were blinded to group allocation, and participants were instructed not to discuss their intervention with the assessors.

Control group usual care program

Participants in the control group received the standard care program offered by the Retired Teachers' Association. This included routine daily activities such as light physical exercise, social interactions, simple arts and crafts, and seated activities like conversation or light cognitive games. No additional interventions were provided. Sessions were conducted twice weekly, lasting at least 40 minutes per session, over a total of 15 sessions, in order to maintain participants' usual daily routines.

Intervention group training program

Based on previous research, the number and duration of intervention sessions typically ranged from 9 to 17 sessions, with session durations between 20 and 60 minutes (22, 25). Accordingly, in this study, each intervention group participated in three physical cognitive games (puzzle, sliding puzzle, and Tangram) or three corresponding smart cognitive games for a minimum of 40 minutes per session, twice weekly, over 15 sessions. The sessions followed a standardized sequence: the puzzle game was played for 10 minutes, followed by a 3-minute break; then the sliding puzzle was played for 10 minutes, followed by another 3-minute break; finally, the Tangram game was conducted. In the physical cognitive games group, all games were performed in a tabletop (physical) format, whereas in the smart cognitive games group, the same games were played in the same sequence on participants' smartphones, with the applications pre-installed. The puzzle game involved assembling separate pieces to form a complete image. The sliding puzzle consisted of a 4×4 square frame containing 15 numbered tiles and one empty space; players moved adjacent tiles into the empty space to achieve a specific order or pattern (e.g., numbers 1–15). The Tangram game included seven geometric pieces (5 triangles, 1 square, and 1 parallelogram) that participants arranged to recreate patterns provided on template cards (Fig. 2). To enhance motivation, games were performed competitively in pairs, and difficulty levels were adjusted according to each participant's cognitive abilities. Session timing was coordinated between researchers and participants to maximize adherence. If a participant chose to withdraw from the study, the

importance of their continued participation was explained, and efforts were made to encourage continuation; if unwilling, the participant was replaced. A facilitator was present during all sessions to provide guidance, correct movements, answer questions, and deliver positive feedback to maintain engagement and motivation. Table 1 provides a detailed overview of each game, including cognitive domain, format, duration per session, frequency, and total sessions.

Table 1
Overview of Cognitive Games, Target Domains, and Intervention Details

Game Type	Cognitive Domain	Format	Duration per Session	Frequency	Total Sessions
Puzzle	Visual memory, attention	Physical / Smart	10 min	Twice weekly	15
Sliding Puzzle	Executive function, problem solving	Physical / Smart	10 min	Twice weekly	15
Tangram	Spatial reasoning, planning	Physical / Smart	10 min	Twice weekly	15

Outcomes measured

Cognitive function was assessed at two points: baseline, prior to the start of the intervention, and immediately following the completion of the intervention. Before the first session, each participant completed the Wechsler Memory Scale (WMS) to record initial cognitive levels across multiple domains. Upon completion of all 15 sessions, the same assessment was administered again to evaluate the effects of the interventions on cognitive function.

All assessments were conducted at the Retired Teachers' Association, the same location where intervention sessions took place. To minimize bias, participants were instructed not to discuss their group allocation during assessments. Assessors were aware of participants' group assignments but administered all tests according to a standardized protocol to reduce measurement error.

To describe the sample's baseline characteristics and control for potential confounding variables, a standardized demographic checklist was used. This checklist collected information on age, sex, marital status, educational level, presence of chronic diseases, and use of assistive devices (e.g., glasses, hearing aids, and canes).

The primary outcome of this study was cognitive function. To assess this, the Wechsler Memory Scale – Adult Version, Third Edition (WMS-III) was used. The WMS-III evaluates seven domains: personal and general information, orientation, mental control, logical memory, digit memory, visual memory, and associative learning. Each domain is scored separately, and the sum of all scores provides a total memory performance score. The WMS-III has been standardized for the Iranian population by Orangi et al. (2002) (26) and Saed et al. (2010) (27).

Statistical Analysis

Collected data were initially preprocessed in Microsoft Excel. Analyses were conducted on an intention-to-treat basis. For participants with missing responses, missing values were replaced using the individual mean of available items. No participant dropped out completely, and all participants completed at least 12 of the 15 sessions. Statistical analyses were performed using SPSS version 27.0.

Descriptive statistics were reported as mean ± standard deviation for continuous variables and as frequencies with corresponding percentages for categorical variables. Prior to conducting inferential analyses, assumptions of normality and homogeneity of variances were assessed. To test study hypotheses and based on the type of variables, the following analyses were conducted: chi-square tests, independent-sample t-tests, paired-sample t-tests (pre- and post-intervention comparisons), repeated measures analyses, and ANOVA or their non-parametric equivalents when assumptions were violated. All analyses were performed at a significant level of 0.05.

Results

Table 2 presents the number of participants in each group. A total of 60 eligible older adults were randomly assigned to three groups of 20 participants each: control, physical cognitive games, and smart cognitive games. During the study, one participant in the physical cognitive games group withdrew after five sessions due to the death of a spouse, and one participant in the smart cognitive games group withdrew due to personal preference despite receiving full explanations. Because interventions were not conducted simultaneously for all participants, two replacement participants were enrolled to maintain group sizes.

Descriptive analyses showed that among the study participants, 28 (46.7%) were male. The mean age was 67.95 ± 2.68 years in the control group and 68.81 ± 2.68 years in the intervention groups. Groups were also comparable in terms of other baseline variables, including educational level, marital status, employment status, presence of chronic diseases, and use of assistive devices.

Baseline Cognitive Function of Intervention and Control Groups

Prior to the intervention, baseline assessments were conducted for both intervention groups (physical and smart cognitive games) and the control group. These assessments covered key cognitive domains, including personal and general information, orientation, mental control, logical memory, digit memory, visual memory, and associative learning. As shown in Table 2, no statistically significant differences were observed between groups in any of the measured variables ($P > 0.05$). These findings indicate that the groups were well-matched at baseline for the evaluation of cognitive function.

Table 2
Participant demographic and baseline characteristics

Variables		Physical games (Intervention group)	Smart games (Intervention group)	Control group	P-value
Age		67.80 (5.19)	67.80 (4.68)	68.05 (4.59)	0.982
Gender	Male	9 (45.0%)	9 (45.0%)	10 (50.0%)	0.935
	Female	11 (55.0%)	11 (55.0%)	10 (50.0%)	
Education	Diploma	13 (65.0%)	13 (65.0%)	12 (60.0%)	0.942
	Academic	7 (35.0%)	7 (35.0%)	8 (40.0%)	
Marital status	Married	12 (60.0%)	12 (60.0%)	13 (65.0%)	0.953
	Widowed	5 (25.0%)	5 (25.0%)	6 (30.0%)	
	Divorced	3 (15.0%)	2 (10.0%)	1 (5.0%)	
	Never married	0 (0.0%)	1 (5.0%)	0 (0.0%)	
Chronic illness	Yes	12 (60.0%)	9 (45.0%)	11 (55.0%)	0.626
	No	8 (40.0%)	11 (55.0%)	9 (45.0%)	
Assistive Devices	Dentures	1 (5.0%)	3 (15.0%)	(5.0%) 1	0.114
	Glasses	9 (45.0%)	4 (20.0%)	1 (5.0%)	
	Cane	3 (15.0%)	1 (5.0%)	3 (15.0%)	
	Walker	1 (5.0%)	5 (25.0%)	6 (30.0%)	
	Hearing Aid	1 (5.0%)	1 (5.0%)	1 (5.0%)	
	None	5 (25.0%)	6 (30.0%)	8 (40.0%)	

Comparison of cognitive function outcomes between intervention and control groups

Cognitive function was evaluated by comparing changes in Wechsler Memory Scale (WMS) scores across the intervention and control groups. Results are presented in Table 3. ANOVA analysis revealed a statistically significant difference between groups in total raw WMS scores at baseline (P = 0.037), which was attributed to the difference between the control group and the smart cognitive games group (P =

0.035). Post-intervention analysis showed significant differences between groups ($P < 0.001$). Post-hoc Tukey tests indicated significant differences between the control and physical cognitive games groups ($P < 0.001$), the control and smart cognitive games groups ($P < 0.001$), and between the physical and smart cognitive games groups ($P = 0.017$). Repeated measures ANOVA confirmed a significant main effect of group ($P < 0.001$) and a significant group × time interaction ($P < 0.001$), indicating that mean WMS scores differed significantly across groups and that the magnitude of change over time varied significantly between groups. Within-group analyses using paired-sample t-tests showed a moderate but significant increase in the control group from pre- to post-intervention ($P = 0.012$, $d = 0.62$). The physical cognitive games group demonstrated a significant and large increase in total WMS scores ($P < 0.001$, $d = 3.43$), while the smart cognitive games group showed an even larger and significant increase compared to the other groups ($P < 0.001$, $d = 4.91$). These results indicate that both types of cognitive games significantly improved total WMS scores in older adults, with the smart cognitive games group exhibiting the greatest overall improvement (Table 3, Fig. 3).

In addition, changes in the WMS subdomain scores were analyzed across all 60 participants. Mean scores improved in all cognitive subdomains following the intervention.

Table 3
Data of measurement outcomes at baseline and post-test

Domains	Group	Baseline Mean (SD)	Post-test Mean (SD)	Test	P value	
Personal and general information	Physical Games	4.35 (0.93)	5.55 (0.69)	-3.874*	<0.001	
	Digital Games	4.40 (0.99)	5.45 (0.94)	-3.827*	< 0.001	
	Control	4.05 (0.94)	4.20 (1.24)	-1.342*	0.180	
Orientation		Physical Games	3.70 (0.57)	4.60 (0.60)	-3.819*	< 0.001
		Digital Games	4.25 (0.64)	4.90 (0.31)	-3.357*	0.001
		Control	4.00 (0.73)	4.00 (0.86)	0.000*	1.000
Mental control	Physical Games	6.35 (1.27)	7.30 (1.13)	-8.324**	< 0.001	
	Digital Games	6.15 (1.23)	7.55 (1.05)	-9.200**	< 0.00	
	Control	6.35 (1.18)	6.40 (1.19)	-0.567**	0.577	
Logical memory	Physical Games	15.60 (3.10)	16.70 (3.36)	-8.904**	< 0.001	
	Digital Games	17.35 (3.39)	18.90 (3.26)	-7.815**	< 0.001	
	Control	15.40 (4.28)	15.65 (4.45)	-2.032**	0.056	
Numerical memory	Physical Games	9.45 (1.90)	10.30 (2.05)	-5.667**	< 0.001	
	Digital Games	9.05 (1.96)	10.50 (2.19)	-8.542**	< 0.001	
	Control	8.85 (1.42)	8.80 (1.47)	0.567**	0.577	
Visual memory	Physical Games	4.60 (1.31)	5.40 (1.31)	-5.812**	< 0.001	

Domains	Group	Baseline Mean (SD)	Post-test Mean (SD)	Test	P value
	Digital Games	4.85 (1.39)	6.00 (1.08)	-5.510**	< 0.001
	Control	4.80 (1.44)	5.00 (1.62)	-1.453**	0.163
Associative learning	Physical Games	11.85 (2.62)	12.80 (2.35)	-7.025**	< 0.001
	Digital Games	12.85 (3.41)	13.90 (2.86)	-5.688**	< 0.001
	Control	11.35 (3.07)	11.55 (3.19)	-1.710**	0.104
Total score	Physical Games	55.90 (4.08)	62.65 (4.34)	-15.322**	< 0.001
	Digital Games	58.90 (4.99)	67.20 (4.49)	-21.977**	< 0.001
	Control	54.80 (6.00)	55.60 (6.13)	-2.792**	0.012

*Wilcoxon

** Paired Samples T-test

Subgroup Analysis of Cognitive Improvements in Intervention and Control Groups

To examine whether the effects of the intervention differed according to baseline cognitive performance, a subgroup analysis was conducted on all 60 participants, categorized into three groups. Cognitive improvement scores (calculated as post-intervention minus pre-intervention values) were computed for each outcome measure and statistically compared across the three groups. As illustrated in Fig. 4, significant differences were observed in cognitive outcomes among the groups, indicating that the type of intervention had a differential impact on cognitive improvements.

The results of the Kruskal–Wallis test showed that before the intervention, there was no significant difference between the groups in terms of mean personal and general information scores (P = 0.316). No baseline differences were found (P = 0.316), but post-intervention differences were significant (P < 0.001). Both intervention groups improved significantly (P < 0.001), whereas the control group did not (P = 0.180). Based on the results of the non-parametric Kruskal–Wallis test, before the intervention there was no significant difference between groups in mean orientation scores (P = 0.051); however, after the

intervention, the differences became significant (P = 0.001). The Wilcoxon test showed that in the control group, no significant change was observed from pre-test to post-test (P = 1.000). In contrast, significant increases in orientation scores were observed in both the physical game group (P < 0.001) and the smart game group (P = 0.001). Therefore, both types of cognitive games improved orientation in older adults.

Regarding mental control, before the intervention there was no significant difference between groups (P = 0.838). After the intervention, ANOVA indicated significant differences (P = 0.005). According to Tukey's post hoc test, these differences were observed between the control and physical game groups (P = 0.037) and between the control and smart game groups (P = 0.006). After the intervention, the mean mental control score of the control group was significantly lower than that of the two intervention groups. Repeated measures ANOVA showed that the main effect of group was significant (P = 0.037), and the group × time interaction effect was also significant (P < 0.001). These findings indicate that although overall group means differed significantly, the magnitude of change over time also differed significantly across groups. Paired samples t-tests showed no significant change in the control group from pre-test to post-test (P = 0.577). In the physical game group, a significant and large increase in mental control scores was observed (P < 0.001, d = 1.86). In the smart game group, a significant and even larger increase was observed (P < 0.001, d = 2.06). These findings suggest that cognitive games had a substantial effect on improving mental control in older adults, with smart games showing a greater effect than physical games.

In terms of logical memory, before the intervention there was no significant difference between groups (P = 0.183). After the intervention, ANOVA showed significant differences (P = 0.025). Tukey's post hoc test indicated that this difference was between the control and smart game groups (P = 0.021). After the intervention, the mean logical memory score of the control group was significantly lower than that of the smart game group. Repeated measures ANOVA showed that although the main effect of group was not significant (P = 0.073), the group × time interaction effect was significant (P < 0.001). This finding indicates that while overall group means were similar, the magnitude of change over time differed significantly across groups. Paired-samples comparisons showed no significant change in the control group (P = 0.056). In the physical game group, a significant and large increase in logical memory scores was observed (P < 0.001, d = 1.99). In the smart game group, a significant increase was also observed, although slightly smaller than in the physical game group (P < 0.001, d = 1.75).

In the domain of digit memory, no significant differences were observed between the groups before the intervention (P = 0.558); however, after the intervention, ANOVA analysis indicated significant differences (P = 0.014). According to the results of the Tukey post-hoc test, this difference was observed between the control and physical game groups (P = 0.044) and between the control and smart game groups (P = 0.020). After the intervention, the mean digit memory score of the control group was significantly lower than that of the other two groups. Repeated measures ANOVA showed that, although the main effect of the group was not significant (P = 0.144), the group × time interaction effect was significant (P < 0.001). This finding indicates that, while the overall mean scores of the groups were similar, the amount of change over time differed significantly across the groups. Paired-sample t-tests revealed that the control

group showed no significant change from pre- to post-test (P = 0.577), whereas the physical game group exhibited a significant and large increase in digit memory scores from pre- to post-test (P < 0.001, d = 1.27). The smart game group also showed a significant and larger increase compared to the other two groups (P < 0.001, d = 1.91).

Regarding visual memory, ANOVA analysis did not show significant differences between groups at pre- or post-test (P > 0.05). Repeated measures ANOVA indicated that, although the main effect of the group was not significant (P = 0.414), the group × time interaction effect was significant (P = 0.001). This finding suggests that, although the overall mean scores were similar, the magnitude of change over time differed significantly across groups. Paired-sample t-tests showed that the control group had no significant change from pre- to post-test (P = 0.163). In the physical game group, a significant and large increase in visual memory scores was observed from pre- to post-test (P < 0.001, d = 1.29), while the smart game group also showed a significant increase, but slightly smaller than that of the physical game group (P < 0.001, d = 1.23).

Finally, in the domain of associative learning, there were no significant differences between groups before the intervention (P = 0.293). After the intervention, significant differences emerged (P = 0.038). According to the Tukey post-hoc test, this difference was observed between the control and smart game groups (P = 0.029). After the intervention, the mean associative learning score of the control group was significantly lower than that of the smart game group. Repeated measures ANOVA indicated that, although the main effect of the group was not significant (P = 0.112), the group × time interaction effect was significant (P < 0.001). This finding suggests that, while the overall mean scores of the groups were similar, the amount of change over time differed significantly among the groups. Paired sample t-tests showed no significant change in the control group from pre- to post-test (P = 0.104). In the physical game group, a significant and large increase in associative learning scores was observed from pre- to post-test (P < 0.001, d = 1.57), whereas the smart game group also showed a significant increase, though smaller than that of the physical game group (P < 0.001, d = 1.27).

Discussion

The present study aimed to examine and compare the effects of physical board games and smart games on cognitive performance in older adults. To assess cognitive performance, the Wechsler Memory Scale (WMS-III) was used in this study. The findings indicated that following the 15-session game-based intervention, the mean cognitive performance scores of both the physical and smart game groups showed significant increases when the total scores of the seven cognitive domains were combined. The group × time interaction effect was also significant. Both the physical and smart game groups demonstrated greater improvements in overall cognitive performance compared to the control group, which received usual care. The observed improvements in cognitive performance were not only statistically significant but also clinically interpretable. Participants showed an increase of more than 2 points on average in the Wechsler test after the intervention, exceedingly the minimal clinically important difference of 2 points established in clinical research, indicating a perceptible improvement in cognitive

status (28). This increase is particularly important in populations with mild cognitive impairment (MCI) or early-stage dementia, where even small changes can signal functional cognitive improvements, such as better medication management, attention to safety cues, or simple financial planning.

Beyond the overall improvement in total cognitive scores, domain-specific patterns emerged. While both interventions improved most cognitive subdomains, the magnitude of change varied depending on the type of game. Physical games showed relatively stronger effects in domains such as logical memory, visual memory, and associative learning, whereas smart games demonstrated more pronounced improvements in digit memory and mental control. This differential pattern indicates that distinct cognitive mechanisms may be activated depending on the mode of engagement.

In the domain of personal and general information, both intervention groups improved, whereas the control group did not. These findings are consistent with previous research indicating that structured cognitive programs and repeated activation of long-term memory pathways enhance retrieval processes in older adults (29–33). Within the framework of the Scaffolding Theory of Aging and Cognition (STAC), repeated cognitive engagement may promote compensatory neural scaffolding, enabling more efficient utilization of preserved cognitive resources (34).

Similarly, improvements in orientation observed in both intervention groups align with prior studies demonstrating that active cognitive exercises and game-based training enhance spatial and environmental processing abilities in older adults (17, 35). Theoretical models of spatial cognition emphasize that interaction with structured visual and problem-solving tasks can strengthen cognitive mapping processes and attentional control, which may explain the observed gains.

In the domain of logical memory, improvements in both intervention groups are consistent with earlier findings suggesting that structured cognitive training and interactive exercises strengthen reasoning and organized information processing (15, 17, 22). Repeated exposure to rule-based tasks and problem-solving activities likely enhances encoding strategies and retrieval organization, contributing to improved logical recall.

Digit memory showed particularly strong improvement in the smart game group. This finding aligns with previous research indicating that adaptive digital cognitive training programs can enhance working memory and processing speed through repetitive, progressively challenging tasks (35, 36). From the perspective of Selection, Optimization, and Compensation (SOC) theory, older adults may optimize remaining cognitive resources through targeted practice, especially when training is structured and feedback-driven (37, 38). The adaptive and rapid-response nature of digital games may explain their comparatively larger impact on working memory.

Visual memory improvements observed in both intervention groups are consistent with studies demonstrating that interactive visual tasks and regular cognitive engagement enhance visual processing and memory performance in older adults (17, 23, 31). Repeated exposure to visually demanding tasks

may strengthen visuospatial pathways and attentional networks, supporting neuroplastic adaptation in aging populations.

In associative learning, both groups demonstrated significant gains, with physical games showing slightly larger improvements. Prior clinical trials have reported that structured board-game and paired-associate interventions improve associative encoding and recall in older adults (39, 40). Physical board games may provide embodied, sensorimotor engagement and social interaction components that reinforce associative binding processes, potentially contributing to their stronger effect in this domain.

Overall, the present findings suggest that both physical and smart cognitive games are effective non-pharmacological strategies for enhancing cognitive function in older adults, but their cognitive impact is not uniform across domains. Physical games may preferentially engage visuospatial integration and associative processes, possibly due to tactile manipulation and social interaction components. In contrast, smart games may exert stronger effects on executive control and working memory, likely due to adaptive difficulty, rapid feedback, and repetitive cognitive demands. This pattern is consistent with previous domestic and international research reporting domain-specific benefits of different cognitive training modalities (22, 41, 42).

Strengths of the study

This study has several notable strengths. First, it employed a randomized controlled trial design with an active control group, allowing for a rigorous evaluation of intervention effects and minimizing selection bias. Importantly, this study directly compared physical cognitive games and smart cognitive games within the same population, providing head-to-head evidence that is currently limited in the literature.

Second, cognitive outcomes were assessed using a standardized and culturally validated instrument (WMS-III), and domain-specific analyses were conducted. This approach enabled a detailed examination of differential effects across multiple cognitive domains rather than relying solely on global cognitive scores.

Third, the intervention incorporated culturally adapted Persian-language games tailored to Iranian older adults. Such contextualization enhances ecological validity and supports the feasibility of implementing non-pharmacological cognitive interventions in community-based settings within Middle Eastern populations.

Collectively, these strengths increase the internal validity, contextual relevance, and practical applicability of the findings

Limitations

Several limitations should be acknowledged. First, this study was conducted in a single community center using convenience sampling, which may limit the generalizability of the findings. The relatively small sample size and the inclusion of literate older adults only may further restrict external validity.

Additionally, although efforts were made to control confounding factors, studies involving older adults are inherently susceptible to unmeasured influences such as fluctuations in physical health, emotional status, or environmental stressors.

Second, some participants had limited prior exposure to digital technologies, which may have influenced engagement and performance in smart game intervention. Moreover, the study did not include long-term follow-up assessments; therefore, the durability of cognitive improvements over time remains uncertain.

Future research with larger, more diverse samples, multi-center designs, and extended follow-up periods (e.g., 6–12 months) is recommended to further evaluate the sustainability and generalizability of these findings.

Conclusion

The findings of this randomized controlled trial indicate that both physical and smart cognitive games were associated with significant improvements in cognitive performance among older adults with mild cognitive impairment. While physical games demonstrated relatively stronger effects in domains such as visual memory, logical memory, and associative learning, smart games showed larger improvements in executive-related functions, including digit memory and mental control. These differential patterns suggest that the mode of cognitive engagement may influence specific cognitive domains.

The combined or tailored use of physical and smart cognitive games may represent a feasible and culturally adaptable non-pharmacological strategy for supporting cognitive health in community-dwelling older adults.

Declarations

Ethics approval and consent to participate

This study was conducted in accordance with the Declaration of Helsinki and was approved by the medical Ethics Review Committee of Qom University of medical sciences (Approval No. 20230641). Informed consent was obtained for all participants prior to their enrollment in the study. The consent procedure was conducted by trained research staff in a quiet and private setting.

Consent for publication

Not applicable.

Competing interests

The authors declare no competing interest

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Author Contribution

F.H. conceived and designed the study, conducted the literature review, collected the data, interpreted the findings, and wrote the first draft of the manuscript. Z.A.A. supervised the study, contributed to the study design and methodology, critically revised and edited the manuscript, and provided scientific guidance throughout the research process. S.G. performed the statistical analyses, assisted with data interpretation, and critically reviewed the manuscript. All authors read and approved the final manuscript.

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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.

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Figures

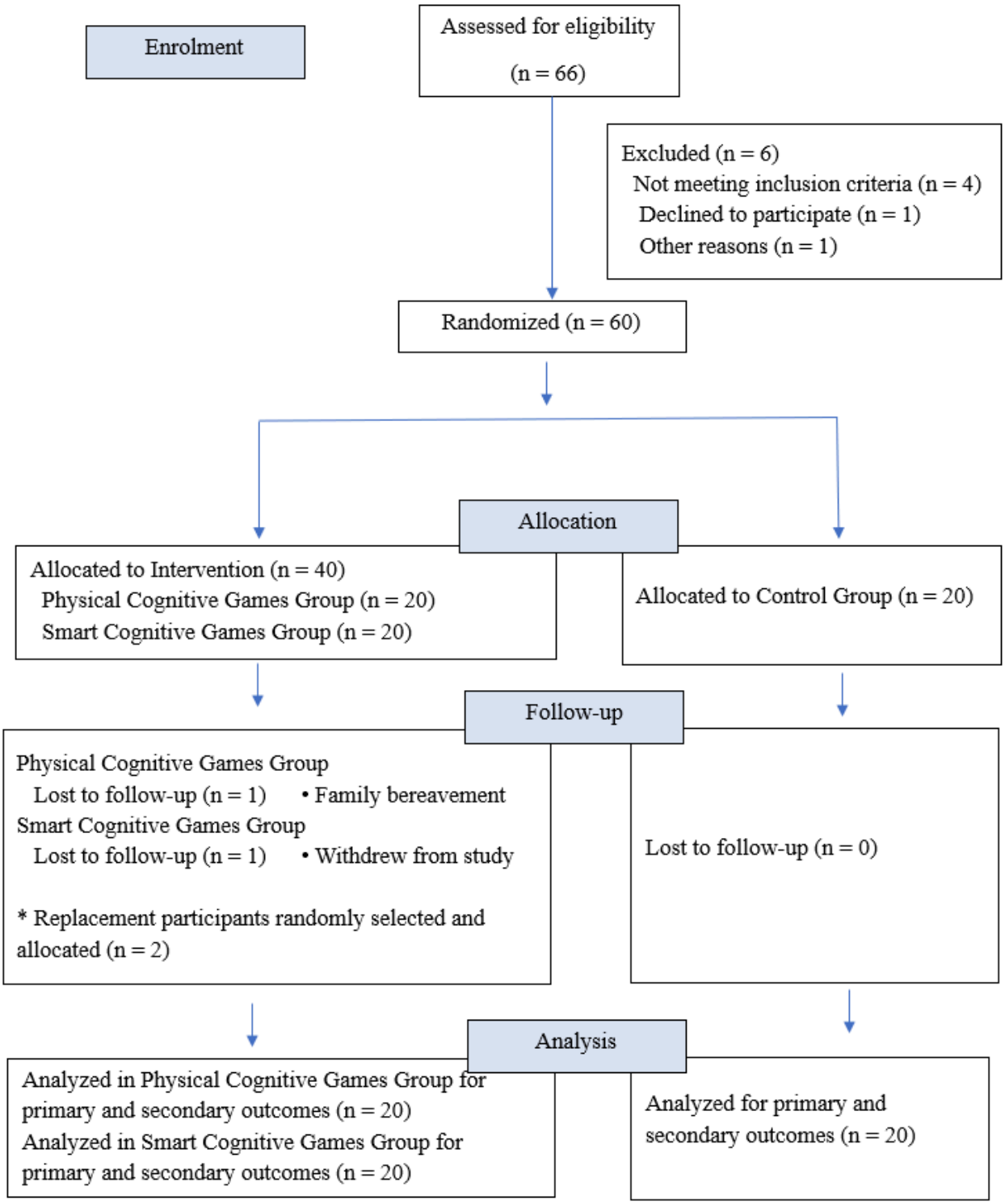


Figure 1

CONSORT 2025 flow diagram (24)



Figure 2

(1) Puzzle games, (2) sliding puzzles, and (3) tangram, which were played in two forms: physical board games and digital games, in two groups.

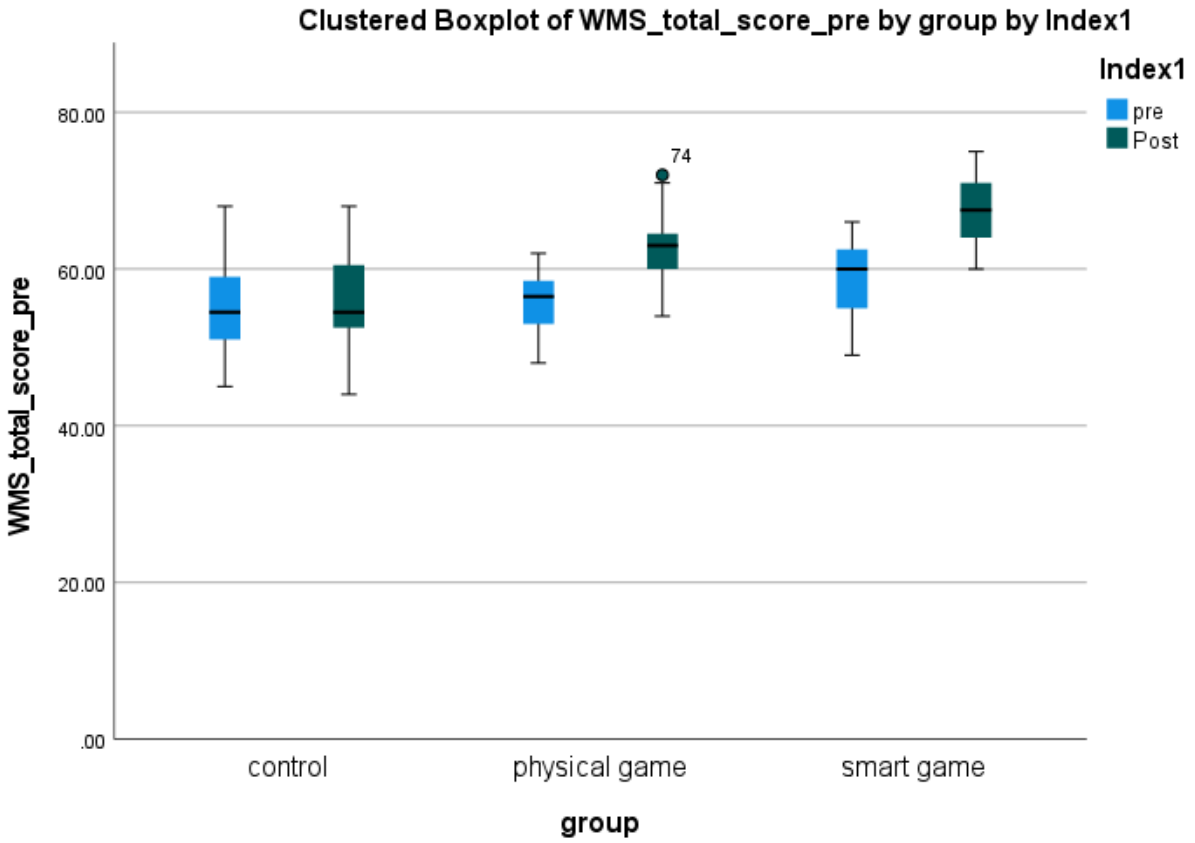


Figure 3

Between-group differences in total cognitive performance score in the intervention effect among the three groups of physical games, digital games, and the control group.

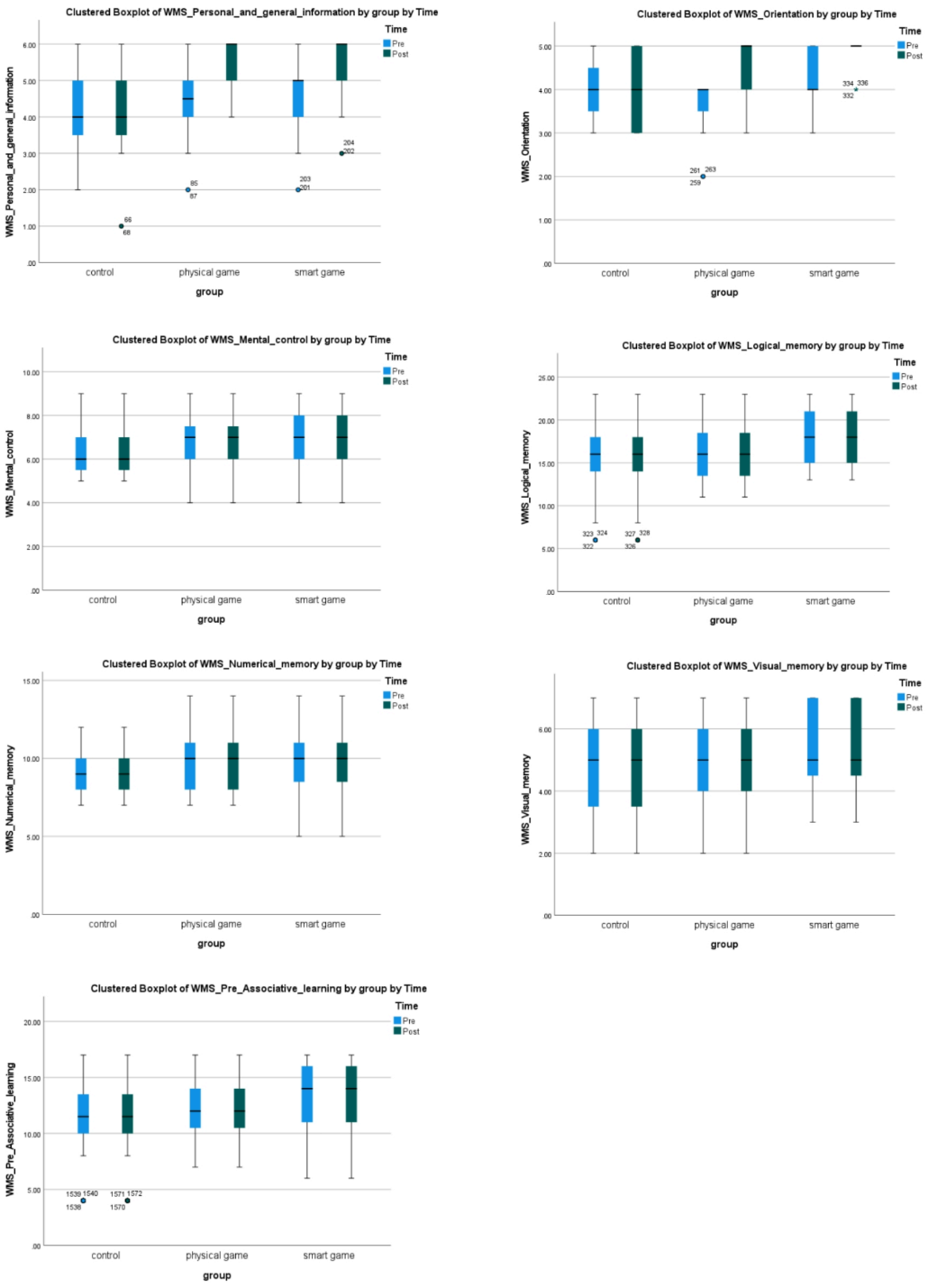


Figure 4

Between-group differences in cognitive performance subscales in the intervention effect among the three groups of physical games, digital games, and the control group.