Review Article

Design Recommendations for User-Centered Games for Multiple Sclerosis Balance Rehabilitation: An Evidence Review

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Abstract

Background: In recent years, exergames have emerged as a potential rehabilitation tool to address balance dysfunction in patients with multiple sclerosis (PwMS). Although preliminary findings have shown promise, their overall effectiveness remains inconclusive, primarily due to their reliance on commercial games. This underscores the critical need for user-centered games tailored to the specific needs of patients. Despite this necessity, existing literature lacks established frameworks that guide the development of such games, highlighting a gap in literature. Therefore, the objective of this research was to propose the first evidence-based framework to guide the development of user-centered games for balance rehabilitation in PwMS.

Materials and Methods: A two-step method was used to achieve this objective. The first step involved the examination of commercial games used in clinical studies, identifying their mechanics and limitations. The

second step involved reviewing the literature to identify relevant findings that could inform the development of user-centered games.
Results: A set of targeted recommendations was proposed, emphasizing the necessity of developing adaptable games with focused therapeutic designs to effectively address the distinct balance impairments observed in PwMS. A game prototype was also presented to illustrate the practical applications of these recommendations.
Conclusion: This research establishes the first structured framework to guide the design of user-centered exergames for balance rehabilitation in PwMS. Beyond its theoretical insights, this framework provides actionable guidelines for developing clinically effective exergames aligned with patient impairments and therapeutic needs. Ultimately, this will contribute to improved therapeutic outcomes, enhanced patient care, and advancements in both rehabilitation and game design fields.
Keywords: Postural Balance, User-Centered Design, Exergaming, Rehabilitation, Multiple Sclerosis.

Introduction

Exergames are digital games that require body movements for interaction and gameplay (1,2). In recent years, they have emerged as innovative therapeutic tools that offer a training approach that is adherent, engaging, motivating, and effective (3). Their interactive nature makes them more enjoyable than traditional exercises in clinical settings (4,5). Consequently, there has been increasing interest in utilizing them as potential interventions for balance dysfunction in patients with multiple sclerosis (PwMS).

This interest has resulted in numerous studies investigating the efficacy of exergames in balance dysfunction in PwMS. Although preliminary findings have shown promise, evidence supporting their effectiveness remains inconclusive. This variability in results is largely attributable to several methodological limitations, particularly the utilization of "off-the-shelf" commercial games (6,7). These games are video games that are primarily designed for entertainment and are widely accessible in stores (8). Before adopting them for rehabilitation, they were originally designed for healthy individuals, without considering the specific needs of disabled patients (8–10). Typically, they feature high-intensity training demands (9), lack therapeutic designs, and rely on preset programs (6,11) that restrict training specifications (3). Consequently, implementing such software, which demands high motor and cognitive skills, can impede patient progress by generating irregular movement patterns, along with other unfavorable outcomes (12). This underscores the critical need for user-centered games tailored to the unique abilities of patients, thereby enhancing rehabilitation outcomes (6,11,12).

However, despite this need, the development of these games presents methodological challenges, particularly the absence of guidelines for their design and development. Although researchers such as Robert et al., Wiemeyer et al., Caruso et al., and Paraskevopoulos et al. have proposed recommendations for the development of serious games for patients with Alzheimer's disease (13), persons with disabilities (14), autistic people (15), and Parkinson's disease patients (16), no similar recommendations have yet been established for games aimed at balance rehabilitation in PwMS. To the best of our knowledge, based on a comprehensive literature search, the current body of literature lacks such a framework, highlighting a gap in the existing knowledge.

Therefore, the objective of this research is to establish a framework that guides the development of user-centered games for balance rehabilitation in PwMS. Conceptually, the need for such a framework is grounded in three key factors. First, PwMS exhibit distinct balance challenges compared to other neurological disorders, such as Parkinson's disease (17), underscoring the need for frameworks specifically tailored to their unique needs. Second, PwMS experience multifaceted balance impairments that affect static (18–22), reactive (23,24), and anticipatory (25,26) balance systems, indicating the need for diverse rehabilitation techniques to address these specific impairments. Third, balance is a specific motor skill rather than a general one, and interventions effective at addressing particular impairments may not lead to generalized improvements across other impairments. This highlights the need for targeted interventions to optimize the treatment efficacy (27). Collectively, these factors demonstrate the need for a structured framework to inform the functionality, tempo, and optimal design of games intended for balance rehabilitation in PwMS to effectively address the multifaceted nature of balance impairments experienced by this population. By proposing such a framework, the present research is the first to addresses this gap in the literature, which is critical for enhancing the usability and therapeutic effectiveness of such games, thereby facilitating their effective implementation in clinical practice (28,29).

To ensure successful development of the framework, an interdisciplinary research team comprising physiotherapists, biomedical engineers, and game designers was formed. This collaborative approach aims to establish a framework for developing games that are not only engaging but also aligned with therapeutic goals and evidence-based practices. Ultimately, this can contribute to improved therapeutic outcomes, enhanced patient care, and advancements in both rehabilitation and game design fields.

Methodology

1. Methods Used to Identify Existing Guidelines for the Design of Balance Rehabilitation Games for PwMS

A comprehensive literature search was conducted across various databases, including PubMed, ScienceDirect, and Google Scholar, to identify guidelines for the development of user-centered games for balance rehabilitation in PwMS.

A set of key terms and their synonyms was used to identify relevant studies aligned with this aim. The primary search terms included "patients with multiple sclerosis," " recommendations," "balance," and "games."

The final search string was structured as follows: ("patients with multiple sclerosis" OR "PwMS" OR "multiple sclerosis patients") AND ("recommendations" OR "guidelines" OR "framework") AND ("balance" OR "balance rehabilitation") AND ("games" OR "game design" OR "user-centered games" OR "personalized games" OR "serious games").

The search results revealed a notable absence of formalized guidelines for the development of balance rehabilitation games for PwMS, thereby highlighting a gap in the existing literature.

2. Methods Used for the Framework Development

To address the aforementioned gap and establish a framework for the design of user-centered games for balance rehabilitation for PwMS, a two-step methodology was employed. The first step involved an in-depth analysis of commercial games currently used for balance rehabilitation in PwMS, identifying their underlying mechanics and limitations. The second step involved reviewing the literature to identify relevant recommendations that inform the development of such games. Both steps were adapted from the approach used by Caruso et al.(15), who proposed a set of targeted recommendations to inform the development of immersive virtual reality games for patients with autism. Unlike other frameworks that rely mainly on literature searches, Caruso et al.'s framework combines both literature review and practical examination of existing games, providing a comprehensive foundation for structuring game design recommendations.

To further strengthen the rigor of the framework, an interdisciplinary research team comprising physiotherapists, biomedical engineers, and game designers was formed. Both physiotherapist and biomedical engineers were responsible for identifying and analyzing clinical studies on the impact of exergames on balance dysfunction in PwMS. Specifically, their roles involved extracting key findings, determining clinical needs, and outlining commercial games used in these studies. Afterward, these games were evaluated to identify their mechanics and limitations through a combination of literature review, video demonstrations, and collaborative discussions with game designers. Based on the overall findings, physiotherapists proposed corresponding intervention strategies, which were subsequently assessed by both game designers and biomedical engineers for feasibility in real-world applications.

In general, meetings were scheduled periodically to discuss progress, align perspectives, and coordinate tasks among team members. Feasibility was assessed in each round through a role-based delegation, with each team member leading evaluations within their respective areas of expertise. While no formal disagreements arose during meetings, challenges emerged primarily, due to differences in terminology across disciplines. For instance, during discussions, physiotherapists had to clarify clinically relevant concepts (e.g., optic flow) for non-clinical team members, which were addressed through video demonstrations. Similarly, game designers explained technical terms (e.g., third-person runner games) to ensure understanding among all members.

Through this collaborative approach the aim was to integrate clinical, technical, and design perspectives, ultimately contributing to a structured framework that supports the development of games that are both engaging and aligned with therapeutic goals and evidence-based practice.

2.1. Examination of Currently Used Commercial Games

In this step, a comprehensive literature search was conducted across various databases, including PubMed, ScienceDirect, and Google Scholar, using a set of key terms and their related synonyms.

The primary search terms included "patients with multiple sclerosis," "exergames," and "balance rehabilitation." The final search string was structured as follows: ("patients with multiple sclerosis" OR "PwMS" OR "multiple sclerosis patients") AND ("exergames" OR "exergame" OR "video games" OR "exercise-based games" OR "interactive games" OR "virtual reality games" OR "Nintendo games" OR "Nintendo game" OR "Wii Fit games" OR "game-based rehabilitation" OR "serious games" OR "kinect-based system" OR "kinect-based games") AND ("balance rehabilitation" OR "balance training" OR "balance").

To ensure methodological rigor, only full-text articles published in English in peer-reviewed journals and conference proceedings up to 2024 were included. Gray literature, such as reports, posters, theses, and dissertations, as well as letters to editors, were excluded. Furthermore, only studies that used the term "virtual reality games" interchangeably with "exergames" were included. However, studies focusing on immersive virtual reality technology were excluded to eliminate the influence of the type of implemented technology on outcomes and ensure a consistent focus on the game design itself.

Consequently, a total of 24 clinical trials were identified through the search process. Of these, 18 met the inclusion criteria and the remaining 6 were excluded. These 6 studies included one thesis, one letter to the editor, one abstract with no full text, and three studies that utilized fully immersive virtual reality technology. Among the included studies, 14 utilized commercially available games or software (30–43), 3 employed user-centered games (44–46), and 1 utilized commercial games with personalized elements for individualized treatment plans for each patient (47).

The commercial games identified in these studies included Heading (soccer), Ski Slalom, Table Tilt, Tight Rope, Reflex Ridge, Space Pop, Just Dance, Zazen, Penguin Slide, Balance Bubble, Perfect 10, Tightrope Tension, Snowboard Slalom, Skateboard Arena, Table Tilt+, Balance Bubble+, Ski Jump, Kinect Sports®, Joy Ride®, Adventures®, Tennis, Table Tennis, Boxing, Archery, Sword Fight, Penguin Picnic, Light Race, Stack'em Up, 20,000 Leaks, and Tilt City. The majority of these games require body shifting for gameplay and interaction, whereas only a few involve stepping movements. These games were systematically analyzed to identify their limitations, and the findings are presented in the Results section.

2.2. Reviewing the Literature for Relevant Recommendations

This step involved a comprehensive literature review to identify three categories of critical information that are essential for establishing a robust framework. The first category involved reviewing studies on the impact of exergames on balance dysfunction in PwMS to determine clinical needs and extract potential recommendations that could inform the effective development of such games. The second category involved extending this analysis to similar studies involving other populations such as older adults to identify additional insights that could enhance the design of balance rehabilitation games. The third category involved reviewing the literature to identify guidelines that inform the development of serious games for patients with disabilities to ensure the inclusion of all necessary criteria required for the development of serious games for health. By conducting these steps, the objective was to establish a comprehensive and well-rounded framework that incorporates the necessary information for designing effective games aimed at balance rehabilitation for PwMS (Table 1).

Table 1. Summary of the retrieved recommendations from the literature

Author (Date)	Targeted Population	Participants (Number and Gender)	Intended Objectives	Proposed Recommendation	Intervention Groups
Wiemeyer et al. (2015)	Persons with disability	Not applicable (NA), expert consensus article.	General recommendations	• Training intensity must be adaptable to the patients' needs and abilities. • Game technology must be easily implemented and adaptable to the patients' needs and abilities. • Designing rehabilitation games requires interdisciplinary expertise	NA.

				and consideration of patient and caregiver preferences.	
Calafiore et al. (2021)	PwMS	NA, Systematic review.	Balance	• Training should be within the flowzone of the patients.	NA.
Anders et al. (2020)	Elderly	Total =15 Females=7 Males =8	Balance	• Training should be within the flowzone of the patients. • Designing purposeful games requires interdisciplinary expertise. • Developing dynamically adjustable games facilitates user-centered training. • Different game designs and mechanics have varying effects on the same training goals. • High speed games aligned with patient abilities may enhance rapid responses to perturbations. • Games requiring obstacle avoidance (dual-task) can increase cognitive load.	Single group, each player played eight 2-minute exergame trials across four conditions: two speed settings and with or without additional obstacles.
Schättin et al. (2021)	PwMS	This article Encompasses two studies Study 1: Total=16 Female=10 Male=6 Study 2: Total=25 Female= 15 Male= 10	Balance	• Effective games must consider the abilities and limitations of the patients.	Study 1 is a single group feasibility study; Study 2 is a single-group design where players tested three exergame concepts initially and then selected which to continue based on their preferences.
Manser et al. (2023)	Elderly with mild neuro-cognitive disorders	Qualitative study involving 10 experts (8 females and 2 males) and 8 older adults (3 females and 5 males).	Investigate patient preferences to design games for older adults with neuro-cognitive disorders.	• Integrating the patient's perspective is essential in game design and development. • Designing games requires understanding the usage context, understanding user's needs, proposing tailored solutions, and evaluating the effectiveness of the design.	NA

Wiskerke et al. (2022)	Persons with neurological disorders	30 stoke patients (8 females and 22 males) in addition to 51 PwMS (38 females and 13 males).	Rank virtual reality balance games by difficulty and relate them to the abilities of patients with neurological disorders.	Parameters such as play speed and extent of body leaning promote challenging training in balance rehabilitation games.	Single-group, participants were required to play 6 out of 9 available games per session.
Willaert et al. (2020)	Healthy older adults	Total=16 Females=9 Males=7	Evaluates whether novel exergames better enhance weight shifting and produce higher levels of muscle activity than commercial games.	• Shifting body weights to the limits of stability (LOS) creates challenging balance training.	Single-group, each participant played 6 different games, with 3 trials per game.
Gouglidis et al. (2011)	Elderly women	A total of 63 women.	To explore the influence of visually guided weight shifting training on the LOS.	• Weight shifting training increases the LOS.	Three groups participated: the first performed anteroposterior weight shifting, the second performed mediolateral weight shifting, and the third served as a control with no intervention.

Table 1 presents the studies from which we adopted our recommendations. It includes the author's name and publication date, the targeted population, the number and gender of participants, the intended objectives, the proposed recommendations, and intervention groups identified in these studies.

Results

Findings from previous studies suggest that rehabilitation-oriented games should be adaptable and easily implemented in rehabilitation settings. Adaptability should encompass both hardware and gameplay elements, thereby enhancing accessibility and functionality in these environments (14).

Furthermore, these studies emphasize the importance of developing games with focused therapeutic designs to ensure alignment with the intended rehabilitation goals. Ideally, this can be achieved through an interdisciplinary approach that combines expertise from various fields with patient insights. Such an approach facilitates a comprehensive understanding of the physiological, social, psychological, and therapeutic needs of the target population and desired rehabilitation outcomes. Ultimately, by gaining a deeper understanding of the abilities and impairments of patients, the development of user-centered games with focused therapeutic designs has become feasible (14,45,48).

Conceptual Framework for the Study's Objectives

Based on the aforementioned suggestions, the establishment of a framework tailored to the objectives of this study requires the integration of relevant information related to the study population (PwMS) and the intended rehabilitation goal (exergames for balance rehabilitation). This information includes: 1) limitations associated with the implementation of commercial games in clinical settings, 2) mechanisms underlying balance dysfunction in PwMS, 3) balance impairments observed in PwMS, and 4) the fundamentals of training. By synthesizing insights from these areas, we propose a set of evidence-based recommendations for the development of games aimed at balance rehabilitation in PwMS. These recommendations encompass considerations for optimal game design, appropriate gameplay pacing, and strategies for effective incorporation of various game parameters to maximize therapeutic efficacy.

1. Limitations Associated with the Implementation of Commercial Games in Clinical Settings

There are several limitations associated with the use of commercial games as tools for balance rehabilitation in PwMS (6). These limitations primarily arise from their non-therapeutic designs, which are often characterized by high-intensity training levels and preset programs. In clinical settings, the use of software that provides intense training can lead to unfavorable outcomes. These could be characterized by the elicitation of compensatory movement strategies that deviate from targeted therapeutic movement patterns as patients attempt to achieve the game objectives. In addition, the exacerbation of symptoms in patients with sensory processing impairments due to exposure to intense visual or auditory feedback designed primarily for engagement rather than rehabilitation (12). Consequently, such adverse outcomes underscore the necessity to develop games that operate within the "flow zone" of the players, a state where the player is neither bored nor excessively challenged, to facilitate effective, engaging, and motivating training (1,7). Ideally, this state can be achieved by developing games that either incorporate machine learning algorithms to automatically adjust gameplay based on real-time performance metrics or provide clinicians with a controlled settings module that enables manual customization of the gameplay experience in response to patient performance.

An example of such a game prototype incorporating a game-setting module is shown in Figure 1. This prototype was developed by our research team in response to these limitations. It allows for the adjustment of several in-game parameters, thereby offering a personalized training approach (1,14,45) that is precise, specific, progressive (1), and aligned with the principles of training (45,49,50) and balance rehabilitation concepts (51).

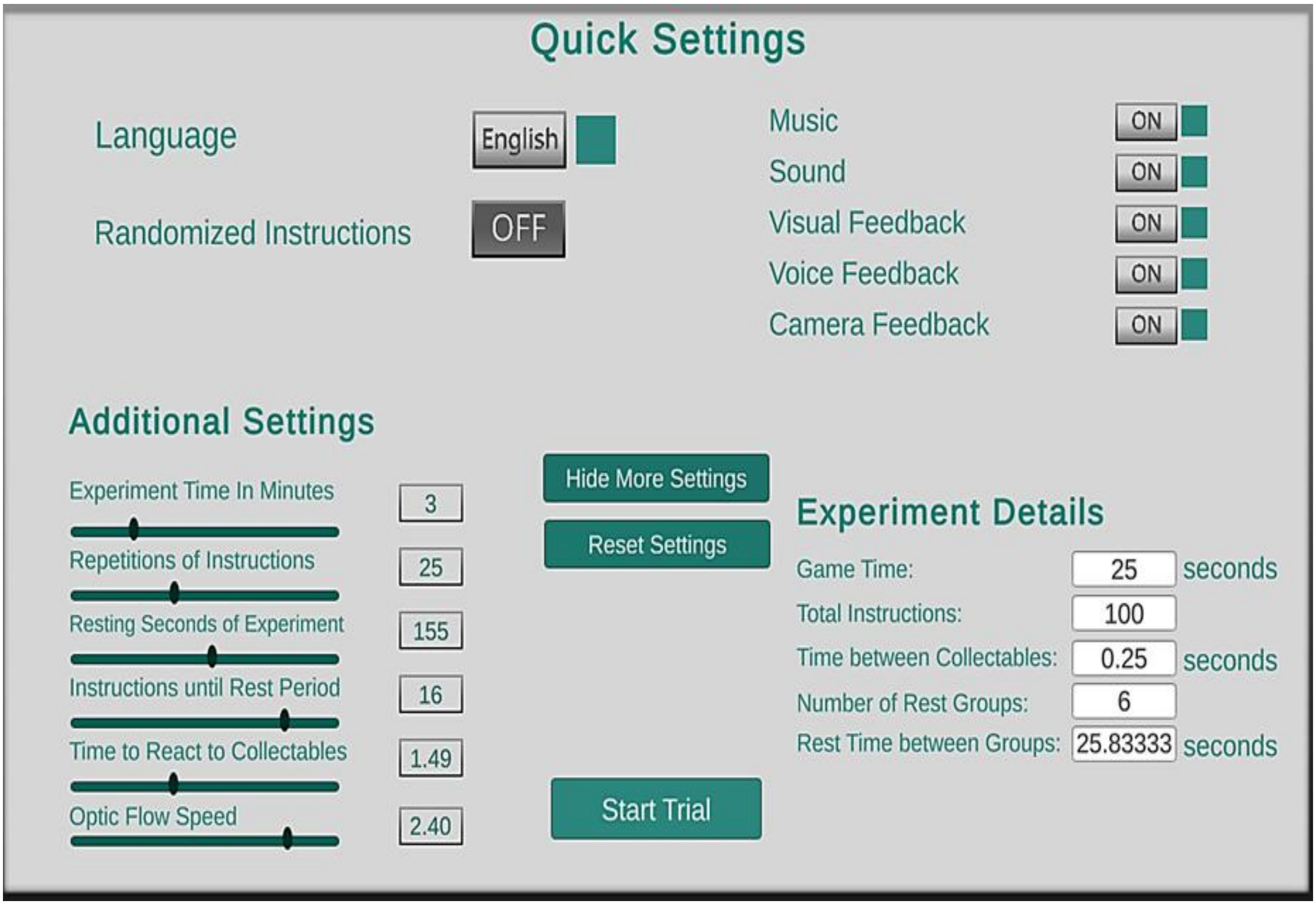

Fig 1. Illustrates a game setting module that enables the dynamic adjustment of gameplay elements, thereby facilitating an individualized, precise, specific, and progressive training approach. This module was custom-designed for balance rehabilitation in PwMS

These parameters include:

- Experiment time in minutes, which denotes the total game time, encompassing both active gameplay time and rest time.
- Repetition of instruction, which denotes the total number of directional leans required by player.
- Resting seconds of the experiment, which denotes the total period during which the player is inactive during the game.
- Instruction until the rest period, which denotes the frequency of instructions provided prior to the rest period.
- Time to react to collectables denotes the time allowed for a player to respond to a stimulus.
- Optic flow speed is a parameter that enables and disables the initiation of a moving visual environment in the game.

By calibrating these parameters to align with the personalized capacity of each patient, the game automatically determines additional gameplay elements using mathematical algorithms implemented during the programming phase. These elements include:

- Game time, which refers to the duration of active gameplay, excluding rest periods.
- The total number of instructions that the player must respond to throughout the game.
- The time interval between the appearance of each collectible (time between collectibles).
- The frequency of rest periods during the game (number of rest groups.
- Duration of each rest period (rest time between groups) (27).

The ultimate objective of implementing such an adjustable prototype is to introduce a personalized, specific, and adaptive training approach that enhances therapeutic outcomes.

2. Optimal Game Design for Balance Rehabilitative Game for PwMS

Designing effective games for balance rehabilitation requires the precise identification of specific balance impairments to be addressed. This identification is important because different game designs and mechanics can vary significantly in their effectiveness in achieving the same therapeutic goals. For instance, high-speed exergames tailored to player's capacity have been shown to elicit faster stepping responses and increased cadence, which are beneficial for improving rapid motor responses to balance perturbations. In contrast, games incorporating dual tasks tend to increase cognitive load and may be more effective in targeting the cognitive aspects of balance control (1). These results highlight the importance of selecting targeted games to address specific balance impairments and optimize the therapeutic outcomes.

For PwMS, a diverse array of game designs and mechanics is required to effectively address the multifaceted impairments affecting static (18–22), reactive (23,24), and anticipatory (25,26) balance systems. These impairments include delayed responses to both predictable and unpredictable displacements, diminished movement toward the LOS (25,52–55), and impairments in sensory integration and reweighting process, which are closely associated with balance dysfunction in PwMS (56–59).

To effectively address these impairments, high-speed games tailored to individual capacities can help improve responses to perturbations (1). Games that challenge users to lean toward their LOS through weight-shifting exercises (60) are necessary to promote movement toward these limits. Games that facilitate sensory integration training, such as the approach proposed by Ibrahim et al. (27), might have the potential to address this impairment. Task-oriented games that target functional activities, such as stepping and sit-to-stand transitions, are crucial for improving stability related to specific motor skills (61,62).

3. Strategies for Optimizing Balance Rehabilitation Games

Previous research has highlighted the need to precisely calibrate specific game parameters, such as the extent of body leaning required for game interaction (63,64) and the speed of the game (63), to significantly enhance the effectiveness of balance training and optimize therapeutic outcomes.

3.1. Extent of Body Leaning

Traditionally, many games used in clinical settings for balance rehabilitation require patients to shift their bodies in different directions to control an onscreen avatar and interact with the game. However, these games often lack the ability to challenge the extent of the body leaning toward the LOS. Movement toward these limits is critical for activities, such as reaching and bending (65) as well as mobility (66). As such, impairments in this capacity can result in instability when performing activities of daily living (25).

To address this problem effectively, it is essential to challenge the extent to which the body leans toward the LOS (64). Ideally, this can be achieved by developing games with adaptable panels, as illustrated in Figure 2. The panel shown in this figure was developed by our research team and complements that shown in Figure 1. It incorporates three parameters to identify the minimal lean angle required by a patient to interact with the game. These parameters include the "Min Lean Angle Left and Right," which identifies the minimal degree of body leaning required in both the left and right directions to interact with the game. The "Min Lean Angle Backward," which identifies the minimum degree of body leaning required in the backward direction and the "Min Lean Angle Forward," which identifies the minimal degree of body leaning required the forward direction. By implementing this systematic approach, the aim was to promote body movement toward the LOS, thereby enhancing the training outcomes.

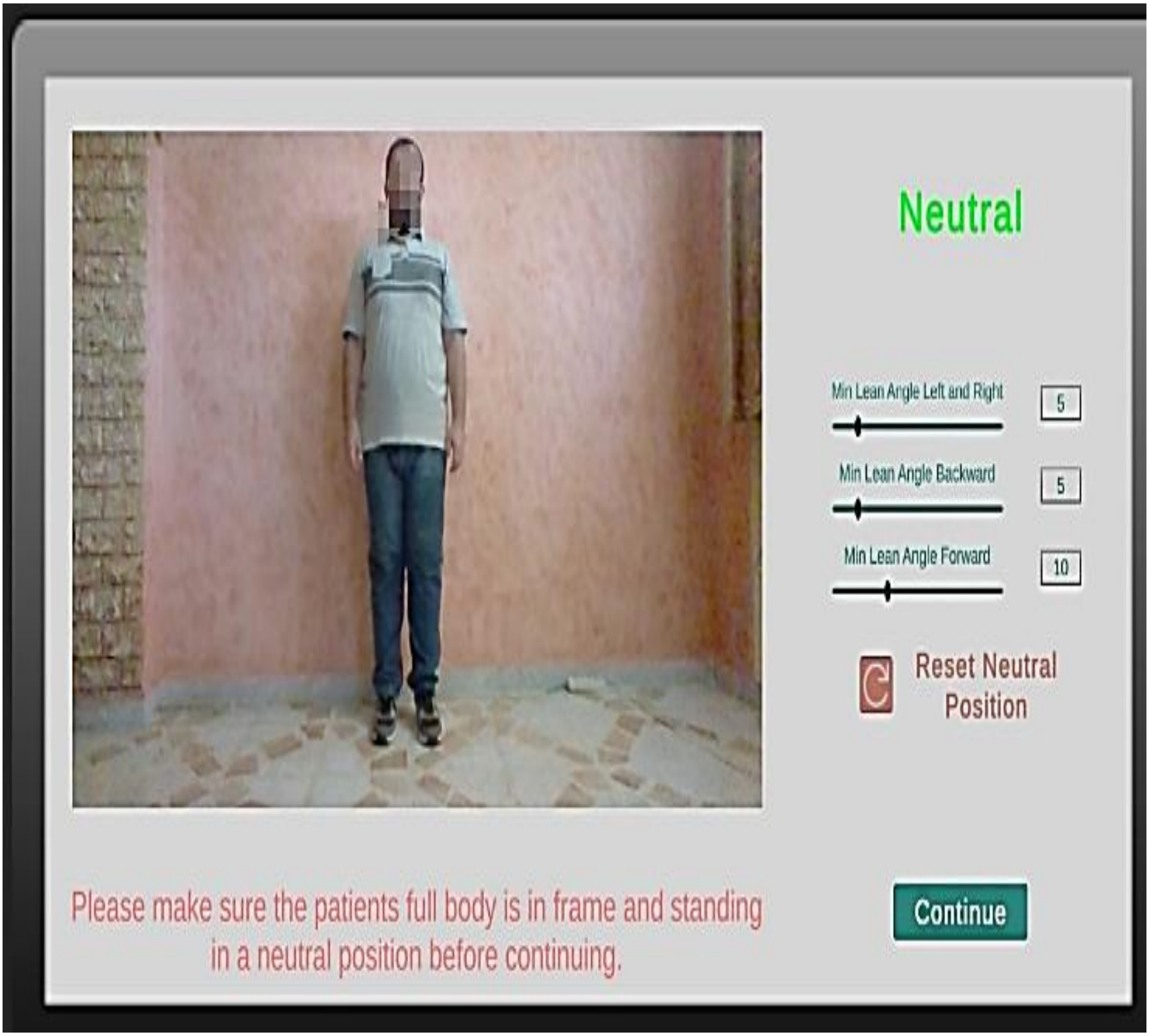

Fig 2. Illustrates a game setting module that enables the identification of the minimal degree of body leaning required for game interaction, thereby promoting leaning toward the LOS

3.2. Speed of Game

In addition to the extent of body leaning, the speed of the game is another critical aspect that requires careful consideration to optimize the efficacy of balance training (63). The rationale behind this necessity stems from previous research, which indicates that engaging in high-speed games that align with patients' capacities has the potential to enhance the effectiveness of training by reducing the reaction time (RT) required to respond to stimuli. Consequently, this improvement enables patients to respond more rapidly to perturbations, ultimately preventing falls (1,67).
To adjust the game speed during training, several parameters, such as "Repetition of Instruction" and "Time to React to Collectables," can be integrated into the games, as illustrated in Figure 1. These parameters enable the adjustment of game speed by either increasing the number of stimuli provided to the player during the game or decreasing the time allowed for the patient to respond to a stimulus. However, it remains unclear which approach is the most effective for balance training. Further research is required to determine the optimal approach.

Pace of the Games
For PwMS, balance rehabilitation games should be designed with a slower tempo than some commercially available games currently used in clinical settings. The reason for this requirement is based on findings from previous research indicating that PwMS exhibit delayed reaction times compared to their healthy counterparts when performing tasks that involve body leanings or when responding to both expected and unexpected perturbations (23,25,52,53,55,66). Designing such games with these considerations ensures not only a safe training approach but also alignment with the specific neurological and physiological needs of this population. Consequently, rehabilitation programs can be more effective in improving balance and reducing the risk of fall.

Discussion

The objective of this interdisciplinary research was to propose a framework that guides the development of user-centered games for balance rehabilitation in PwMS. This objective was achieved by synthesizing relevant recommendations derived from the broader literature and identifying the mechanics and limitations of commercial games currently used in practice. Building on the results obtained, this study proposed a set of targeted recommendations, summarized in (Table 2) to inform the development of such games.

Table 2. Summary of the key recommendations for the design of balance rehabilitation games for PwMS

Rehabilitation Goals	Corresponding Recommendation	Game Mechanics Examples

Games should be specifically designed to target particular impairments.	A systematic and comprehensive assessment of balance control domains should be conducted to identify impairments and select targeted interventions.	NA.
Games should be designed with adaptable features.	Adaptability can be achieved either by incorporating machine learning algorithms that modify gameplay based on patient performance or by integrating a controlled settings module that enables clinicians to adjust gameplay mechanics such as game speed and the number of stimuli according to the patient's performance.	NA.
Enhancing reduced capacities to reach the LOS.	Games should be designed to promote body leaning by incorporating weight-shifting exercises that encourage controlled movement toward the LOS.	Games should incorporate tasks that require players to lean their bodies toward a specific point to score or catch an object. If the required degree of leaning is not achieved, the players fail to score.
Enhance responses to perturbations.	High speed games that are tailored to individualized patients' capacities are required.	Games should incorporate tasks that challenge patients' response capabilities, such as avoiding an oncoming ball. These tasks should be presented at high speeds aligned with the individualized patients' capacities.
Addressing impairments in sensory integration and reweighting process.	Implement games that involve sensory integration training.	Games should be designed to facilitate sensory integration training by incorporating features that target different sensory conditions, such as eyes open, eyes closed, and reduced visual reliance. In the eyes-open condition, patients can respond to visual stimuli. In eyes-closed condition, patients are required to respond to auditory cues while keeping their eyes closed. For reduced visual reliance, auditory stimuli can be

		presented while patients are exposed to visual environments containing optic flow illusions.
Address cognitive aspect of postural control system.	Implement games that involve dual-task activities.	Games should be designed to require patients to focus on multiple tasks simultaneously, thereby creating a dual-task condition. In addition to physical exercise, such games should incorporate additional motor or cognitive challenges—such as avoiding obstacles, matching objects, catching, responding to objects with specific characteristics among distractors, or executing different motor responses depending on stimulus type.
Task-specific training.	Beyond the above recommendations, games should be specifically designed to target functional tasks, such as stepping, sit-to-stand, or others, as balance is a task-specific motor skill that requires targeted interventions to effectively address particular impairments.	NA

Importantly, the recommendations underscore the need to develop dynamically adjustable games rather than relying on preset designs to support a personalized, precise, specific, and progressive training approach. This in turn ensures that the game remains appropriately challenging for each patient and keeps them within their "flow-zone." As a result, such adaptable games may improve long-term adherence to rehabilitation programs, enhance therapeutic effectiveness, and increase the usability and functionality of the games (1).

Beyond this, the proposed recommendations highlight the significance of developing games with diverse designs and mechanics to address the multifaceted impairments affecting static, reactive, and anticipatory balance systems in PwMS. For instance, to enhance postural responses to perturbations, it is recommended to implement high-speed games that align with the patients' capabilities. To improve movement toward LOS, games that challenge the extent of body leaning toward these limits are necessary. Games that facilitate sensory integration training are recommended to address impairments in sensory integration and reweighting process.

By implementing these targeted recommendations, we hypothesize that games can become more effective by providing individualized and specific solutions to the various impairments observed in PwMS.

Practical application:

Here, it becomes important to highlight the practical feasibility of implementing the proposed recommendations, particularly those incorporated into the prototype developed by the research team. The prototype was developed using Unity, and body movement detection was achieved through the “ThreeDPoseUnityBarracuda” plugin, which is available through the Unity developer community. Therefore, the development of a similar system should be relatively cost effective.

Beyond development feasibility, such prototypes can be readily implemented in clinical settings. Our prototype is compatible with computers running the Windows operating system and was tested on both an HP Victus 15-FB2063DX laptop and a Lenovo laptop with an Intel Core i3 processor. While the game operated smoothly and without a noticeable lag on HP Victus, significant performance limitations were encountered on the Lenovo device. However, the game is expected to run effectively on systems equipped with at least 8 GB of RAM, a solid-state drive (SSD), and an Intel Core i5 or preferably i7 processor, though further testing is needed to confirm this.

Preliminary, unpublished data from our team indicate that the prototype is suitable for use by individuals with disabilities up to level 6 on the Expanded Disability Status Scale (EDSS), specifically for patients who experience walking difficulties and use a cane for ambulation but can stand unaided.

As such, in addition to the theoretical insights provided by the framework, its practical application and implementation appear feasible. Therefore, we recommend that future research focuses on developing more user-centered games for balance rehabilitation in PwMS, as commercial games remain the predominant option in clinical practice. Indeed, aside from our game prototype, there are three additional user-centered games developed for PwMS (68–70). While these prototypes were designed to provide adaptable training, each was developed with different training objectives, making direct comparisons among them challenging. Thus, more game designs targeting both similar and different objectives are needed to identify optimal training protocols both within the same objective and across diverse objectives. This will help determine the most effective training protocols.

Limitations

This research proposes a theoretical framework based on a synthesis of existing literature on game-based balance rehabilitation for PwMS, with extensions to related populations such as older adults. These conceptual analyses were subsequently adapted to address the specific rehabilitation needs of PwMS. Consequently, a key limitation of this approach is the absence of real-world implementation to support the proposed recommendations. Therefore, future empirical studies are necessary to validate and refine the framework if needed. Such research will be critical for identifying effective therapeutic designs and protocols tailored to the unique needs of this population.

Conclusion

This research provides actionable guidelines for the development of user-centered games aimed at balance rehabilitation for PwMS. It underscores the necessity of developing dynamic, adjustable games that operate at a slower tempo than the commercial games typically used in clinical settings. It also emphasizes the importance of incorporating diverse game designs and mechanics to effectively address the multifaceted balance impairments observed in PwMS. By proposing such targeted interventions, this research has the potential to improve patient care, enhance therapeutic outcomes, and influence the development of future rehabilitation games. As the first research to establish a structured framework guiding the design of user-centered exergames for this purpose, this research represents a significant step forward in both the rehabilitation and game design fields. Beyond PwMS, the framework may hold relevance to other populations, such as older adults, offering valuable insights for designing exergames tailored their needs.

Future work

Future work will focus on validating the prototype developed in the present study. During the development phase, preliminary validation was conducted with both healthy individuals and PwMS to assess the basic functionality of the system. While the initial results indicated that the game operated as intended, no structured clinical trial was conducted. Therefore, subsequent research will involve a structured clinical trial to evaluate the efficacy of the prototype and compare its outcomes with those of existing commercial games.

Compliance with ethical guidelines

This article is a review article with no human or animal sample.

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Authors’ Contribution

Conceptualization, Data collection, Data analysis, Writing: Hiyam Ibrahim, Emmanuel Guardiola and Ahmad Diab; Supervision, Review, and Editing: Emmanuel Guardiola and Ahmad Diab.

Conflict of interest

The authors declared no conflict of interest.

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