Impact of a game-based intervention on chronic low back pain considering the interference of kinesiophobia in middle-aged and older adults

Impacto de una intervención basada en juegos sobre el dolor lumbar crónico considerando la interferencia de la kinesiofobia en adultos de mediana edad y mayores

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Abstract

Introduction: Chronic low back pain (CLBP) is a prevalent condition among middle-aged and older adults, causing physical, psychological, and social impairments. Innovative interventions, such as gamified exercise programs, may improve adherence and engagement while reducing pain.
Objective: This pre- and post-experimental study analysed the effect of an analog game (gamification of physical exercise) on CLBP and explored how kinesiophobia influences engagement and pain outcomes in middle-aged and older adults. Methods: Twenty-five participants (66.8 ± 13.5 years; 76% female) completed four sessions of the Tree Game, a structured floor-based analog game combining physical, cognitive, and social challenges. Pain intensity was measured with the Numeric Pain Rating Scale (NPRS) at baseline (T0), post-intervention (T1), and after a no-intervention period (T2). Engagement and focus were assessed through post-session open-ended reflections. Baseline kinesiophobia was measured using the Tampa Scale for Kinesiophobia (TSK-13).
Results: Pain intensity decreased significantly from T0 to T1 (6.9 ± 2.9 vs. 3.4 ± 2.9, $p < 0.001$) and remained lower at T2 (4.6 ± 2.5, $p < 0.001$). Engagement shifted from task execution to cognitive concentration and competitiveness/social interaction across sessions, indicating progressive immersion. No significant interaction was found between baseline kinesiophobia and pain outcomes. Conclusions: The Tree Game effectively reduced pain intensity while promoting cognitive and social engagement. Emphasizing game mechanics and immersive elements may enhance participant involvement, supporting gamified physical interventions as a multifaceted strategy for managing CLBP in older adults.

Keywords

Chronic low back pain; cognitive engagement; gamification; immersive intervention; kinesiophobia; serious games.

Resumen

Introducción: El dolor lumbar crónico (DLC) es una condición prevalente entre adultos de mediana edad y mayores, causando afectaciones físicas, psicológicas y sociales. Intervenciones innovadoras, como los programas de ejercicio gamificados, pueden mejorar la adherencia y el compromiso, a la vez que reducen el dolor.
Objetivo: Este estudio pre y post-experimental analizó el efecto de un juego analógico (gamificación del ejercicio físico) sobre el DLC y exploró cómo la kinesiophobia influye en el compromiso y los resultados del dolor en adultos de mediana edad y mayores.
Métodos: Veinticinco participantes (66,8 ± 13,5 años; 76% mujeres) completaron cuatro sesiones del Tree Game, un juego analógico estructurado basado en el suelo que combina desafíos físicos, cognitivos y sociales. La intensidad del dolor se midió con la Escala Numérica de Dolor (END) al inicio (T0), post-intervención (T1) y tras un período sin intervención (T2). El compromiso y la concentración se evaluaron mediante reflexiones abiertas después de cada sesión. La kinesiophobia basal se midió con la Tampa Scale for Kinesiophobia (TSK-13).
Resultados: La intensidad del dolor disminuyó significativamente de T0 a T1 (6,9 ± 2,9 vs. 3,4 ± 2,9, $p < 0{,}001$) y se mantuvo más baja en T2 (4,6 ± 2,5, $p < 0{,}001$). El compromiso evolucionó desde la ejecución de tareas hacia la concentración cognitiva y la interacción competitiva/social, reflejando una inmersión progresiva. No se encontró interacción significativa entre la kinesiophobia basal y los resultados sobre el dolor.
Conclusiones: El Tree Game redujo eficazmente la intensidad del dolor y promovió el compromiso cognitivo y social. Potenciar los elementos de juego y la inmersión puede aumentar la participación, respaldando las intervenciones físicas gamificadas como estrategia multifacética para el manejo del DLC en adultos mayores.

Palabras clave

Dolor lumbar crónico; compromiso cognitivo; gamificación; intervención inmersiva; juegos serios; kinesiophobia.

Introduction

Chronic low back pain (CLBP) is defined as pain or discomfort localized in the lumbar region persisting for three or more months (Burton et al., 2006; Stretanski MF et al., 2025). CLBP represents a major public health concern, being one of the leading causes of disability worldwide (Buchbinder et al., 2018) and a condition that demands substantial medical and therapeutic attention (Hoy et al., 2010). Globally, approximately 1.9 billion people are affected by CLBP (Mills et al., 2019). In the Portuguese population, CLBP is the most prevalent type of chronic pain, affecting around 37% of adults (Antunes et al., 2021). Among middle-aged adults (40–64 years), prevalence reaches 43.76%, and among older adults (>65 years) is 61.37% (Azevedo et al., 2012). Considering the projected increase in the elderly population in Portugal in the coming years (Instituto Nacional de Estatística, 2024), the incidence of CLBP is likely to rise further.

CLBP is associated with physical impairments due to trunk muscle weakness and reduced functionality, limiting the range of motion during activities of daily living (Di Iorio et al., 2007). Beyond these physical limitations, CLBP also impacts mental health, potentially contributing to depression, anxiety, kinesiophobia, pain catastrophizing, and fear-avoidance beliefs (Yang et al., 2023). The association between CLBP and mental health factors appears to involve shared neuroplastic mechanisms, which may explain the bidirectional relationship (Yang et al., 2023).

Kinesiophobia, defined as an irrational and debilitating fear of movement, is central to the development and persistence of CLBP (Monticone et al., 2013; Unsgaard-Tøndel et al., 2013). Individuals with kinesiophobia often perceive physical activity as potentially harmful, reinforcing avoidance behaviours and creating a vicious cycle of inactivity, deconditioning, and persistent pain (Bordeleau et al., 2022; Rainville et al., 2011; Vlaeyen et al., 2016). Addressing these psychological mechanisms is therefore critical for effective CLBP management.

Management strategies for CLBP include both pharmacological and non-pharmacological interventions. Pharmacological approaches commonly involve analgesics, anti-inflammatories, and muscle relaxants (Mauck et al., 2022). Non-pharmacological strategies encompass structured exercise programs, manual therapy, psychological interventions (e.g., cognitive-behavioural therapy), and health education for self-management (Mauck et al., 2022). Structured exercise (Masyitah et al., 2025) is widely recommended for CLBP treatment (van Middelkoop et al., 2010)(García Meneses et al., 2025) yet adherence and motivation remain major barriers (Zadro et al., 2019a). Dual-task exercise programs have shown promise in reducing kinesiophobia by allowing individuals to perform movements without perceiving pain (Asefi Rad & Wippert, 2024).

Gamification has emerged as an innovative approach to enhance adherence and engagement in exercise programs for CLBP patients (Heston, 2023). By directing attention to external game mechanics and dynamics, gamification reduces the focus on bodily sensations, alleviating perceived pain and promoting immersive movement experiences (Matheve et al., 2020). Given these mechanisms, it is crucial to explore which aspects of the game or contextual factors capture the user's attention during the intervention, aiming to understand and characterise how engagement is managed and maintained throughout the exercise program. Previous research has shown that both the design of game mechanics and the context in which the game is implemented can significantly influence user engagement. For example, Wang et al. (2021) highlighted that autonomy-supportive elements and lifestyle integration in serious health games can enhance adherence and sustained involvement. Similarly, Ridgway et al. (2021) demonstrated that personalisation of game elements based on user characteristics and contextual factors increases engagement and effectiveness of gamified interventions. Moreover, Vermeir et al. (2025) investigated attention and behavioural engagement in a gamified attention bias modification program for chronic pain, showing that monitoring which game features capture attention is key to optimise engagement and intervention outcomes. Incorporating such insights into the design and implementation of gamified exercise programs for chronic low back pain may help ensure that users remain focused and motivated throughout the intervention, potentially maximising both physical and psychological benefits. In addition to improving motivation, gamified interventions can enhance physical outcomes such as muscle strength, functional performance, balance, and fall risk reduction (Alfieri et al., 2022), and may positively influence psychological factors, including kinesiophobia (Vlaeyen & Linton, 2012).

Previous studies exploring gamified exercise in middle-aged and older adults with CLBP have predominantly focused on digital games and virtual reality (VR) interventions (Yalfani et al., 2022). These studies reported significant reductions in pain intensity, particularly through VR-based interventions such as Wii Fit U, core and strength training with Wii Fit Plus, Oculus Go, and Xbox Kinect (Monteiro-Junior et al., 2015; Yalfani et al., 2022; Zadro et al., 2019b). However, improvements in mental health outcomes, including mood, anxiety, pain self-efficacy, and kinesiophobia—were generally non-significant (Monteiro-Junior et al., 2015; Stamm et al., 2022; Yalfani et al., 2022; Zadro et al., 2019b).

While digital gamification has demonstrated efficacy for pain reduction, analogue (non-digital) games offer distinct advantages that warrant investigation. Analogue games can be more ecologically valid, inclusive, and easily implementable across diverse clinical, community, and home-based settings (Mortenson et al., 2017). They allow flexible adaptation to individual functional levels, promote social interaction, and may provide similar cognitive and physical stimulation without requiring costly technology (Chang & Wu, 2024) . This presents a meaningful opportunity to expand research on gamified exercise in middle-aged and older adults with CLBP, integrating both physical and psychological outcomes.

In summary, CLBP is a complex condition affecting both physical and mental health, with kinesiophobia and fear-avoidance behaviours playing a critical role in its persistence. Gamification of exercise presents a promising approach to overcome barriers to adherence and reduce pain intensity, yet evidence regarding its impact on mental health remains limited. Furthermore, analogue gamified interventions represent a potentially ecological and inclusive strategy that is underexplored in this population, highlighting a clear gap for future research.

Therefore, the objective of this pre- and post-experimental study is to examine the effects of an analogue game-based exercise program on chronic low back pain (CLBP) in middle-aged and older adults, while exploring the role of kinesiophobia in moderating these effects. Specifically, the study aims to evaluate changes in pain intensity following participation in the game-based exercise compared to an equivalent period without the intervention, and to investigate how kinesiophobia, measured by the Tampa Scale of Kinesiophobia, may influence the modulation of pain intensity, and to assess the engagement during gameplay.

Method

A pre- and post-experimental study was conducted between March and April 2025, involving individuals aged ≥40 years diagnosed with CLBP. The intervention consisted of applying the Tree Game, a structured therapeutic activity developed within the Agilidades Method—a hybrid clinical framework that combines analogue and technological tools to promote motor and cognitive stimulation in an accessible and inclusive manner. In this study, the Tree Game was applied in its fully analogue version, without the use of digital components, to ensure broad accessibility and adaptability to the clinical setting and target population.

Data were collected at three time points: T0 (baseline, prior to the intervention), T1 (immediately after the intervention), and T2 (following a designated timeout period in which no exposure to the Tree Game occurred). This timeout period allowed for the assessment of the short-term retention or decline of effects observed at T1. This study design enabled the analysis of both the immediate impact and short-term sustainability of the intervention's effects.

The study protocol was reviewed and approved by the Ethics Committee of the Polytechnic University of Leiria (approval reference: CE/IPLEIRIA/11/2025), in accordance with the Declaration of Helsinki.

Participants

Participants were recruited from a range of settings, including nursing homes, adult day care centres, senior universities, outpatient clinics, and through community outreach on social media, coordinated by four researchers (B.H., F.A., L.J., M.A.). Partner institutions conducted an initial informal screening of older adults who expressed willingness to participate. All participants provided written informed consent before enrolment.

Eligibility criteria were then formally assessed and confirmed during an initial on-site visit by the research team. Inclusion criteria were: (i) middle-aged and older adults (≥ 40 years); (ii) diagnosis of CLBP condition for at least 3 months; (iii) independent ambulation without the use of assistive devices; (iv) pain intensity score ≥ 3 on the Numeric Pain Rating Scale (Langford et al., 2023); (v) a score ≥ 23 on the Tampa Scale for Kinesiophobia (TSK-13), indicating clinically relevant fear of movement (Roelofs et al., 2004) ; (vi) a score between 25 and 30 on the Mini-Mental State Examination (MMSE) (O'Bryant et al., 2008) , indicating preserved cognitive function; and (vii) a score < 32 on the Falls Efficacy Scale (FES-I) (Marques-Vieira et al., 2018), indicating low to moderate fall risk. Exclusion criteria included the use of mobility aids and the presence of severe spinal pathology involving neurological compromise or functional incapacitation (e.g., inability to ambulate, bed confinement).

A target sample size was established with a minimum desired threshold of 22 participants, based on findings from five previous studies on this topic (Brown et al., 2020; Monteiro-Junior et al., 2015; Stamm et al., 2022; Yalfani et al., 2022; Zadro et al., 2019b), which reported sample sizes ranging from 22 to 60 participants. Accordingly, the sample size adopted for the present study was deemed methodologically appropriate for its exploratory nature.

Procedure

At baseline (T0), participants completed a clinical and sociodemographic questionnaire. The Numeric Pain Rating Scale (NPRS), as the main outcome measure for pain intensity, was administered at T0, immediately after the intervention (T1), and after a subsequent equal no-intervention time out period (T2). The Tampa Scale for Kinesiophobia (TSK-13) was applied only at baseline to categorize participants according to their level of kinesiophobia, allowing for the consideration of its potential influence on pain intensity.

After each intervention session, a retrospective adherence questionnaire was completed to assess participant engagement during gameplay.

Instrument

Clinical and Sociodemographic questionnaire

The questionnaire consisted of 25 items covering sociodemographic variables (e.g., age in years, sex [female/male], education level [basic, secondary, higher], and profession [open-ended]), clinical history (e.g., current health status [open-ended], number and type of comorbidities [checklist], medication use [yes/no], and physiotherapy engagement [yes/no]), and physical activity details (type [group-based, individual, sports] and frequency [times per week]). Pain assessment included closed-ended questions on presence (yes/no), location (marked on a body chart), type (acute, stabbing, burning, etc.), frequency (constant, frequent, rare), and its impact on sleep quality and disposition (yes/no). Functional limitations due to pain were assessed using ordinal response scales, which allow the evaluation of symptom intensity or functional restriction through ordered categorical responses. For example, participants were asked about changes in pain throughout the day (increases, decreases, remains the same) and the level of limitation when performing daily activities (no limitation, slight discomfort, moderate discomfort, severe discomfort, unable to perform). The questionnaire design was informed by established guidelines for assessing clinical and sociodemographic variables in pain research, as recommended by (Dworkin et al., 2008) ensuring comprehensive and standardised data collection aligned with best practices in the field.

Numeric Pain Rating Scale (NPRS)

The NPRS was used to assess the intensity of CLBP at three time points: baseline (T0), after the final intervention session (T1), and after a comparable control period without the intervention (T2). Participants rated their pain intensity on an 11-point numeric scale from 0 ("no pain") to 10 ("worst imaginable pain"). Pain scores were classified into four levels: no pain (<0.5), mild (0.5–4.4), moderate (4.5–7.4), and severe (>7.5). Beyond its ease of use and interpretability, the NPRS has demonstrated strong psychometric properties, including high test-retest reliability (ICC = 0.95), construct validity through correlation with other pain measures, and responsiveness to clinical change (Alghadir et al., 2018; Farrar et al., 2001).

Tampa Scale for Kinesiophobia (TSK-13)

The TSK-13 was used to assess fear of movement and re-injury associated with CLBP (Vlaeyen et al., 1995) at baseline (T0). The TSK-13 is a self-reported questionnaire consisting of 13 items, each rated on a 4-point Likert scale from 1 (“strongly disagree”) to 4 (“strongly agree”), with total scores ranging from 13 to 52. Higher scores indicate greater fear of movement. Scores above 37 are typically interpreted as clinically relevant kinesiophobia. The TSK-13 has shown good psychometric properties, including acceptable internal consistency (Cronbach’s $\alpha \approx 0.80$), test-retest reliability, and construct validity through its correlation with pain intensity, disability, and psychological distress (Roelofs et al., 2004).

For this study, the categorization of TSK-13 scores into three levels of kinesiophobia was based on the theoretical distribution of the scale and on previous studies (Neblett et al., 2017; Roelofs et al., 2004) with the following cut-off ranges adopted: mild (23–32), moderate (33–42), and severe (43–52).

Engagement during gameplay

The evaluation of engagement during gameplay followed the approach described (MacLean et al., 2025). After each session, participants were asked a single open-ended question: 'What was the focus of your attention while playing?' This question was designed to capture participants’ subjective experiences, including motivation, attentional focus, and overall perception of the activity. Responses were collected freely, without constraints, and analysed using qualitative content analysis, which allowed for the identification of emergent themes and categories that reflected how participants experienced and interpreted the gameplay in each session.

Game-based intervention

The Tree Game (TG) is a highly immersive floor-based board game designed to integrate physical, cognitive, and language-based stimuli within the same task structure. The game promotes motor and cognitive engagement through a narrative of cooperative or competitive farming, where players aim to "grow a tree" by completing targeted challenges. The central component of the game is a floor mat measuring 170 x 200 cm, which illustrates a large tree with two symmetrical sides. Each side contains branches numbered from 1 to 10, coloured either red or green. At the base of the tree, on each side, there is an illustrated basket, representing the area where each player stores their game pieces — either apple-shaped or flower-shaped tokens, depending on their team or assigned role.

Gameplay involves the completion of pre-selected challenges, which are adapted based on the participant's clinical condition and pain status, as assessed by the research team. These challenges may include motor sequences, physical exercises, or combined motor-cognitive tasks. Each successfully completed challenge allows the participant to draw a token at random (either a red/green apple or flower) and place it on the corresponding branch of the tree — matching both the number and colour indicated. Placement can occur either on the player’s own side of the tree or on the opponent's side, depending on the strategic or cooperative logic being used.

The objective of the game is to collaborate or compete to "care for the farm", symbolised by the act of making the tree grow through the successful placement of tokens. Game progression is visually represented by the filling of the tree's branches with apples and flowers, encouraging motivation through immediate feedback and symbolic reward. At the end of the session, the number of tokens placed by each player is counted, corresponding to the number of challenges successfully completed. The winner is the player who has contributed the most tokens to the tree.

The game’s structure integrates simple mechanics (task execution, token placement, random draw), clear dynamics (turn-taking, physical interaction with the board, cooperation or competition), and a narrative framework that enhances player engagement by associating gameplay with the symbolic act of nurturing and growth. An example of the Tree Game (TG) implementation with study participants is shown in Figure 1.

Figure 1. Implementation of the Tree Game (TG) during a study session. Participants engage in motor-cognitive tasks on the floor-based board, placing apple- or flower-shaped tokens on the tree branches according to completed challenges.

Game-based protocol

The intervention was conducted over four structured sessions, each comprising a pre-defined set of challenges systematically categorised by type and difficulty. Exercises were organised into four primary categories: warm-up challenges, specific exercises targeting chronic low back pain (CLBP) such as mobility, flexibility, and strengthening tasks, non-specific physical exercises, and cognitive or language-based tasks. To allow for progressive intensification, each physical exercise was classified into three difficulty levels: A (easy), B (moderate), and C (vigorous), facilitating an incremental increase in both physical demands and cognitive load across the four sessions. Moreover, the number of dual-task challenges, combining physical movements with cognitive or language components, was gradually increased, promoting integrated motor-cognitive engagement throughout the intervention.

During the first three sessions, serving as baseline, participants were presented with 23 challenge cards per session. These were distributed across two warmtwo warm-up tasks twelve physical exercises (both specific and non-specific), six language activities, and three cognitive tasks, ensuring a balanced combination of motor and cognitive engagement. In the fourth session, advanced rules were introduced as a progression mechanism to enhance participant engagement and immersion. Gameplay in this session was organized into timed three-minute rounds, during which participants attempted to complete as many challenges as possible, simulating real-world time pressure and stimulating motor-cognitive integration. To maintain continuous engagement, participants who completed all 23 challenges before their opponent continued to play using previously completed cards selected at random, accumulating additional points until their counterpart finished their session. This design minimised downtime, encouraged sustained effort, and fostered competitive motivation throughout the activity.

A detailed account of the distribution of challenges by type and difficulty level is presented in Table 1, illustrating the structured progression and comprehensive coverage of both physical and cognitive domains across the intervention sessions.

Table 1. Distribution of challenge cards per session by type and difficulty level.

Session	Warm-up	Specific CLBP A	Specific CLBP B	Specific CLBP C	Non-specific A	Non-specific B	Non-specific C	Cognitive/Language	Dual Task	Total Challenges
1st	2	5	3	1	3	1	0	6	2 (A)	23
2nd	2	3	5	1	3	1	0	6	2 (A)	23
3rd	2	1	4	4	2	1	0	6	3 (B)	23
4th	2	1	2	4	2	1	1	5	5 (C)	23

CLBP, Specific exercises for chronic low back pain; A, Easy; B, Moderate; C, Vigorous.

Data analysis

Data analysis was performed with IBM SPSS Statistics version 29. Significance level was defined as $p<0.05$. Quantitative variables were described using mean and standard deviation values, whereas categorical variables were described using absolute and relative frequencies.

Data normality was assessed with Shapiro-Wilk test and the Mauchly's test was used to assess the assumption of sphericity. Pain intensity was compared between the different time points using a repeated measures ANOVA test followed by post hoc analysis with a Bonferroni adjustment. Additionally, pain intensity was compared between the different time points and across kinesiophobia groups using a two-way repeated measures ANOVA test with Huynh-Feldt correction.

Regarding the content collected through the single open-ended question administered after each session ("What was the focus of your attention while playing?"), a content identification methodology was applied. Two independent examiners performed the initial coding of the responses and subsequently reached consensus through discussion. To preserve clarity and focus on the most prominent aspects of participants' experience, only first-level categories were identified — no subcategories were established. This approach enabled the extraction of key thematic elements that emerged directly from participants' narratives.

Results

A total of 40 people volunteered to participate in the study. Of these, 10 people were excluded for the following reasons: age < 40 (n=1), MMSE ≤ 25 (n=4), TAMPA ≤ 24 (n=1), FES-I > 32 (n=2), and use of walking aid (n=2). Although 30 participations were allocated for intervention, only 27 participants received the intervention (three participants reported being unable to attend with the desired regularity). During the intervention, 2 participants withdrew from study due to scheduling incompatibility. Thus, the sample under analysis consists of 25 participants.

Sociodemographic and Clinical Characteristics of the Participants

Table 2 describes the sociodemographic and clinical characteristics of the 25 participants in the study: 76% were female (n=19) and 24% were male (n=6), with mean (±SD) age of 66.8 (±13.5) years. Regarding educational level, 12% were literate with basic reading and writing skills, 40% had completed primary education, 24% secondary education, and 24% higher education. Recruitment occurred in various contexts: 28% from nursing homes, 20% from senior universities, and 52% from the general community. Concerning employment status, 68.0% were retired and 32.0% were employed (Table 2).

Comorbidities, classified by ICD codes, showed that 40.0% of participants had 1 to 2 codes, 48% had 3 to 4 codes, and 12% had 5 to 6 codes (Table 2). Regarding medication use, 96% reported using medication (Table 2). Physiotherapy was reported by 20% of participants, while practice of physical activity was reported by 72% of the participants: 52% engaged in group-based activities, 24% in individual activities, and 24% in sports-related activities. Regarding frequency, 20% did not engage in physical activity, 12% practiced 1–2 times per week, 24% 2–3 times per week, and 44% four or more times per week (Table 2). At T0, mild kinesiophobia was the most prevalent, affecting 44% of participants (n=11), with a mean and standard deviation of 34.4±7.4. The second most prevalent subcategory was moderate kinesiophobia, observed in 40% (n=10), followed by severe kinesiophobia in 16% (n=4) (Table 2).

Table 2. Sociodemographic and clinical characteristics at baseline (T0) (n=25).

Variable	Values
Age (years), Mean±SD	66.8±13.5
Sex	
Female	19 (76%)
Male	6 (24%)
Educational Level	
Literate (basic reading/writing)	3 (12%)
Primary education	10 (40%)
Secondary education	6 (24%)
Higher education	6 (24%)
Recruitment Context	
Nursing home	7 (28%)
Senior university	5 (20%)
General community	13 (52%)
Employment Status	
Employed	8 (32%)
Retired	17 (68%)
Comorbidities (ICD codes)	

1–2 codes	10 (40%)
3–4 codes	12 (48%)
5–6 codes	3 (12%)
Medication Use	
Yes	24 (96%)
No	1 (4%)
Physiotherapy	
Yes	5 (20%)
No	20 (80%)
Physical Activity	
Yes	18 (72%)
No	7 (28%)
Type of Physical Activity	
Group-based	13 (52%)
Individual	6 (24%)
Sports activity	6 (24%)
Frequency of Physical Activity	
Does not engage	5 (20%)
1–2 times per week	3 (12%)
2–3 times per week	6 (24%)
4 or more times per week	11 (44%)
Kinesiophobia (TAMPA)	34.4±7.4
Mild (23–32)	11 (44%)
Moderate (33–42)	10 (40%)
Severe (43–52)	4 (16%)

All variables described as n (%), except Age. SD – Standard deviation.

Table 3 presents the distribution of pain characteristics among participants at baseline (T0). Most participants reported pain localised to the lumbar region accompanied by pain in one or more additional body parts, with 44% experiencing lumbar pain plus one additional region, and 32% lumbar pain plus two regions. The majority (68%) reported symptom duration of one year or more. Regarding pain types, stabbing pain was most frequent (36%), followed by acute (28%) and annoying (20%) sensations (Table 3). Pain frequency was predominantly constant, reported by 48% of participants, while 28% described their pain as almost constant. A substantial proportion (76%) had sought or intended to seek medical care for their pain. Medication use was reported by 52% of participants, and 28% experienced urgent pain episodes (SOS) (Table 3).

Pain interference with sleep quantity and quality was reported by 36% of the sample, and 52% indicated that pain affected their overall disposition. Social participation was limited due to pain for 32% of participants. Pain intensity tended to increase throughout the day for 60% of individuals. Furthermore, 84% reported that pain interfered with their movements (Table 3). Regarding functional limitations, 28% reported no limitation in performing daily activities, while 12% experienced slight discomfort, 28% moderate discomfort, 20% severe discomfort, and 12% were unable to perform the activity (Table 3).

Table 3. Distribution of pain characteristics at baseline (T0) (n=25).

Pain Characteristics	n (%)
Pain location	
Lumbar only	4 (16)
Lumbar + 1 additional body part	11 (44)
Lumbar + 2 additional body parts	8 (32)
Lumbar + ≥3 additional body parts	2 (8)
Symptom duration	
≥ 3 months	3 (12)
≥ 6 months	5 (20)
≥ 1 year	17 (68)
Pain quality	
Acute	7 (28)
Annoying	5 (20)
Stabbing	9 (36)
Burning	1 (4)
Pins and needles	3 (12)
Pain frequency	
Constant	12 (48)
Almost constant	7 (28)
Frequent	5 (20)
Rare	1 (4)
Sought or intends to seek medical care	19 (76)

Use of medication for pain	
Yes	13 (52)
No	5 (20)
Urgent episodes (SOS)	7 (28)
Pain interferes with quantity and quality of sleep [Yes]	9 (36)
Pain affects disposition [Yes]	13 (52)
Pain has prevented social participation [Yes]	8 (32)
Pain interferes with movements [Yes]	21 (84)
Pain changes over the day	
Increases	15 (60)
Decreases	2 (8)
Remains the same	8 (32)
Level of limitation in performing activity	
No limitation	7 (28)
Slight discomfort	3 (12)
Moderate discomfort	7 (28)
Severe discomfort	5 (20)
Unable to perform	3 (12)

Pain Intensity Modulation with Game Intervention

Repeated measures ANOVA determined that mean pain intensity differed statistically significantly between time points ($p<0.001$) (Table 4). Post hoc analysis with a Bonferroni adjustment revealed that pain intensity was significantly decreased from baseline (6.9±2.9) to post-intervention (3.4±2.9) ($p<0.001$), and from baseline (6.9±2.9) to timeout period (4.6±2.5) ($p<0.001$), but not from post-intervention to timeout period ($p=0.208$) (Table 4).

Table 4. Pain intensity at baseline (T0), post-intervention (T1) and timeout period (T2) (n=25).

	T0	T1	T2	*p* value
Pain Intensity, Mean±SD	6.9±2.9	3.4±2.9	4.6±2.5	<0.001 [a]
No pain	-	6 (24%)	2 (8%)	–
Mild	4 (16%)	12 (48%)	9 (36%)	
Moderate	10 (40%)	4 (16%)	9 (36%)	
Severe	11 (44%)	3 (12%)	5 (20%)	

a – Repeated Measures ANOVA test. Post hoc analysis with a Bonferroni adjustment: T0-T1 ($p<0.001$); T0-T2 ($p<0.001$); T1-T2 ($p=0.208$). SD – Standard deviation.

Additionally, a two-way repeated measures ANOVA shows that there is no interaction between the intervention and the levels of kinesiophia of the participants at baseline on the pain intensity ($p=0.277$) (Table 5).

Table 5. Pain intensity across time in participants with different levels of kinesiophobia at baseline (n=25).

	Kinesiophobia (TAMPA)			
Pain intensity	Mild (n=11)	Moderate (n=10)	Severe (n=4)	*p* value
T0	5.8±1.7	7.4±1.5	8.8±2.5	0.277
T1	3.3±2.1	3.9±2.9	2.5±5.0	
T2	4.0±2.6	4.9±2.8	5.3±1.0	

Engagement during gameplay

Table 6 summarizes participants' reported engagement factors during each of the four game sessions. The data indicate a shift in the aspects of immersion over time. Initially, a higher proportion of participants focused on performing the exercises or activities (44.0% in the first session), which decreased substantially by the fourth session (0%). Similarly, completing exercises remained a moderate focus throughout the sessions.

Notably, competitiveness showed a marked increase in the fourth session, with 68.0% of participants reporting this aspect, compared to minimal reports in earlier sessions. Concentration peaked during the second and third sessions (56.0% and 52.0%, respectively) before decreasing in the final session.

External factors and the ability to perform exercises without pain were minimally reported across sessions, indicating that these factors were less relevant to the participants' immersion experience during the game.

Overall, these results suggest that as participants progressed through the sessions, their engagement shifted from task execution to competitive involvement, reflecting a dynamic immersion experience.

Table 6. Participants' reported engagement aspects during each game session [n (%)].

Table 6. Participants' reported engagement aspects during each game session [n (%)].

Engagement aspect	1st Session	2nd Session	3rd Session	4th Session
Performing exercises/activities	11 (44.0%)	3 (12.0%)	4 (16.0%)	0 (0.0%)
Completing exercises/activities	7 (28.0%)	4 (16.0%)	6 (24.0%)	2 (8.0%)
Competitiveness	2 (8.0%)	2 (8.0%)	0 (0.0%)	17 (68.0%)
Concentration	3 (12.0%)	14 (56.0%)	13 (52.0%)	5 (20.0%)
External factors	1 (4.0%)	2 (8.0%)	0 (0.0%)	1 (4.0%)
Performing exercises without pain	1 (4.0%)	0 (0.0%)	2 (8.0%)	0 (0.0%)

Discussion

This study aimed to evaluate the effects of a game-based exercise intervention on pain intensity in patients with chronic low back pain (CLBP), while also exploring the influence of kinesiophobia and the engagement during gameplay. The detailed characterisation of pain features and related behavioural habits provided valuable context to interpret the observed trends and outcomes.

The present study included a heterogeneous sample of older adults, predominantly female, with a wide age range and varied clinical and sociodemographic profiles. This diversity reflects the complexity of the ageing population and enhances the ecological validity of the intervention. In fact, according to Marttinen et al. (2019) and, it is important that the sample includes participants from diverse living environments, as functional capacities, engagement, and response to interventions can vary significantly across settings. By including older adults from community settings, nursing homes, and senior universities, the study ensures that the game-based intervention is evaluated across a spectrum of real-world contexts, enhancing its adaptability and ecological validity.

The sample displayed a balanced distribution in terms of educational attainment and a high prevalence of comorbidities, with 88% of participants presenting three or more ICD-coded diagnoses. These characteristics underscore the clinical relevance of the intervention, as was applied in a population with considerable health complexity. Importantly, evidence from Geneen et al. (2017) highlights that exercise interventions are effective and feasible even in older adults with multiple comorbidities, supporting the appropriateness of implementing a structured, game-based program in this context. Despite this, most participants were actively engaged in physical activity (72%) and adhered to pharmacological treatment (96%), suggesting a baseline level of health engagement that may have facilitated responsiveness to the intervention (Clarke & Witham, 2017).

The predominance of female participants (76%) aligns with sex trends commonly observed in aging research (Guralnik et al., 2000), particularly in studies involving physical activity (Liao et al., 2021) community engagement (Ong et al., 2024). While this may limit the generalisability of findings to older men, it also reflects a demographic more likely to seek and benefit from such interventions. Future research should aim to explore sex-specific responses and motivations, especially in the context of game-based rehabilitation strategies.

At baseline, most participants (84%) reported experiencing pain in multiple anatomical regions, extending beyond the lower back. This multisite pain presentation is consistent with findings in older adults, where chronic musculoskeletal conditions often manifest in more than one location, compounding functional limitations (Butera et al., 2019). Notably, 68% of the sample reported pain duration exceeding one year, and nearly half (48%) described their pain as constant, reflecting a chronic and persistent pain profile. The most frequently reported pain quality was stabbing (36%), followed by acute sensations (28%), highlighting the varied sensory experiences within this population. Pain significantly interfered with daily life, particularly movement (84%), mood or disposition (52%), sleep (36%), and social participation (32%). These results underscore the pervasive impact of chronic pain on multiple dimensions of functioning and reinforce the need for interventions that address both physical and psychosocial components of pain management in older adults (Deng et al., 2025; Keefe et al., 2013).

The findings of this study align with existing evidence suggesting that serious games may contribute to the reduction of pain intensity in older adults. The significant decrease in pain observed immediately after the intervention (T0–T1; $p < 0.001$) and maintained at follow-up (T2; $p < 0.001$ vs. T0) reflects the moderate effect size reported in a recent systematic review (pooled SMD = –0.62; 95% CI: –1.15 to –0.10), which highlighted the efficacy of serious games in pain alleviation within this population (Saragih et al., 2024a).

However, our results also highlight the short-term nature of these effects. No significant difference was observed between post-intervention and follow-up ($p = 0.208$), although there was a non-significant trend toward a slight increase in pain intensity over time. This suggests that, while the intervention was effective immediately after implementation, its benefits may diminish without continued engagement. This observation aligns with limitations noted in previous studies, where interventions involving game-based or virtual reality (VR) approaches for lower back pain predominantly focused on immediate outcomes, often omitting follow-up assessments (Garcia et al., 2022; Maddox et al., 2023). For instance, immersive VR was employed in some studies and non-immersive VR in others (Lo et al., 2024), with most reporting significant improvements in pain scores, disability indices, stability, and kinesiophobia, yet without evaluating the durability of these effects over time. Similarly, meta-analytic evidence on serious games for older adults with pain indicates that such interventions can effectively reduce pain (pooled SMD = −0.62; 95% CI: −1.15 to −0.10), but the impact on pain-related disability and fear of movement remains uncertain, and long-term effects were not consistently assessed (Saragih et al., 2024b). Furthermore, comparisons with analog game-based interventions remain limited, due to the evident scarcity of such studies. One relevant example is the pilot mixed-methods study by Rosa et al. (2025) which implemented a non-pharmacological therapy for chronic pain in institutionalized older adults. While the short-term benefits were promising, follow-up assessments to determine long-term effectiveness were not included.

Importantly, in our study, no significant interaction was found between baseline kinesiophobia and intervention outcomes ($p = 0.277$), suggesting that the effectiveness of the intervention was not influenced by participants' fear of movement—a point where prior reviews highlighted limited and inconclusive evidence. Indeed, a recent randomised controlled trial demonstrated that baseline kinesiophobia did not predict therapeutic outcomes in patients with chronic spinal pain, reinforcing our finding that fear of movement may not undermine short-term efficacy (Van Bogaert et al., 2021). Together, these findings underscore the potential of game-based interventions for pain relief while emphasizing the need for strategies that sustain benefits beyond the immediate post-intervention period (Saragih et al., 2024a). Additionally, broader frameworks such as SALSA, as employed in other systematic reviews (Gutiérrez-Pérez et al., 2023), highlight the relevance of multi-domain approaches—combining physical, cognitive, and psychosocial interventions—to enhance the long-term efficacy of serious games in geriatric pain management. Together, these findings underscore the potential of game-based interventions for pain relief while emphasizing the need for strategies that sustain benefits beyond the immediate post-intervention period.

Our study observed a progressive increase in cognitive engagement among participants across the sessions. In the first session, attention was primarily directed toward performing exercises correctly (44%), reflecting initial efforts to understand task demands. During the second and third sessions, participants exhibited high levels of concentration (56% and 52%, respectively), indicating sustained cognitive involvement, while in the fourth session, focus shifted toward competitiveness (68%), suggesting deeper engagement with the social and strategic aspects of the game. This evolution highlights the dual contribution of the intervention: participants were not only performing physical exercises but also increasingly engaging with cognitive challenges and game mechanics. Such growing attention to the rules, objectives, and dynamics of the game may have reinforced immersion, a factor widely recognised in the literature as enhancing motivation, adherence, and potentially the effectiveness of pain management interventions (Azizoddin et al., 2024; Vugts et al., 2017). Immersion allows participants to allocate cognitive resources toward the gaming experience, which can facilitate distraction from pain sensations, enhance coping strategies, and sustain engagement over time. Therefore, the observed patterns of engagement suggest that cognitive involvement and focus on game mechanics may be critical mediators of the intervention's potential impact on pain management. While physical execution remained central, initially, the increasing cognitive and social dimensions likely contributed to a more holistic and engaging experience, supporting the notion that serious games can serve as multifaceted interventions for chronic pain, promoting both active participation and psychological coping (Vugts et al., 2018).

Despite the promising findings, several limitations should be acknowledged. First, the study employed a pre- and post-experimental design without a control group, which limits the ability to attribute observed effects solely to the intervention. Second, the sample size was relatively small (n = 25) and predominantly female (76%), potentially affecting the generalisability of the results to broader or more gender-balanced populations (Medrano-Ureña & Castejón-Riber, 2025). Third, participants were recruited from diverse settings, including nursing homes, senior universities, and the community, which, while enhancing ecological validity, also introduced heterogeneity in baseline characteristics, such as physical activity levels and comorbidity profiles. Another limitation relates to the short duration of the intervention and follow-up. Although the study included a brief timeout period to assess short-term retention, long-term effects on pain modulation, cognitive engagement, and adherence to game-based interventions remain unknown. Similarly, the intervention used a fully analogue version of the Tree Game, which, while increasing accessibility, may not fully capture the engagement dynamics potentially offered by digital or hybrid formats. Furthermore, assessment of participant engagement relied on a single open-ended post-session question, which, although rich in qualitative information, may not have captured all dimensions of immersion, motivation, or social interaction. Future studies could benefit from employing validated engagement or presence scales, alongside objective behavioral metrics, to more comprehensively assess participants' involvement.

Conclusions

This study provides evidence supporting the short-term efficacy of a gamified, analogue exercise intervention—the Tree Game—in reducing pain intensity among middle-aged and older adults with chronic low back pain (CLBP). The intervention not only decreased pain immediately post-intervention but maintained lower pain scores after a no-intervention timeout period, highlighting its potential to produce clinically meaningful effects in the short term. Importantly, the study revealed dynamic patterns of participant engagement: focus shifted progressively from task execution to sustained cognitive involvement and, finally, to competitiveness and social interaction, reflecting increasing immersion with repeated exposure. These findings suggest that cognitive engagement and attention to game mechanics may act as key mediators of the intervention's effectiveness, potentially enhancing pain coping strategies and participant motivation.

While baseline kinesiophobia did not significantly moderate outcomes, the structured game-based approach appeared accessible and engaging across participants with varying fear of movement, supporting its feasibility for heterogeneous populations. The Tree Game also demonstrated adaptability to different settings, from community environments to nursing homes, underscoring its potential for broad clinical and recreational application.

However, limitations including the small sample size, short follow-up period, and reliance on self-reported engagement measures warrant caution in generalizing these results. Future research should explore long-term effects, incorporate larger and more diverse cohorts, and examine objective indicators of cognitive and social engagement. Overall, this study emphasizes the promise of gamified interventions as multifaceted tools that combine physical, cognitive, and social dimensions to support pain management, promote adherence, and foster immersive experiences. The integration of such approaches in clinical and community settings may contribute to more holistic, engaging, and patient-centered strategies for chronic pain management in older adults.

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