ROWING VR TO PROMOTE PHYSICAL LITERACY AND INCLUSION

CANOTTAGGIO VR PER PROMUOVERE LA PHYSICAL LITERACY E L'INCLUSIONE

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ABSTRACT
This study explores the potential of Virtual Reality (VR) rowing to enhance the inclusion and development of individuals with disabilities, based on the Universal Design for Learning (UDL) and the International Classification of Functioning, Disability, and Health (ICF) frameworks. A key innovation is the proposed pre-assessment protocol, which customizes the VR experience to individual needs, optimizing engagement and outcomes. VR rowing offers a safe, adaptable environment for physical, cognitive, and social growth, contributing to more inclusive physical activity and rehabilitation.

Questo studio esplora il potenziale di strumenti per il canottaggio in Realtà Virtuale (VR) per promuovere l'inclusione e lo sviluppo delle persone con disabilità, attraverso i framework Universal Design for Learning (UDL) e la Classificazione Internazionale del Funzionamento, della Disabilità e della Salute (ICF). Un'innovazione chiave è il protocollo di pre-valutazione proposto, che personalizza l'esperienza VR in base alle necessità individuali, ottimizzando l'engagement e i risultati. Il canottaggio VR offre un ambiente sicuro e adattabile per la crescita fisica, cognitiva e sociale.

KEYWORDS
VR, Disability Inclusion, Physical Activity, Pre-assessment Protocol, UDL
Realtà Virtuale, Inclusione, Sport, Protocollo di Pre-valutazione, UDL

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Introduction

Today, sports and physical activities are widely recognized as effective tools for promoting physical literacy, enhancing social inclusion, and improving the overall well-being of individuals with disabilities. However, despite these advantages, individuals with disabilities still face significant barriers, such as high costs, insufficient infrastructure, and limited accessibility. These challenges restrict their participation in traditional sports, contributing to social exclusion.
In this context, virtual reality (VR) emerges as a promising technology that could address these issues. VR environments offer individuals with disabilities the opportunity to engage in sports in a realistic yet safe setting. With highly customizable and adaptable features, VR enables users to enhance motor skills while fostering interpersonal abilities, self-esteem, and a sense of belonging.
An example of VR's educational potential in sports is VR rowing. By offering adaptable training environments tailored to diverse physical and cognitive needs, VR rowing provides individuals with disabilities a fully inclusive avenue for physical activity. In addition to supporting physical well-being, VR rowing can aid in developing essential social and relational skills, such as teamwork, effective communication, and relationship-building.

1. Physical Literacy and Special Needs

Physical literacy is widely regarded as a multidimensional competence that is essential for promoting holistic development and fostering lifelong engagement in physical activities. Physical literacy encompasses more than just physical skills; it integrates physical, psychological, cognitive, and social components that together empower individuals to engage meaningfully in a variety of movement contexts (Monacis & Colella, 2022). Within the context of special needs, the pursuit of physical literacy takes on particular importance, as it involves supporting individuals in inhabiting and enabling a body that may not always align with idealized or easily accepted norms. For individuals with disabilities, physical literacy often involves a complex interplay of personal aspirations, societal expectations, and adaptive challenges, highlighting the need for personalized pedagogical approaches that respect and amplify each person's unique abilities and potential. This section examines the theoretical frameworks underlying physical literacy in special needs populations, emphasizing how inclusive practices and technological advancements can empower individuals with disabilities to realize meaningful and personally empowering movement experiences. The analysis underscores the importance of

non-linear pedagogy, adaptive assessment methods, and technology-driven strategies in supporting motor learning among individuals with special needs.

A key aspect of physical literacy is that it involves not only physical competence but also the motivation, confidence, knowledge, and understanding necessary for participation in physical activities (Pascali & Monacis, 2024). In individuals with special needs, these dimensions must be sensitively adapted to align with diverse motor, social, and cognitive abilities. Traditional physical education models often fall short of meeting these requirements, making it essential to explore inclusive frameworks that prioritize personalized learning objectives and flexible pedagogical approaches. Monacis and Colella (2019) argue that integrating learning technologies is critical in this context, as technological tools can facilitate the acquisition of motor skills in ways that accommodate each learner's unique challenges. When applied effectively, technology allows learners with special needs to engage in personally relevant and adaptive physical activities that resonate with their abilities and aspirations.

Non-linear pedagogy is a crucial pedagogical strategy for promoting physical literacy in students with disabilities. Non-linear pedagogy advocates for flexible, learner-centered methodologies that prioritize exploration, variation, and self-directed learning over rigid, prescriptive instruction (Monacis, Annoscia, & Pascali, 2024). For students with special needs, non-linear pedagogy offers a pathway for discovery-based learning that respects each individual's pace and personal capabilities. This approach allows learners to experience movement in ways that are self-expressive and adapted to their physical and psychological realities, thus fostering the confidence and engagement necessary to achieve physical literacy. By encouraging students with disabilities to explore movement within a safe and adaptable learning environment, non-linear pedagogy helps develop fundamental movement skills while fostering autonomy and resilience. This approach respects the delicate balance between inhabiting a body that may not correspond to societal norms or personal aspirations, and nurturing a positive self-identity that values movement and physical expression as sources of empowerment.

Technology plays an essential role in supporting physical literacy among individuals with special needs, especially in creating inclusive, interactive, and motivating environments that are often difficult to achieve in traditional physical education settings (Monacis & Colella, 2020). Tools such as virtual reality and interactive exergames provide immersive, controlled environments in which students with disabilities can safely practice and enhance motor skills without the pressures or risks inherent in real-world settings. Virtual reality technology enables

customizable and adaptive interfaces that meet specific needs, thus facilitating a more individualized and impactful approach to physical education. Monacis and Colella (2019) emphasize the pedagogical value of virtual reality, noting that these technologies not only enhance motor skills but also promote social interaction, addressing the multifaceted nature of physical literacy. By leveraging technology, educators can create supportive, accessible environments that encourage students with disabilities to explore movement on their own terms, resulting in meaningful progress in physical literacy and personal agency.

The assessment of physical literacy in students with disabilities requires sensitivity and adaptability. Conventional assessment methods may fail to accurately reflect the nuanced progress of students with disabilities, potentially overlooking their growth in motivation, engagement, and adaptive skills. Pascali and Monacis (2024) advocate for evaluation tools that prioritize qualitative measures over rigid quantitative standards, focusing on individual development and emotional engagement rather than uniform benchmarks. Inclusive assessment tools that consider personal growth and social participation, in addition to physical competence, provide a holistic understanding of a student's physical literacy journey. By utilizing adaptable assessment methods, educators gain a deeper insight into how students with special needs navigate their unique pathways to physical literacy, thus facilitating a more supportive and individualized educational experience.

Incorporating technology into physical literacy education also allows for real-time monitoring and feedback, which are particularly beneficial for students with disabilities. Feedback tools, such as motion-tracking software and wearable sensors, provide immediate feedback on movement patterns, helping learners make adjustments and improve motor skills within a supportive framework (Monacis & Colella, 2020). This technology-driven feedback not only supports learners but also aids educators by offering detailed insights into each student's performance, enabling more personalized instruction. Real-time feedback is invaluable for individuals with disabilities, as it allows them to track their progress and make informed adjustments in a non-judgmental environment, fostering both physical competence and self-confidence.

The social and emotional dimensions of physical literacy are equally essential for individuals with special needs. Physical literacy is not limited to physical capability but encompasses a sense of confidence, social belonging, and emotional resilience. For students with disabilities, who may encounter both social and cognitive barriers, fostering an inclusive environment that encourages social interaction,

collaboration, and self-expression is crucial. Participating in adaptive sports and group activities allows students with special needs to experience the joys of movement and physical activity in an environment that values their individuality and promotes a sense of community. Physical activities that emphasize teamwork and cooperation help students cultivate essential interpersonal skills, build relationships, and strengthen their self-concept in relation to others. For many, developing physical literacy is an empowering process that nurtures both a positive self-image and a resilient social identity.

Achieving physical literacy is crucial not only in educational settings but also in the broader context of lifelong health and physical activity. For individuals with disabilities, physical literacy can lead to greater opportunities for engaging in recreational and competitive sports, improving quality of life and social integration. Early foundations in physical literacy equip individuals with special needs with the tools and motivation needed to maintain an active lifestyle, benefiting both physical and mental health. As Monacis and Colella (2022) highlight, an inclusive approach to physical literacy enriches the lives of individuals with disabilities and contributes to a society that values diversity and embraces individuals for their unique strengths. An inclusive approach to physical literacy encourages everyone, regardless of physical or cognitive abilities, to engage meaningfully in physical activities, reinforcing a sense of agency, community, and personal fulfillment.

In conclusion, physical literacy provides a robust framework for promoting inclusive physical education among individuals with special needs. By adopting non-linear, personalized pedagogical approaches, implementing flexible assessment methods, and incorporating technology to create accessible and supportive learning environments, educators can facilitate the journey toward physical literacy in ways that honor each individual's unique experience of their body. A nuanced understanding of the body—where abilities and aspirations may diverge from societal ideals—is key to fostering physical literacy for students with disabilities, as it emphasizes not only skill acquisition but also the celebration of diverse physical expressions. By supporting the physical, social, and emotional growth of individuals with special needs, physical literacy becomes a tool for empowerment, enabling individuals to participate fully in the world and embrace their embodied experiences with confidence and dignity.

2. Sport, Inclusion and Participation

In recent years, the positive impact of sports and physical activity on individual well-being has become well-established. Participation in sports enhances mental and physical health, promotes socialization and cooperation, and is an invaluable educational and developmental resource. Moreover, sports foster inclusion across various social contexts and are critical in promoting social participation among individuals with disabilities. For instance, integrating sports activities into school curricula can help create genuinely inclusive educational environments where students with disabilities are empowered to develop their unique strengths and actively engage in diverse school activities (Romano, 2023). Research further indicates that physical activity and sports involvement provide not only physical benefits but also a sense of belonging for individuals with disabilities of all ages, facilitating friendships, interpersonal skill development, and increased self-esteem and self-efficacy (Aitchison et al., 2022; Alcaraz-Rodríguez, Medina-Rebollo, Muñoz-Llerena, & Fernández-Gavira, 2021; Scarinci, Toto, Lombardi, & Furia, 2022).

The journey toward inclusion through sports, however, has unfolded gradually over multiple stages. Initial efforts to integrate individuals with disabilities into sports date back to 1948, when neurologist Sir Ludwig Guttman organized the first competitive sporting event for war veterans. His goal was to support veterans' rehabilitation and reintegration, while demonstrating the therapeutic potential of sports for individuals with disabilities (Goh, 2020). The first Paralympic Games, held in 1960, emphasized values of inclusion, empowerment, participation, and freedom, marking a significant step toward recognizing sports as an educational tool for enhancing the physical, social, and mental well-being of people with disabilities. Another milestone occurred on September 22, 1989, with the founding of the International Paralympic Committee (IPC), which aimed to support the growth of the Paralympic Games and ensure equal opportunities for athletes. Further, on June 19, 2001, the International Olympic Committee (IOC) signed an agreement with the IPC, mandating that countries hosting the Olympic Games also host the Paralympic Games (Goh, 2020).

Over the years, international policies and programs have emerged to advance the inclusion of people with disabilities in sports. The 2006 ratification of the Convention on the Rights of Persons with Disabilities (CRPD) (UN, 2006) marked a transformative shift toward a more inclusive perspective on disability (Asunta, Hasanen, Kiuppis, Rintala, & McConkey, 2022). Article 30 of the Convention recognizes sports participation as a fundamental right of people with disabilities, framing sports not only as a rehabilitation tool but as a means of constructing an

inclusive society committed to the rights of all citizens. An exemplary case of sports inclusion is the Special Olympics, the world's largest sports program for individuals with intellectual disabilities. The Special Olympics provides training and competition across more than 30 Olympic sports (McConkey & Menke, 2020), including tennis, football, badminton, and basketball. Recently, it launched the "Unified Sports" program, where individuals with and without intellectual disabilities train and compete together (Accardo et al., 2023). Such initiatives foster meaningful connections and mutual understanding, enabling participants to learn from one another and enhancing self-perception, autonomy, and societal engagement for individuals with disabilities (Carbone, Smith, Lewis, & LeBlanc, 2021).

Today, sports represent an effective means to challenge cultural barriers and transform perceptions of disability. Through sports, disability is redefined—not as an obstacle or limitation, but as a source of resilience and resourcefulness (WHO, 2012). Participation in sports allows individuals with disabilities to develop greater self-awareness and confidence in their abilities, offering a pathway beyond a life of passive observation. Often isolated or confined within family circles, individuals with disabilities benefit from sports by moving toward a life of interaction, connection, solidarity, and teamwork (Di Maglie, 2019).

For instance, research has shown that physical activity can help alleviate depressive and stressful states—common in individuals with intellectual disabilities or autism spectrum disorder (Spratt et al., 2018)—by fostering relationships with peers, coaches, and other members of sports organizations.

Despite broad recognition of sports as a fundamental right for all, including people with disabilities, practical barriers persist. Many individuals with disabilities continue to face exclusion across numerous domains, including sports (McConkey & Menke, 2020; Goh, 2020). Many sports organizations and their members lack the training, experience, and understanding necessary to support athletes with disabilities effectively. Moving forward, prioritizing staff training and incorporating emerging tools will be essential to creating sports environments that are more accessible and inclusive.

3. Rowing VR: tool and characteristics

As previously noted, social participation for people with disabilities is not always guaranteed. In the realm of sports, individuals with disabilities often encounter significant barriers to active participation; despite their efforts, physical, social, and

cognitive obstacles frequently result in their exclusion (Covarrubias et al., 2024). Within this context, virtual reality (VR) has emerged as a promising tool to facilitate social inclusion and promote the mental and physical well-being of individuals with disabilities (Jin, Feng, Ni, & Shan, 2018). VR's immersive, simulated, and secure environments offer these individuals opportunities to practice, enhance, or rehabilitate motor skills in a safe, controlled setting (Afridi, Nawaz, Tariq, & Rathore, 2022). Applying VR in sports education for people with disabilities can help overcome many barriers traditionally associated with conventional training. VR technology allows users to explore environments often inaccessible due to high costs, limited facilities, or inadequate equipment (Putranto, Heriyanto, Achmad, & Kurniawan, 2023). Furthermore, VR's capacity to minimize the risks associated with outdoor training while providing realistic, engaging experiences is especially notable (Kang & Kang, 2019).

Beyond its physical benefits, VR promotes educational inclusion by enabling individuals with disabilities to engage in immersive sports activities alongside non-disabled peers, fostering a shared and enjoyable environment. In recent years, VR-based simulations for sports activities have advanced considerably, incorporating sophisticated simulators and digital games. Exergames—interactive video games designed to promote physical activity—are a prime example. These games, which have gained renewed interest with VR's development, allow individuals to acquire or improve motor skills through engaging gameplay (Costa et al., 2019). Exergames accessible on standard digital devices can enhance motor control, postural balance, gait, and strength (Karaosmanoglu, Cmentowski, Nacke, & Steinicke, 2024). Additionally, these games support mental well-being and cognitive skill development by stimulating specific brain regions associated with cognitive processes (Costa et al., 2019). A systematic review by Zhao et al. (2020) highlighted the potential of VR-based exergames as tools to stimulate cognitive functions in individuals with mild cognitive impairment.

Among VR exergames, rowing simulators are gaining recognition as effective tools for engaging major muscle groups and developing strength, endurance, and posture (Li, Wu, & Han, 2019). Research suggests that VR environments simulating rowing not only improve physical performance but also elicit positive emotions such as enjoyment and satisfaction (Shoib et al., 2020; Li, Wu, & Han, 2019). Immersive environments that realistically replicate rowing movements enhance participants' motivation and engagement, preparing them for real-world physical challenges (Mouatt et al., 2023). Numerous VR tools and applications now support simulated rowing sessions; for example, Holofit by Holodia integrates fitness with

VR technology, requiring only a compatible rowing machine and VR headset, such as Meta Quest or Pico, to access virtual worlds and interact with a global community through the HOLOFIT platform. Alternatively, M3 (Multi-Modal Motion synthesis) offers a unique experience by combining haptic, visual, and acoustic feedback in a CAVE system, creating a highly immersive environment that mirrors real-world interactions (Van Delden, 2020). Motion-tracking technology, such as the Meta Quest 2 VR headset with an XR hand module, further enhances the VR experience by providing realistic, interactive rowing training in a safe and controlled environment (Covarrubias et al., 2024).

Although VR rowing has yet to be widely explored from an inclusivity perspective, it demonstrates considerable educational potential. Many VR rowing machines feature accessibility menus designed to accommodate users with disabilities, underscoring a commitment to adaptability. This customization capability allows the rowing experience to be tailored to meet the diverse physical and cognitive needs of users by adjusting activity intensity, duration, and difficulty. A multidisciplinary approach that integrates educational and engineering principles could further support the development of accessible protocols for educators and professionals, enhancing physical and social skills in users with disabilities. VR rowing holds additional promise in supporting physical literacy for people with disabilities by fostering motor skills such as coordination and muscle control.

While rowing simulators primarily aim to improve physical health, they also offer potential benefits for mental health. These advantages could extend to individuals with disabilities, supporting the development of essential social-emotional skills, defined by the OECD (2023) as vital competencies in educational contexts. VR rowing provides virtual group experiences that promote social participation, teamwork, and emotional inclusion (Covarrubias et al., 2024). Engaging in virtual sports activities with peers who share similar characteristics and experiences fosters a sense of belonging and reinforces self-confidence. Moreover, the adaptable and controlled nature of VR training can help reduce stress levels, a common challenge for individuals with disabilities seeking accessible sports environments.

In rehabilitation, VR is also emerging as a valuable tool for professionals, enhancing traditional methods and enabling tailored, individualized approaches (Afridi, Nawaz, Tariq, & Rathore, 2022). VR rowing can support the rebuilding of muscle strength, joint mobility, and endurance for people with disabilities. New VR technologies provide a comprehensive rehabilitation experience, often surpassing the limitations of traditional techniques. For example, VR-based rehabilitation can

alleviate anxiety by shifting focus away from pain, resulting in a more positive experience (Afridi et al., 2022). Real-time feedback further enhances the rehabilitation process, allowing users to modify exercises with greater awareness of their progress. Repetitive exercise, a key component of rehabilitation, is also well-supported by VR; while traditional methods often feel monotonous, VR's immersive environments offer realistic simulations that encourage users to reach their goals with a reduced risk of reinjury (Kang & Kang, 2019). The efficacy of VR simulators is supported by Howard (2017), who found that VR rehabilitation programs, compared to conventional approaches, increase engagement and improve outcomes through enhanced physical and cognitive fidelity.

In sum, while VR rowing simulators remain underutilized in the sports, educational, and rehabilitation fields for individuals with disabilities, they hold substantial promise as tools to facilitate social inclusion and participation. VR rowing has the potential to enhance motor learning, quality of life, and personal growth for individuals with disabilities, as well as to promote their social integration. With ongoing advancements in VR technologies, the accessibility of sports and rehabilitation activities could greatly improve, offering individuals with disabilities tailored and adaptable services that support holistic development.

4. Using Rowing VR based on ICF and UDL

Leveraging Virtual Reality rowing through the principles of the International Classification of Functioning, Disability, and Health and Universal Design for Learning presents a powerful, inclusive avenue for physical literacy that is particularly meaningful for individuals with disabilities. Both frameworks champion inclusive, adaptable approaches to engagement, recognizing that true inclusion in physical activity demands both physical and psychological accessibility (Zengaro & Zengaro, 2025; Pushkarenko et al., 2023). Virtual Reality (VR) rowing, in this context, creates an immersive space where users can safely interact, practice, and develop motor skills while bypassing common barriers like cost, limited facilities, and the physical inaccessibility of traditional sports environments (Asare, 2024). This approach fosters both social inclusion and physical well-being, inviting individuals to develop skills, confidence, and a sense of agency.

The International Classification of Functioning, Disability, and Health (ICF) offers a holistic lens on disability, viewing an individual's abilities not only in relation to physical or cognitive factors but also as shaped by social and environmental interactions. When applied to Virtual Reality rowing, this framework encourages

designers to develop VR experiences that are not only adaptable in terms of physical needs but are also inclusive of psychological and social aspects, which are equally vital for meaningful engagement. This model of inclusion is reflected in VR rowing systems, which offer adjustable difficulty levels, real-time feedback, and multimodal guidance—features that allow individuals to progress at their own pace and experience a sense of achievement. Moreover, VR rowing aligns with the ICF by recognizing that physical activity involves not only bodily functions but also the lived experience of inhabiting and enabling one's body, which may not always align with one's idealized or socially desirable image of a "normal" body. In this context, the ICF-based pre-assessment protocol serves as an essential first step in the individualized design of VR rowing interventions. Here is an example of a pre-assessment form appropriately developed for these objectives:

Protocol Key Points in UDL and ICF Context:	
1.	**Physical Functioning Assessment**: Ensures users can safely engage with the VR rowing environment based on their motor skills, range of motion, and endurance. The pre-assessment will test these elements to adjust the VR experience to their physical abilities.
2.	**Cognitive Functioning Assessment**: Measures how the user processes, retains, and responds to information in the VR environment. This assessment helps in modifying the VR rowing experience to match their cognitive abilities and learning styles.
3.	**Social Participation**: Evaluates the individual's ability to communicate and engage with others in social settings, especially within virtual communities created in VR environments. The pre-assessment measures comfort levels with social interaction, facilitating inclusivity in VR rowing sessions.
4.	**Environmental Adaptations**: Pre-assessments will identify the need for any assistive technology or adaptations to make the VR rowing space fully accessible. The environment should be tailored to the user's physical, cognitive, and technological needs.
5.	**Motivation and Engagement**: Engagement in VR rowing is fostered by providing various entry points for the user to interact with the system. Difficulty adjustments, real-time feedback, and immersive environments increase motivation, while also taking into account individual preferences, interests, and goals.

Table 1: *Protocol Key Points in UDL and ICF Context*

This protocol, while rooted in the ICF framework, also embraces the flexibility central to the Universal Design for Learning. It ensures that each participant's unique needs are acknowledged and that adaptations to the VR rowing program are made accordingly. Here is an example of UDL Protocol appropriately developed for these objectives:

Aspect	Protocol Element	Pre-assessment in ICF Context
Physical Functioning	**Motor Skills**: Assess coordination, balance, and muscle strength through specific physical tests (e.g., standing on one leg, walking with support, arm/leg movements).	**Motor Skills**: Test individual's ability to perform basic physical movements, focusing on coordination and balance. Evaluate muscle strength and joint flexibility for rowing.
	Range of Motion: Assess joint flexibility, particularly in the arms, legs, and torso for rowing movements.	**Range of Motion**: Evaluate flexibility, especially in key joints for rowing motions (hips, knees, shoulders).
	Cardiovascular Endurance: Assess the ability to sustain moderate physical activity, important for intensity level adjustments in VR sessions.	**Cardiovascular Endurance**: Assess endurance level to gauge appropriate intensity of VR rowing exercises and avoid overexertion.
Cognitive Functioning	**Attention and Focus**: Provide varied VR experiences to assess the individual's ability to focus on the task, responding to visual/audio cues.	**Attention and Focus**: Test attention span and focus through simple tasks, like following directions or completing basic motor tasks without distraction.
	Memory and Learning Ability: Assess capacity to remember sequences and adapt to new instructions or changes in the VR environment.	**Memory and Learning Ability**: Test individual's short-term memory by asking them to repeat instructions or remember sequence of movements.
Social Participation	**Social Interaction**: Create opportunities for cooperative and competitive VR rowing, fostering social skills and teamwork.	**Communication Skills**: Assess verbal or non-verbal communication skills to determine how the individual can interact with others in a virtual environment.
	Engagement with Others: Design features that allow interaction with other users in real-time, fostering inclusivity and a sense of belonging.	**Social Confidence**: Evaluate confidence in social interactions through group activities or peer interaction in educational/rehabilitation settings.
Environmental Factors	**Assistive Technology**: Integrate assistive devices (e.g., prosthetics, wheelchairs) into the VR environment to ensure safety and comfort.	**Assistive Devices**: Determine which assistive devices (e.g., hearing aids, specialized equipment) are needed for the VR rowing experience.
	Accessibility: Ensure that the VR space accommodates a variety of physical needs by adjusting virtual settings to allow easy navigation and participation.	**Environmental Accessibility**: Assess physical accessibility and any needed adaptations for a user's personal environment (e.g., space to maneuver wheelchair or walking aids).
Feedback Mechanisms	**Real-time Feedback:** Provide feedback on performance through visual, auditory, or tactile signals. Enable the participant to adjust techniques and progress in real-time.	**Real-time Feedback:** Assess individual's ability to respond to feedback and adjust activities, accordingly, providing opportunities for real-time adjustments during tasks.
Motivation and Engagement	**Engagement Strategies:** Use various difficulty levels and immersive environments to maintain motivation, allowing users to choose between different rowing experiences.	**Motivation and Goal Setting:** Discuss the user's preferences for activities and set achievable, personalized goals based on their interests, prior experiences, and abilities.
Progress Tracking	**Progressive Difficulty:** Adjust difficulty levels based on progress, ensuring the user is continually challenged but not overwhelmed.	**Progress Monitoring:** Track user progress in physical, cognitive, and social dimensions to determine the most effective level of engagement and improvement.
Inclusivity	**Multimodal Engagement:** Provide multiple ways to interact with VR rowing (e.g., gesture control, voice commands) to accommodate different learning styles.	**Multiple Means of Engagement:** Adapt interactions in VR to reflect the individual's learning style (e.g., visual cues, auditory feedback, or tactile stimulation).

Table 2: *VR Rowing Protocol Based on Universal Design for Learning and Pre-Assessment in the Context of the International Classification of Functioning, Disability, and Health (ICF)*

This adaptive process is crucial for fostering a truly inclusive environment, where the experience of engaging in VR rowing can contribute to the development of motor skills, social-emotional learning, and self-esteem. For example, by using the pre-assessment tools outlined in the ICF framework, it is possible to identify specific

challenges that individuals with disabilities may face in participating in sports. Some participants may require assistance with mobility, while others might need sensory adaptations. By incorporating this information into the VR rowing experience—through features like adjustable difficulty, custom audio feedback, or haptic sensations—we can ensure that all individuals, regardless of their physical or cognitive abilities, can actively participate. This pre-assessment not only ensures physical and cognitive adaptations but also facilitates a deeper sense of belonging and engagement, aligning with the UDL's principles of offering multiple means of engagement, representation, and expression. By leveraging both ICF and UDL, VR rowing can serve as a dynamic and powerful tool to enhance physical literacy for individuals with disabilities. In the context of disability and special needs, the concept of the body is complex and often marked by a tension between reality and aspiration. For many, the lived experience of their bodies does not align with societal expectations or personal desires, making it difficult to embrace a sense of physical agency. VR rowing creates an environment where users can "inhabit" their bodies in empowering ways, allowing them to engage with sport and movement without facing the judgment, constraints, or risks that might exist in physical spaces. This technology can thus serve as a space for reconciling with one's body, facilitating a positive and productive engagement that is empowering rather than discouraging. Universal Design for Learning (UDL) principles, which promote flexibility and multiple means of engagement, add a complementary layer to this approach by focusing on how learning—whether of physical, cognitive, or social skills—can be made accessible and adaptable. Within the VR rowing environment, UDL principles are evident in features like adjustable sensory cues, including visual, auditory, and tactile feedback. Such customizations cater to the diverse ways individuals process and respond to stimuli, enhancing both engagement and learning. By supporting physical activity in a way that is fully adaptable to user preferences and needs, VR rowing extends beyond mere exercise to become a genuinely enjoyable and inclusive form of learning. This flexibility supports the development of motor skills, promotes a positive self-image, and encourages an active, engaged relationship with one's own body. Beyond physical benefits, VR rowing environments hold significant promise for psychological and social development, especially for individuals with disabilities who may experience isolation or social exclusion in traditional sports settings. VR technology enables real-time interaction with others, creating opportunities for cooperative and competitive activities within the virtual space. This social component is critical, as it allows users to experience teamwork, camaraderie, and shared accomplishment, which are often lacking in the lives of people with disabilities due to physical and

social barriers. Studies have shown that inclusive virtual environments can help foster a sense of community, build social-emotional skills, and combat the isolation that individuals with disabilities often experience (Covarrubias et al., 2024; Lapierre et al., 2024). Furthermore, Virtual Reality rowing systems can be tailored to support repetitive, purposeful practice, a key aspect of motor learning. In traditional environments, repetition can become monotonous and is often limited by physical fatigue or environmental factors. VR rowing offers a compelling alternative, allowing users to repeat movements and exercises in an engaging, visually rich setting that maintains motivation. This combination of immersion and repetition has been shown to improve both skill acquisition and retention, enabling users to master complex motor skills over time (Pascali & Monacis, 2024). The ability to simulate realistic rowing environments also allows individuals to experience a sense of progress and improvement, fostering resilience and commitment. For individuals with disabilities, this adaptability to pace and intensity helps to mitigate the anxiety that may accompany physical challenges, promoting a more positive and motivating experience. From a rehabilitation perspective, VR rowing also aligns with the ICF's goal of fostering recovery and adaptation to personal goals and environmental challenges. For example, VR rowing can support the development of key motor skills such as coordination, balance, and muscle control, making it an effective tool in the rehabilitation of individuals with physical disabilities. Real-time feedback mechanisms in VR systems allow users and rehabilitation professionals to monitor progress accurately, ensuring that exercises are both effective and safe. Additionally, the immersive quality of VR minimizes the psychological strain often associated with repetitive rehabilitation exercises, offering a novel approach that shifts the focus from medical recovery to engaging personal development. As Afridi and colleagues (2022) have noted, VR rehabilitation programs provide an engaging alternative to conventional methods, enhancing motivation and improving outcomes through physical and cognitive fidelity to real-life movements. For educators and practitioners, the combination of the International Classification of Functioning, Disability, and Health and Universal Design for Learning frameworks in the development of VR rowing systems signals an important shift toward a more inclusive pedagogy. Educators can utilize VR rowing to design adaptive sports education programs that cater to a range of abilities, allowing users to develop not only physical skills but also interpersonal competencies such as communication, cooperation, and emotional resilience. As Covarrubias and others (2024) suggest, the social component of VR sports, combined with its flexibility, enables individuals with disabilities to feel integrated into the group experience, fostering a sense of belonging and mutual respect. Moreover, the use of advanced VR tools, such as

motion-tracking and haptic feedback, provides educators and rehabilitation professionals with new ways to customize experiences based on the specific needs of each participant. This feature is critical for supporting a truly inclusive approach, as it allows each individual to set personal goals, monitor their progress, and engage with activities in a way that is tailored to their capabilities. As highlighted by Clutterbuck et al. (2024), the ability to integrate motion-tracking technologies into VR environments enriches the experience for users, creating a virtual space that closely mirrors real-life interactions and prepares individuals for real-world challenges. In sum, the use of Virtual Reality rowing informed by the International Classification of Functioning, Disability, and Health and Universal Design for Learning demonstrates the transformative potential of inclusive, adaptable technologies in supporting physical literacy for individuals with disabilities. By creating immersive, socially enriching, and skill-building experiences, VR rowing enables users to engage in meaningful physical activity that nurtures both personal development and social connection. This approach empowers individuals to inhabit their bodies in fulfilling, accessible ways, fostering an appreciation for their physical abilities and supporting their integration into broader social and educational contexts. As VR technology continues to evolve, it holds the potential to redefine accessibility in sports and rehabilitation, providing a future where physical and social inclusion are both achievable and celebrated.

Conclusions

This study has examined the potential of Virtual Reality (VR) rowing, framed within the principles of Universal Design for Learning (UDL) and the International Classification of Functioning, Disability, and Health (ICF), to support the inclusion, physical, and cognitive development of individuals with disabilities. A central innovation of this work is the proposed pre-assessment protocol, which facilitates the customization of the VR rowing experience to meet the diverse needs and abilities of participants. By integrating the ICF and UDL frameworks, this protocol offers a holistic approach, considering the functional, cognitive, and environmental factors that influence participation. It ensures that each individual can fully engage with the VR environment in a way that is accessible, motivating, and conducive to personal growth. The use of VR rowing provides a unique opportunity to overcome many of the barriers that people with disabilities often face in physical education and rehabilitation settings. Rowing itself is a physical activity that promotes strength, endurance, and coordination—skills that are critical for improving motor function in individuals with disabilities. VR rowing, however, takes this a step

further by offering these benefits in a controlled, safe, and inclusive environment. The ability to adapt the intensity and difficulty of the exercises ensures that users can experience these benefits at their own pace, making the activity more accessible while also providing a sense of achievement. The pre-assessment protocol proposed here is a key innovation. By assessing an individual's physical functioning, cognitive abilities, and social participation, it creates a personalized framework for engaging in VR rowing. This assessment ensures that each user's experience is aligned with their unique needs, preferences, and goals, helping to optimize both engagement and outcomes. More than just a tool for inclusion, the protocol fosters motivation and continued participation, critical factors for the long-term success of physical activity programs. The integration of the UDL framework into this protocol is particularly significant. UDL emphasizes multiple means of engagement, representation, and expression, offering various ways for individuals with disabilities to interact with the VR rowing system. Whether through gesture control, voice commands, or visual cues, the system adapts to the user's strengths and preferences, ensuring that all participants, regardless of their abilities, can engage meaningfully. The flexible, adaptable nature of the protocol means that each person's experience is not just accessible, but tailored to their specific needs, fostering a deeper sense of engagement and achievement. The combination of VR rowing and the pre-assessment protocol offers a real opportunity for transformative change. It moves beyond just offering a new technology for rehabilitation; it promotes a more inclusive and equitable model of physical activity and education for people with disabilities. By focusing on physical literacy, social participation, and individualized support, this approach can redefine how we view and interact with disability in physical contexts. It also demonstrates the power of emerging technologies in bridging gaps, promoting social inclusion, and helping individuals with disabilities feel a sense of belonging. The importance of pre-assessment in this process cannot be overstated. As outlined by the ICF framework, understanding a person's functional abilities and the environmental factors that may influence their participation is essential for optimizing outcomes. The pre-assessment identifies not only the individual's strengths but also potential barriers to participation, setting the stage for a tailored VR experience that can be adjusted over time as the individual progresses. This dynamic, individualized approach is central to the principles of disability inclusion and rehabilitation.

In conclusion, VR rowing, combined with a robust pre-assessment protocol grounded in UDL and ICF, represents a promising and innovative approach to promoting inclusion and enhancing the physical and cognitive development of people with disabilities. This method offers an accessible and adaptable way for

individuals to engage in physical activity, fostering not only physical well-being but also social connection and personal growth. As we look to the future, the pre-assessment protocol proposed in this study provides a valuable model for developing more inclusive and effective physical education and rehabilitation programs. By integrating these frameworks into the design and implementation of VR rowing, we move toward more equitable and inclusive sports experiences. The proposed ICF pre-assessment and UDL-based VR rowing protocol provide a practical model for educators, therapists, and rehabilitation professionals, enhancing the accessibility and effectiveness of VR interventions in disability sports. Through these thoughtful adaptations, VR rowing can significantly contribute to the development of physical, cognitive, and social skills, promoting a more inclusive approach to physical activity for all.

References

Accardo, A. L., Ferguson, S. L., Alharbi, H. M., Kalliny, M. K., Woodfield, C. L., & Vernon-Dotson, L. J. (2023). Unified Sports, social inclusion, and athlete-reported experiences: A systematic mixed studies review. *Inclusion*, 11(1), 23-39.

Afridi, A., Nawaz, A. N., Tariq, H., & Rathore, F. A. (2022). The emerging role of virtual reality training in rehabilitation. *Journal of the Pakistan Medical Association*, 72(1), 188-191.

Aitchison, B., Rushton, A. B., Martin, P., Barr, M., Soundy, A., & Heneghan, N. R. (2022). The experiences and perceived health benefits of individuals with a disability participating in sport: A systematic review and narrative synthesis. *Disability and Health Journal*, 15(1), 101164.

Alcaraz-Rodríguez, V., Medina-Rebollo, D., Muñoz-Llerena, A., & Fernández-Gavira, J. (2021). Influence of physical activity and sport on the inclusion of people with visual impairment: A systematic review. *International Journal of Environmental Research and Public Health*, 19(1), 443.

Asare, F. (2024). *Disability and assistive technology advancements in disability sport: Understanding the embodied experiences of disabled athletes* (Doctoral dissertation, The University of Waikato).

Asunta, P., Hasanen, E., Kiuppis, F., Rintala, P., & McConkey, R. (2022). 'Life is team play': Social inclusion of people with intellectual disabilities in the context of Special

Olympics. *Sport in Society*, 25(10), 2146-2161. https://doi.org/10.1080/17430437.2022.2037565

Carbone, P. S., Smith, P. J., Lewis, C., & LeBlanc, C. (2021). Promoting the participation of children and adolescents with disabilities in sports, recreation, and physical activity. *Pediatrics*, 148(6).

Clutterbuck, G. L., de Sousa Junior, R. R., Leite, H. R., & Johnston, L. M. (2024). The SPORTS participation framework: Illuminating the pathway for people with disability to enter into, participate in, and excel at sport. *Brazilian Journal of Physical Therapy*, 101081.

Costa, M. T. S., Vieira, L. P., de Oliveira Barbosa, E., Oliveira, L. M., Maillot, P., Vaghetti, C. A. O., ... & Monteiro-Junior, R. S. (2019). Virtual reality-based exercise with exergames as medicine in different contexts: A short review. *Clinical Practice and Epidemiology in Mental Health*, 15, 15-20.

Covarrubias, M., Singh, P., Marrone, F., Bertozzi, F., Tarabini, M., & Galli, M. (2024, July). Enhancing inclusive sport participation for students with special needs through VR and rowing simulator. In *2024 IEEE International Workshop on Sport, Technology and Research (STAR)* (pp. 38-43). IEEE.

Di Maglie, A. (2019, February). Lo sport per valorizzare le differenze come risorse. In *La differenza come risorsa. Atti del Workshop 2018* (pp. 149-170).

Goh, C. L. (2020). To what extent does the Paralympic Games promote the integration of disabled persons into society? *The International Sports Law Journal*, 20(1), 36-54.

Howard, M. C. (2017). A meta-analysis and systematic literature review of virtual reality rehabilitation programs. *Computers in Human Behavior*, 70, 317-327.

Jin, C., Feng, Y., Ni, Y., & Shan, Z. (2018). Virtual reality intervention in postoperative rehabilitation after total knee arthroplasty: A prospective and randomized controlled clinical trial. *International Journal of Clinical and Experimental Medicine*, 11(6), 6119-6124.

Kang, S., & Kang, S. (2019). The study on the application of virtual reality in adapted physical education. *Cluster Computing*, 22, 2351-2355.

Karaosmanoglu, S., Cmentowski, S., Nacke, L. E., & Steinicke, F. (2024). Born to Run, Programmed to Play: Mapping the Extended Reality Exergames Landscape.

In *Proceedings of the CHI Conference on Human Factors in Computing Systems* (pp. 1-28).

Lapierre, N., Huet-Fiola, C., Labrie, D., Vincent-Blouin, E., Côté, C., Gagnon, M., ... & Routhier, F. (2024). Digital platforms to facilitate physical activities for people with physical or sensory disabilities: A scoping review. *Disability and Health Journal*, 101626.

Li, X., Wu, Z., & Han, T. (2019). Gamification-Based VR Rowing Simulation System (Vol. 1, Issue 2018, pp. 484–493).

McConkey, R., & Menke, S. (2020). The community inclusion of athletes with intellectual disability: A transnational study of the impact of participating in Special Olympics. *Sport in Society*, 25(9), 1756–1765. https://doi.org/10.1080/17430437.2020.1807515

Monacis, D., & Colella, D. (2019). Il contributo delle tecnologie per l'apprendimento e lo sviluppo di competenze motorie in età evolutiva. *Italian Journal of Educational Research*, (22), 31-52.

Monacis, D., & Colella, D. (2020). Technologies in physical education: Pedagogical and didactical implications. *Italian Journal of Health Education, Sport and Inclusive Didactics*, 4(4_sup).

Monacis, D., Annoscia, S., & Pascali, G. (2024). Physical literacy and non-linear pedagogy: How can technologies enhance motor learning? *Italian Journal of Health Education, Sport and Inclusive Didactics*, 8(3).

Monacis, D., & Colella, D. (2022). Physical literacy: Definition and didactic-methodological approaches. Towards an Italian model? *Italian Journal of Health Education, Sport and Inclusive Didactics*, 6(1_sup).

OECD (2023), *Equity and Inclusion in Education: Finding Strength through Diversity*. OECD Publishing, Paris. https://doi.org/10.1787/e9072e21-en.

Pascali, G., & Monacis, D. (2024). Metodi di valutazione della physical literacy nella scuola primaria. Review della letteratura. *IUL Research*, 5(9), 311-330.

Putranto, J. S., Heriyanto, J., Achmad, S., & Kurniawan, A. (2023). Implementation of virtual reality technology for sports education and training: Systematic literature review. *Procedia Computer Science*, 216, 293-300.

Romano, A. (2023). Beyond barriers: Innovative strategies for the inclusion of students with special educational needs in school sports activities. *Italian Journal of Health Education, Sport and Inclusive Didactics*, 7(4). https://doi.org/10.32043/gsd.v7i4.1026

Scarinci, A., Toto, G. A., Lombardi, D., & Di Furia, M. (2022). Inclusive education models applied to physical education and adapted physical activity. *Italian Journal of Health Education, Sport and Inclusive Didactics*, 6(1_sup). https://doi.org/10.32043/gsd.v6i1s.477

Shoib, N. A., Sunar, M. S., Nor, N. N. M., Azman, A., Jamaludin, M. N., & Latip, H. F. M. (2020, December). Rowing simulation using rower machine in virtual reality. In *2020 6th International Conference on Interactive Digital Media (ICIDM)* (pp. 1-6). IEEE.

Spratt, E., Mercer, M. A., Grimes, A., Papa, C., Norton, J., Serpe, A., ... & Newton, J. (2018). Translating benefits of exercise on depression for youth with autism spectrum disorder and neurodevelopmental disorders. *Journal of Psychology and Psychiatry*, 2.

Van Delden, R., Bergsma, S., Vogel, K., Postma, D., Klaassen, R., & Reidsma, D. (2020). VR4VRT: Virtual reality for virtual rowing training. In *Extended Abstracts of the 2020 Annual Symposium on Computer-Human Interaction in Play*(pp. 388-392).

Zengaro, F., & Zengaro, S. A. (2025). Inclusive physical literacy for all: Innovating teaching strategies to embrace diverse abilities. In *Global Innovations in Physical Education and Health* (pp. 473-490). IGI Global.

Zhao, Y., Feng, H., Wu, X., Du, Y., Yang, X., Hu, M., ... & Zhao, Y. (2020). Effectiveness of exergaming in improving cognitive and physical function in people with mild cognitive impairment or dementia: Systematic review. *JMIR Serious Games*, 8(2), e1684