

Components of Flow in VR Exergames Across Age Groups: A Phenomenological Study

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ABSTRACT

This study aimed to explore the components of “flow” in VR exergames across different age groups, focusing on the psychological, motivational, and contextual factors that shape immersive engagement. A qualitative phenomenological research design was employed to capture participants’ lived experiences of flow in VR exergames. Data were collected through semi-structured interviews with 18 participants from India, representing adolescents, young adults, middle-aged adults, and older adults. Recruitment was purposive to ensure diversity in age and VR experience. Interviews, lasting 45–70 minutes, were audio-recorded, transcribed verbatim, and analyzed thematically using NVivo 14. Data collection continued until theoretical saturation was reached. Credibility was enhanced through peer debriefing, reflexivity, and maintaining an audit trail of coding decisions. Thematic analysis revealed four overarching themes: immersive engagement, challenge–skill balance, enjoyment and motivation, and social and contextual factors. Subthemes included sensory immersion, time distortion, emotional resonance, progressive difficulty, perceived competence, intrinsic enjoyment, extrinsic rewards, social comparison, age-related perceptions, and technological barriers. Across age groups, participants described experiences of deep concentration, detachment from reality, and transformation of exercise into enjoyable play. Flow was enhanced by adaptive design features, immediate feedback, and social interaction but hindered by cybersickness, equipment cost, and cultural skepticism. VR exergames effectively foster flow by combining immersive engagement, balanced challenges, and motivational rewards, while also enabling social connection. However, age-related differences and contextual factors influence how flow is experienced, underscoring the importance of user-centered design. The findings contribute to both theoretical understanding of flow and practical strategies for optimizing VR exergames in health, rehabilitation, and fitness contexts.

Keywords: Virtual reality; Exergames; Flow; Immersion; Challenge–skill balance; Motivation; Age groups; Phenomenological study

Introduction

The rapid advancement of digital technologies has redefined how individuals engage with physical activity, rehabilitation, and leisure. Virtual reality (VR) exergames, which combine immersive environments with bodily movement, have emerged as a promising medium to enhance motivation, enjoyment, and health outcomes across diverse populations. Exergaming, initially popularized as a recreational activity, is now increasingly adopted as a therapeutic and educational tool due to its capacity to stimulate both physical and cognitive engagement (1-3). Within this growing field, the concept of “flow”—a state of optimal

immersion and intrinsic motivation—has become central to understanding why VR exergames are so effective in sustaining user participation (4-6).

Flow, as described in psychological literature, refers to a mental state characterized by intense focus, loss of self-consciousness, time distortion, and an intrinsic sense of reward. This phenomenon is particularly relevant in VR exergames, where immersive technology intensifies sensory engagement and creates conditions conducive to flow experiences (7, 8). The measurement of flow has been refined through psychometric tools such as the Flow State Scale (FSS) and Dispositional Flow Scale (DFS), validated in multiple cultural contexts (5, 6, 9-12). These instruments underscore the multidimensionality of flow, including components such as balance between challenge and skill, clear goals, and immediate feedback.

While flow has been widely studied in sports and gaming, its role in VR exergames warrants deeper exploration, particularly across age groups. Younger players may achieve flow through rapid immersion and novelty, whereas older adults may experience different barriers, including cybersickness, cognitive load, or technological unfamiliarity (13-15). Thus, investigating flow across the lifespan in VR exergames is essential to optimizing design and tailoring interventions for different users.

VR exergames have demonstrated significant therapeutic benefits in both clinical and non-clinical populations. For instance, case studies have shown improvements in musculoskeletal conditions such as frozen shoulder when VR exergames are integrated into physiotherapy (16). Similarly, Parkinson's disease patients have benefited from exergaming interventions that enhance motor function, balance, and engagement (17, 18). Post-stroke rehabilitation has also incorporated VR exergames with evidence of improved safety and feasibility for upper limb recovery (19). Moreover, immersive VR exergames promote psychosocial well-being among community-dwelling older adults (20).

Beyond clinical populations, VR exergames support mental health outcomes such as mood regulation and cognitive functioning. Acute sessions of VR exergames have been shown to enhance executive function and emotional well-being (21, 22). Similarly, VR exposure therapy has been applied in treating phobias, underscoring the broader therapeutic potential of immersive systems (23). These findings indicate that VR exergames not only address physical fitness but also contribute to psychological resilience and cognitive health.

One reason for the growing popularity of VR exergames is their ability to sustain user motivation through flow. Flow enhances enjoyment, intrinsic motivation, and persistence in physical activity (7, 8). Studies reveal that exergames provide greater satisfaction and flow compared to equivalent real-life activities such as cycling (7). Furthermore, exergames can serve as effective motivators for inactive adults, improving affective states and reducing unhealthy behaviors such as excessive food consumption (24).

Importantly, flow is influenced by contextual and demographic factors. For example, elderly populations have reported significant improvements in motor and cognitive skills through VR exergames when usability and acceptance are carefully addressed (25-27). Conversely, challenges such as cybersickness, accessibility, and device comfort can disrupt the flow experience and limit adherence (13). Understanding these variations is critical for tailoring interventions across different age groups.

The design of VR exergames plays a decisive role in facilitating flow. Immersive environments, responsive feedback, and emotionally engaging virtual characters are critical features that enhance motivation and performance (28). Human-centered design approaches have emphasized adaptability to specific populations, such as individuals with dementia, ensuring accessibility and safety while maintaining flow (29). Similarly, novel developments such as augmented reality (AR) exergames extend opportunities for aerobic training and enjoyment among healthy adults (8).

Game mechanics, such as adaptive difficulty levels and social feedback, also influence user engagement. Research indicates that group size and non-player character spectators can significantly shape user motivation and flow in VR exergames (30). Emotional rapport with VR trainers has been particularly effective in long-term adherence among senior users (31). These findings suggest that social, emotional, and design dimensions must be integrated when creating exergames that foster sustainable flow.

The role of VR exergames varies considerably across age demographics. For children and adolescents, exergames serve as innovative tools to stimulate physical activity and counter sedentary lifestyles (3). For young adults, exergames provide enjoyable fitness alternatives and opportunities for immersive entertainment (8). Middle-aged adults may benefit from the stress-relieving aspects of exergames, balancing exercise with cognitive engagement (22, 24). Older adults, on the other hand, often perceive exergames as a safe and socially engaging way to maintain mobility and prevent falls (1, 14).

Empirical studies have reinforced these differences. For instance, tai chi-based VR exergames have been effective in reducing fall risk among elderly populations (1), while VR tele-exergaming has demonstrated promise in improving cardiometabolic health indicators among youth with cerebral palsy (32). This illustrates the adaptability of exergames to different health and developmental needs across the lifespan.

Despite their promise, VR exergames are not without limitations. Cybersickness remains a prominent barrier, particularly in seated VR applications (13). Accessibility issues such as equipment cost, usability for individuals with cognitive or physical impairments, and the requirement for adequate physical space also pose challenges (14, 33). Additionally, critiques of flow measurement instruments, such as the DFS-2 and FSS-2, highlight methodological limitations in capturing the complexity of flow experiences (12).

Furthermore, not all exergames produce equally positive outcomes. For instance, while many studies highlight benefits, questions remain regarding long-term adherence and the sustainability of health improvements (34, 35). Addressing these gaps requires nuanced research approaches that consider both psychological and physiological dimensions of exergaming.

Although the literature demonstrates the benefits of VR exergames, there is still limited understanding of how flow is experienced across different age groups. Existing research often emphasizes clinical outcomes or usability, while the subjective, phenomenological dimensions of flow remain underexplored (4, 28). Moreover, while psychometric validation of flow instruments is well established (5, 6, 9), qualitative insights into the lived experience of flow in VR exergames are scarce.

This study addresses this gap by applying a phenomenological approach to examine the components of flow in VR exergames among diverse age groups in India.

Methods and Materials

Study Design and Participants

This study employed a qualitative research design using a phenomenological approach to explore the components of “flow” in VR exergames across different age groups. Phenomenology was chosen as it allows for an in-depth understanding of participants’ lived experiences, perceptions, and meanings associated with engagement in VR-based physical activity.

A purposive sampling strategy was used to recruit participants from India who had experience with VR exergames. The final sample consisted of 18 participants, encompassing diverse age groups ranging from adolescents to older adults, to capture variation in perceptions and experiences. Recruitment was carried out through VR gaming centers, fitness clubs integrating VR technologies, and online community groups. Participation was voluntary, and informed consent was obtained from all individuals prior to the interviews.

Data Collection

Data were collected through semi-structured interviews designed to elicit rich descriptions of participants' experiences of flow while engaging in VR exergames. The interview guide included open-ended questions about immersion, attention, enjoyment, challenge-skill balance, time perception, and social interaction within VR exergames. Probing questions were used to encourage elaboration and capture subtle aspects of the flow experience.

Each interview lasted between 45 and 70 minutes and was conducted either face-to-face or online, depending on participant preference and accessibility. All interviews were audio-recorded with permission and subsequently transcribed verbatim. Data collection continued until theoretical saturation was reached, meaning no new significant themes or insights emerged from the interviews.

Data analysis

Thematic analysis was applied to the interview transcripts, supported by NVivo 14 software for systematic coding and organization of data. The analysis followed several iterative steps: (1) familiarization with the data through repeated readings of transcripts, (2) generation of initial codes capturing meaningful statements and concepts, (3) clustering of codes into broader categories and themes reflecting components of flow, (4) refinement of themes through constant comparison across participants and age groups, and (5) synthesis of final thematic structures that encapsulated the essence of flow experiences in VR exergames.

Credibility of the analysis was enhanced through peer debriefing among the research team and maintaining an audit trail of coding decisions. Reflexivity was also practiced to minimize researcher bias and ensure interpretations remained grounded in participants' accounts.

Findings and Results

The study included 18 participants from India who represented diverse age groups and backgrounds. Among them, 10 were male and 8 were female. In terms of age, 5 participants were adolescents (13–19 years), 6 were young adults (20–35 years), 4 were middle-aged adults (36–55 years), and 3 were older adults (above 55 years). Educational levels varied, with 7 participants holding undergraduate degrees, 6 with postgraduate qualifications, and 5 with secondary school education. Regarding gaming experience, 12 participants reported regular engagement with VR exergames (at least twice a week), while 6 indicated occasional use (less than once a week). This distribution allowed for capturing perspectives across age, gender, and experience levels.

Table 1. Themes, Subthemes, and Concepts

Themes (Categories)	Subthemes	Concepts (Open Codes)
1. Immersive Engagement	Sensory immersion	"Feeling inside the game", "realistic graphics", "surround sound effects", "embodied presence", "losing track of the room"
	Concentration and focus	"Tunnel vision", "blocking distractions", "complete mental absorption", "forgetting external worries"
	Time distortion	"Minutes feel like seconds", "forgetting schedule", "unexpectedly long play sessions"
	Emotional resonance	"Joyful excitement", "adrenaline rush", "reduced stress", "feeling uplifted"
	Detachment from reality	"Escape from daily life", "forgetting physical space", "dreamlike state", "temporary disconnection"
	Feedback immediacy	"Instant response of movements", "clear feedback loops", "reinforcement from scores and visuals"

2. Challenge–Skill Balance	Progressive difficulty	“Levels that adjust automatically”, “gradual learning curve”, “avoiding frustration”
	Perceived competence	“Feeling capable”, “mastering controls”, “improving stamina”, “confidence boost”
	Adaptability of gameplay	“Game adjusts to player speed”, “customizable intensity”, “inclusive for all ages”
	Physical challenge	“Sweating during play”, “heart racing”, “full-body movement”, “fitness benefits”
	Mental challenge	“Strategic decision-making”, “planning moves”, “quick reflexes”, “memory recall”
3. Enjoyment and Motivation	Intrinsic enjoyment	“Fun for its own sake”, “pleasure in movement”, “playful experimentation”
	Extrinsic rewards	“Points and scores”, “unlocking new levels”, “competition-driven motivation”
	Social enjoyment	“Playing with friends”, “family participation”, “cooperative tasks”, “peer encouragement”
	Sense of achievement	“Overcoming tough levels”, “personal milestones”, “progress tracking”, “sense of pride”
	Replayability	“Returning to same game often”, “always something new”, “variety of tasks”, “unpredictable elements”
4. Social and Contextual Factors	Motivation to exercise	“Exercising without noticing effort”, “enjoyable alternative to gym”, “habit formation”
	Shared experiences	“Laughing with peers”, “group challenges”, “bonding moments”
	Social comparison	“Measuring performance with others”, “leaderboards”, “peer competition”
	Age-related perceptions	“Younger players embrace tech quickly”, “older players cautious but curious”, “different endurance levels”
	Accessibility and comfort	“Ease of use”, “intuitive controls”, “lightweight headsets”, “safe environment”
	Cultural influences	“Perception of gaming in Indian families”, “acceptance of VR as fitness”, “generational attitudes”
	Technological barriers	“Motion sickness”, “hardware cost”, “space requirements”, “internet connectivity issues”
	Context of use	“At home vs. gaming centers”, “public vs. private play”, “integration in schools/gyms”

Theme 1: Immersive Engagement

Sensory immersion. Participants described being enveloped by the sensory richness of VR exergames, noting how realistic graphics and surround sound enhanced their sense of presence. One participant explained, *“The moment I put on the headset, it feels like I’m inside another world — I forget that I’m standing in my living room.”* Another added that the embodied presence of avatars amplified their connection to the game environment.

Concentration and focus. Many participants reported that VR exergames helped them block out distractions, creating a state of deep concentration. As one middle-aged participant put it, *“Once I start playing, I don’t even hear my phone ringing. It’s like all my focus narrows down to the game.”* This tunnel vision was often linked to the experience of flow.

Time distortion. A recurring element of immersion was the altered perception of time. Several players felt that long play sessions passed quickly. One younger participant said, *“I thought I had played for 15 minutes, but when I checked, it had been almost an hour.”* This distortion reinforced the sense of losing oneself in the activity.

Emotional resonance. Emotional responses, such as joy and excitement, were commonly reported. Some described the activity as stress-reducing and mood-enhancing. An older participant noted, *“When I’m moving in the game, I feel lighter — like my worries are pushed aside for that time.”* These affective responses strengthened engagement.

Detachment from reality. For several players, VR exergames provided an escape from daily routines. One participant reflected, *“It’s like stepping into a dream. For those moments, I don’t think about my job or responsibilities.”* This sense of disconnection was both relaxing and motivating.

Feedback immediacy. Participants valued the immediate responses to their movements and the clarity of feedback loops. A young adult commented, *“When I punch or jump, the game reacts instantly. It feels rewarding and makes me want to keep going.”* Such reinforcement mechanisms sustained attention and enjoyment.

Theme 2: Challenge–Skill Balance

Progressive difficulty. Participants emphasized the importance of games gradually increasing in complexity. As one respondent observed, *“If it starts too hard, people give up. But when the challenge grows with you, it keeps you hooked.”*

Perceived competence. Mastery and competence were central to sustaining flow. Participants described satisfaction in feeling capable and improving over time. One explained, *“At first I struggled with the controls, but now I feel like an expert, and that makes me proud.”*

Adaptability of gameplay. The ability of games to adjust to player needs was considered crucial, especially across age groups. A participant in his 60s said, *“The game slowed down for me when I was struggling. That made me feel included rather than left behind.”*

Physical challenge. The bodily demands of exergames were frequently highlighted. Sweating, increased heart rate, and fatigue were perceived positively, as signs of both exercise and flow. One participant noted, *“It’s the first time I’ve enjoyed a workout without realizing it’s exercise.”*

Mental challenge. Beyond physical exertion, cognitive stimulation was also appreciated. Quick decision-making and memory recall were part of the flow experience. A participant explained, *“You have to think fast, and that keeps your brain sharp as much as your body.”*

Theme 3: Enjoyment and Motivation

Intrinsic enjoyment. Many participants emphasized the sheer fun of playing, independent of rewards. One young participant said, *“I play because it’s fun, not because I want points. The joy itself is enough.”*

Extrinsic rewards. Nevertheless, external motivators such as points, levels, and leaderboards enhanced engagement. As one participant remarked, *“When I see my score rising, I feel encouraged to try harder.”*

Social enjoyment. Shared play created opportunities for laughter and bonding. A participant reflected, *“When I play with my kids, we end up laughing so much — that’s the best part.”*

Sense of achievement. Progress was often linked to pride and satisfaction. One adult said, *“When I cleared a tough level, I felt like I had accomplished something big, even though it’s just a game.”*

Replayability. Many participants noted the appeal of returning to games that offered variety. A student explained, *“Every time I play, I discover something new, so it never feels boring.”*

Motivation to exercise. The capacity of exergames to transform exercise into play was a powerful motivator. One participant commented, *“I used to hate the gym, but with VR games, I’m sweating and smiling at the same time.”*

Theme 4: Social and Contextual Factors

Shared experiences. Playing together was seen as a way to strengthen relationships. A participant explained, *“It’s not just a game; it’s a moment we share as a family.”*

Social comparison. Competition and comparison also shaped experiences. As one participant said, *“When I see my friend’s score, I push myself harder to beat it.”*

Age-related perceptions. Different age groups engaged with VR exergames differently. A teenager noted, *“We pick it up fast, but my parents need more time.”* An older adult added, *“It’s challenging, but I like trying something new.”*

Accessibility and comfort. Practical concerns such as intuitive controls and safe environments affected participation. A participant observed, *“If the headset feels heavy, I lose interest. Comfort makes a big difference.”*

Cultural influences. The cultural context of gaming in India influenced acceptance. Some families supported VR as fitness, while others viewed it skeptically. One participant said, *“In my home, gaming was seen as a waste of time — now they see it helps my health.”*

Technological barriers. Challenges like motion sickness, costs, and space limitations were reported. A participant remarked, *“Sometimes I get dizzy after long sessions, and not everyone can afford the equipment.”*

Context of use. The setting shaped experiences, with differences between home, gyms, and public spaces. A participant explained, *“At home it feels private, but in a gym it becomes more social and competitive.”*

Discussion and Conclusion

The present study examined the components of flow in VR exergames across different age groups through a phenomenological approach. Four overarching themes were identified: immersive engagement, challenge–skill balance, enjoyment and motivation, and social and contextual factors. These findings expand current understanding of how flow emerges in VR exergames, highlighting the interplay of psychological, physiological, and sociocultural dimensions. By linking lived experiences of participants to existing theoretical and empirical research, this discussion situates the study’s results within broader scholarly debates on VR exergaming, flow, and age-related differences.

Immersive engagement emerged as a central condition for flow in VR exergames. Participants consistently described experiences of sensory immersion, concentration, time distortion, and emotional resonance. These findings echo previous studies showing that VR provides uniquely powerful affordances for immersion, creating presence and detachment from reality (7, 13). The phenomenon of losing track of time and space aligns with flow theory’s emphasis on absorption and altered temporal perception, which have been repeatedly validated in exergame contexts (5, 6).

The immediacy of feedback was another factor reinforcing immersion. Participants valued rapid, clear responses to their actions, which sustained their focus and facilitated learning. Similar observations have been reported in exergame design studies emphasizing the role of on-body and in-game feedback in enhancing usability and enjoyment (14, 28). Furthermore, emotional responses such as joy and stress reduction reported by participants are consistent with evidence showing that VR exergames improve mood and executive functioning (21, 22). Taken together, these results support the idea that immersive qualities of VR are uniquely suited to fostering flow states, distinguishing them from traditional physical activity or even non-immersive exergames (18, 35).

Another important dimension identified was the balance between challenge and skill. Participants described how progressive difficulty, adaptability, and perceived competence shaped their ability to sustain flow. This resonates strongly with core principles of flow theory, which emphasize that tasks must be demanding but achievable to maintain engagement (5, 9). Studies in VR exergaming demonstrate that adaptive difficulty contributes to inclusivity across age groups, enabling both younger and older users to remain engaged without frustration (15, 26).

Physical exertion and cognitive challenge were both perceived as vital. Participants welcomed sweating and increased heart rate as indicators of effort and achievement, aligning with evidence that VR exergames are effective in promoting fitness and motor rehabilitation (16, 17). Simultaneously, they appreciated the cognitive demands of quick decision-making and problem-

solving, consistent with research showing that VR exergames stimulate executive functioning and attention (22, 30). This integration of physical and cognitive challenge underscores the multidimensional nature of flow in VR contexts.

Notably, older participants highlighted the importance of adaptable design, such as slower pace and simpler controls, to avoid disengagement. Such findings reinforce prior studies emphasizing the need for human-centered and age-sensitive exergame design (1, 29). The present study thus confirms that perceived competence and the ability to master challenges are not only precursors to flow but also determinants of accessibility and equity in VR exergaming.

Enjoyment and motivation were strong drivers of flow experiences in this study. Participants consistently emphasized intrinsic enjoyment as the primary reason for sustained engagement, echoing research showing that fun and playfulness are central to adherence in VR exergaming (7, 8). Extrinsic motivators such as points, rewards, and leaderboards were also appreciated, but they were secondary to the intrinsic satisfaction of movement and achievement. This supports findings that intrinsic motivation is a more reliable predictor of sustained engagement in VR-based interventions (28, 31).

The sense of achievement and replayability identified in participant narratives align with studies highlighting the importance of progression systems and variety in exergames (25, 30). Exergames that offered ongoing novelty and challenge were seen as more engaging, consistent with evidence that long-term adherence requires dynamic and varied experiences (20, 33). Additionally, participants reported that exergames transformed exercise into an enjoyable, habit-forming activity, echoing findings that VR can increase physical activity in otherwise inactive adults (3, 24).

These results reinforce the theoretical argument that flow is both a psychological state and a motivational driver, bridging the gap between enjoyment and adherence. They also highlight how VR exergames, by facilitating flow, may address one of the most persistent challenges in health promotion: sustaining long-term motivation for physical activity (19, 34).

Social and contextual dimensions also played an important role in shaping flow experiences. Participants reported that shared experiences with friends or family enhanced enjoyment and strengthened bonds, a finding echoed by research on social interaction in VR exergames (30, 31). Social comparison and competition were also identified as motivators, supporting prior evidence that leaderboards and group dynamics can amplify flow experiences (11, 28).

Age-related differences were evident in participants' narratives, with younger users quickly adapting to technology while older adults required more support. These generational distinctions are consistent with studies showing that usability, comfort, and cultural attitudes shape acceptance of exergames (1, 27). Cultural factors also influenced perceptions, as participants reported differing family attitudes toward gaming. This resonates with findings that cultural context shapes the integration of VR into health and fitness practices (6, 33).

Technological barriers such as cybersickness, equipment cost, and space requirements were also mentioned, aligning with prior studies that highlight these obstacles as threats to immersion and flow (13, 14). The distinction between private and public settings further revealed contextual influences: home use promoted privacy and relaxation, while gym or community settings facilitated social flow. This finding echoes evidence that context of use moderates exergame effectiveness and enjoyment (23, 32).

Overall, the findings of this study are consistent with and extend existing research on flow in VR exergames. Immersion, challenge–skill balance, intrinsic enjoyment, and social context have been repeatedly highlighted as determinants of flow (4, 7, 8). However, by adopting a phenomenological lens, this study contributes nuanced insights into how these factors are lived and experienced across age groups. For instance, while prior studies have measured flow using psychometric scales (5, 6, 9), this study highlights the subjective meaning of flow, such as detachment from reality, emotional uplift, and social bonding.

Moreover, the study underscores the importance of contextual sensitivity in designing exergames for diverse users. Whereas existing research often focuses on specific clinical groups (16–18), this study spans the lifespan, illustrating how age shapes

flow experiences. By comparing adolescents, young adults, middle-aged adults, and older adults, the research provides a comprehensive perspective on inclusivity in VR exergaming.

Finally, the findings support the argument that flow is not merely an individual psychological state but a socially and culturally situated phenomenon. This resonates with emerging scholarship emphasizing the relational and contextual aspects of flow (2, 31). In this sense, VR exergames represent a unique intersection of technology, psychology, and culture, capable of generating immersive, motivating, and socially meaningful experiences across generations.

This study has several limitations that must be acknowledged. First, the sample size was relatively small (18 participants) and limited to individuals from India, which may restrict the generalizability of findings to other cultural or geographic contexts. Second, data were collected through semi-structured interviews only, which relied on self-reported experiences and may be subject to recall bias or social desirability effects. Third, while efforts were made to include participants across age groups, the distribution was uneven, with fewer older adults, potentially limiting the depth of insights from this demographic. Finally, as a qualitative phenomenological study, the findings provide rich descriptions but do not allow for causal inferences or quantitative measurement of flow.

Future research should adopt mixed-methods designs combining qualitative insights with quantitative measures such as the Flow State Scale (FSS-2) to provide both depth and breadth of understanding. Longitudinal studies are needed to examine how flow evolves with sustained VR exergaming and whether it predicts long-term adherence to physical activity. Expanding samples to include diverse cultural contexts would also clarify how cultural attitudes shape flow experiences. Moreover, future research should explore design innovations, such as adaptive algorithms and biofeedback, that may optimize flow for different age groups. Finally, comparative studies between VR and non-VR exergames could further elucidate the unique contribution of immersion to flow.

Practitioners designing or implementing VR exergames should focus on enhancing immersive features while ensuring accessibility across age groups. Developers should integrate adaptive difficulty levels, customizable controls, and options for both individual and social play to maximize inclusivity. Attention should be given to minimizing cybersickness, reducing equipment costs, and creating culturally appropriate content. In clinical and rehabilitation settings, VR exergames should be tailored to patient needs, balancing physical challenge with psychological engagement. In educational and fitness contexts, exergames can be leveraged to promote active lifestyles by making exercise enjoyable and socially engaging.

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Authors' Contributions

All authors equally contributed to this study.

Declaration of Interest

The authors of this article declared no conflict of interest.

Ethical Considerations

All ethical principles were adhered in conducting and writing this article.

Transparency of Data

In accordance with the principles of transparency and open research, we declare that all data and materials used in this study are available upon request.

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