



# Virtual reality to promote road safety in older adults: Evaluation of a training-based preventive approach

## Virtuelle Realität zur Förderung der Verkehrssicherheit bei älteren Erwachsenen: Evaluation eines trainingsbasierten präventiven Ansatzes

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### Abstract

Background: Demographic change is increasing the proportion of older individuals in society, which also heightens the risk of accidents, particularly in road traffic. Virtual reality (VR) applications offer innovative opportunities to promote mobility, safety, and accident prevention among older adults through engaging and safe training environments.

Objective: This study examined the effects of a VR-based training program (Wegfest) on functional mobility, subjective safety, and accident prevention in older adults. It also explored connections to the digital transformation in health professions education and practice.

Methods: In a VR intervention study, older adults completed eight training sessions in a simulated traffic environment. Assessments included the Timed Up and Go Test (mobility), the Falls Efficacy Scale – International (FES-I), the Montreal Cognitive Assessment (MoCA), subjective sense of safety, and the number of collisions in the VR setting. Pre-post comparisons were analyzed using Wilcoxon signed-rank tests.

Results: The training led to significant improvements in mobility ( $p = .002$ ;  $d = 0.784$ ) and a reduction in fear of falling ( $p = .005$ ). Subjective safety increased significantly ( $p < .001$ ), while collision frequency decreased ( $p < .001$ ). Cognitive performance remained stable ( $p = .56$ ). These results indicate that VR training can enhance both objective and subjective aspects of accident prevention.

Conclusion: VR-based training represents a promising tool to support mobility and safety in older adults. In the context of digital transformation, programs like Wegfest offer valuable potential for patient-centered care and professional training, while also fostering digital literacy among healthcare professionals and older users.

### Abstract

Hintergrund: Der demografische Wandel führt zu einem steigenden Anteil älterer Menschen in der Gesellschaft und damit zu einem erhöhten Unfallrisiko, insbesondere im Straßenverkehr. Virtual-Reality-(VR)-Anwendungen bieten innovative Möglichkeiten, Mobilität, Sicherheit und Unfallprävention im Alter durch sicheres und motivierendes Training zu fördern.

Ziel: Diese Studie untersuchte die Auswirkungen eines VR-basierten Trainingsprogramms (Wegfest) auf funktionale Mobilität, subjektives Sicherheitsgefühl und Unfallvermeidung bei älteren Erwachsenen. Zudem wurden Bezüge zur digitalen Transformation in Ausbildung und Praxis der Gesundheitsberufe betrachtet.

Methode: Im Rahmen einer Interventionsstudie absolvierten ältere Teilnehmende acht Trainingseinheiten in einer VR-Umgebung mit Alltagssituationen im Straßenverkehr. Erfasst wurden Mobilität (Timed Up and Go Test), Sturzangst (FES-I), kognitive Leistung (MoCA), subjektives Sicherheitsgefühl sowie die Anzahl an Kollisionen. Für die Auswertung kamen Wilcoxon-Rangsummentests zum Einsatz.

Ergebnisse: Es zeigten sich signifikante Verbesserungen der Mobilität ( $p = .002$ ;  $d = 0.784$ ) sowie eine Reduktion der Sturzangst ( $p = .005$ ). Das subjektive Sicherheitsgefühl stieg deutlich an ( $p < .001$ ), während die Anzahl der Kollisionen signifikant sank ( $p < .001$ ). Die kognitive Leistung blieb unverändert ( $p = .56$ ). Die Ergebnisse sprechen dafür, dass VR-Training sowohl objektive als auch subjektive Aspekte der Unfallprävention verbessert.

Schlussfolgerung: VR-basiertes Training stellt ein vielversprechendes Instrument zur Förderung von Mobilität und Sicherheit im Alter dar. Vor dem Hintergrund der digitalen Transformation kann Wegfest einen Beitrag zur patientenzentrierten Versorgung, zur Ausbildung von Gesundheitsfachpersonen und zur Förderung digitaler Gesundheitskompetenz leisten.

### Keywords

Virtual Reality – Older Adults – Accident Prevention – Mobility Promotion – Digital Transformation

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Virtuelle Realität – Ältere Menschen – Unfallverhütung – Mobilitätsförderung – Digitale Transformation



## INTRODUCTION

In light of demographic change and continuously rising life expectancy, the promotion of health and the prevention of disease in older age is gaining increasing importance (Gellert et al., 2024). As the number of individuals over the age of 65 increases globally, mobility, autonomy, and social participation become central components of healthy and self-determined aging (Weidner & Wittrahm, 2020). In particular, mobility functions as a key resource for participation, self-care, and quality of life in later life. Limitations in mobility often lead to social isolation, loss of independence, and a higher risk of secondary diseases (Trauzettel, 2021).

At the same time, it is well known that the risk of falls, accidents, and injuries in public spaces rises significantly with age (RKI, 2024). Street crossing, in particular, represents a highly complex everyday task requiring the coordinated interplay of motor skills (e.g., balance, gait), cognitive processes (e.g., attention, reaction time, decision-making), and sensory functions (especially visual and auditory perception) (Zito et al., 2015; Dommes et al., 2014). Epidemiological data confirm that adults aged 65 and older are disproportionately involved in traffic accidents. According to the German Federal Statistical Office, around 29% of all road traffic fatalities in 2023 were from this age group—an alarming figure, particularly considering the increased risk of severe injury outcomes due to reduced physical resilience (Destatis, 2025).

The ability to cross streets safely is hindered by a range of age-associated changes. Common contributing factors include slower reaction times, reduced walking speed, impaired depth perception, and visual decline (Dommes et al., 2014; Granacher et al., 2010). In addition, cognitive challenges such as the simultaneous processing of multiple stimuli or the accurate estimation of distances and speeds in moving traffic add to the difficulty (Zito et al., 2015). Together, these factors compound to form a significant risk of accidents—particularly in urban areas with high traffic density and complex road layouts (Cabrera-Arnau, 2020; Yu, 2020).

Given this problem, innovative technology-assisted approaches to health prevention are becoming increasingly relevant (Trauzettel, 2021). In the context of digital transformation, new opportunities are emerging to design preventive interventions that are tailored to specific target groups, closely related to everyday life, and highly interactive. One key technology in this domain is virtual reality (VR). VR enables realistic and risk-free simulation of complex everyday scenarios—such as safely crossing a street—within immersive digital environments (Napetschnig, 2024). Users can respond to situation-specific challenges, test alternative actions, and train safety-relevant skills (Appel et al., 2020).

The use of VR for preventive purposes in gerontology offers several advantages. First, it provides a safe training environment that enables realistic behavior under controlled conditions (Appel et al., 2020). Second, the modular design of VR applications allows for individual adaptation to users' performance levels—for example, by varying traffic density, lighting conditions, or acoustic stimuli (Napetschnig, 2024). The high degree of interactivity and immersion also boosts motivation to participate—often a critical factor in traditional preventive programs (Wienrich et al., 2021; Appel et al., 2020).

Against this background, the present study aims to empirically investigate the effectiveness of a VR-based training program designed to support safe street crossing in older adults. The focus is on the application “Wegfest,” which was developed in a realistic and adaptive VR environment to specifically address both functional and subjective aspects of safety. The study aims to determine whether repeated VR-based exposure to complex traffic situations can lead to measurable improvements in mobility behavior as well as in perceived safety.

## THEORETICAL BACKGROUND

Virtual reality (VR) applications have emerged as a promising and innovative approach in geriatric practice for addressing age-related functional impairments in a preventive manner (Napetschnig, 2024). They are particularly used to promote physical activity, provide cognitive training, alleviate pain, and support psychosocial resources. In virtual training environments, older adults can safely and repeatedly practice movement patterns without the risk of physical strain or injury (Appel et al., 2020). Moreover, VR-based programs enable situation-specific confrontation with real-life challenges—such as navigating complex environments, reacting to traffic conditions, or coping with anxiety-inducing situations (Fuchs et al., 2025; Buchwitz et al., 2024; Paletta et al., 2024).

A specific subtype of these applications is the “serious game,” which integrates didactic objectives and employs game mechanics to promote skill acquisition, motivation, and behavioral change (DeSmet et al., 2018). Unlike games designed solely for entertainment, serious games are intended to support targeted learning processes—for example, through exergames for physical activation or memory games to enhance cognitive functions (Fuchs et al., 2025; Trauzettel, 2021). Research indicates that this combination of interactivity, goal orientation, and immersive environments fosters enjoyment of learning and therapy adherence, particularly among older users. Additionally, they can reduce emotional barriers to technology use by providing positive experiences and immediate feedback (Trauzettel, 2021).



The immersive nature of VR—defined as full sensory immersion in a computer-generated environment—plays a central role in its effectiveness (Carroll et al., 2023). Through multisensory stimuli such as visual motion sequences, spatial audio, and natural interaction patterns (e.g., hand tracking or voice control), a strong sense of presence is created (Carroll et al., 2023). According to recent theoretical models such as the Cognitive-Affective Model of Immersive Learning (CAMIL), this presence fosters not only cognitive processing of learning content but also emotional involvement and motivation (Makransky & Petersen, 2021). This is particularly important in older age, where learning processes are more influenced by emotional relevance and real-life applicability (Parong & Mayer, 2021).

Empirical evidence supports the positive effects of VR interventions on multiple dimensions of health in older adults. Studies have shown significant improvements in balance, gait, cognitive processing speed, and fall-related self-efficacy following repeated use of VR-based training programs (Carroll et al., 2023; Donath et al., 2016; Benham et al., 2019; Szczepocka et al., 2024). Additionally, reductions in perceived stress or chronic pain have been documented through virtual nature environments or mindfulness training in VR. Such interventions also increase confidence in one's own abilities, which is associated with higher levels of life satisfaction and autonomy in old age (Napetschnig, 2024).

The growing body of evidence and the technological maturity of VR-supported applications argue for their targeted integration into prevention, rehabilitation, and professional education for both older adults and healthcare workers. This article contributes to that discourse by examining the effectiveness of a specifically developed VR application ("Wegfest") aimed at promoting safety-related competencies in road traffic among older adults. The goal is to enhance not only functional skills but also subjective perceptions of safety through immersive and repeatable training conditions.

## DEVELOPMENT AND IMPLEMENTATION OF THE VR APPLICATION "WEGFEST"

### Concept and technological implementation

This article expands on the findings from Napetschnig's (2024) dissertation and provides a concise overview and new insights into the development and pilot testing of the VR application "Wegfest" for a broader professional audience. The VR application "Wegfest" was developed through an interdisciplinary process aimed at providing older adults with a realistic, safe, and adaptive training

environment specifically tailored to the demands of everyday road traffic. This interdisciplinary process actively involved software developers, gerontology experts, and healthcare professionals (e.g., physiotherapists) from the outset. Regular feedback loops with these experts and iterative testing with older adults ensured that the application met both technical requirements and user-specific needs, focusing on usability, accessibility, and relevance to everyday challenges. The central focus was the promotion of safety-relevant competencies related to street crossing—a task that, due to motor, sensory, and cognitive changes in aging, is often associated with uncertainty and an increased risk of injury (Napetschnig, 2024; Dommes et al., 2014).

Technologically, "Wegfest" is based on the Unity engine, a powerful platform for developing interactive 3D environments. The application was optimized for use with the "Meta Quest 2" head-mounted display (HMD), allowing wireless and untethered movement. Interaction within the virtual environment is facilitated through two main components: physical walking in a controlled real-world space and intuitive control via hand-tracking technology. The latter allows for natural, gesture-based interaction without the need for handheld controllers, offering a low-threshold access point especially for older adults with limited technology experience.

The traffic scenarios presented in the application were modeled based on real street environments in German cities. Various parameters were considered, including lane width, traffic volume, vehicle types (e.g., cars, e-scooters, bicycles), lighting conditions (daytime, dusk, night), acoustic cues, and infrastructure elements such as traffic lights, crosswalks, and pedestrian islands.

*Figure 1* and *Figure 2* shows two examples of different street scenes from "Wegfest".

These variables allow for the gradual adjustment of scenario complexity and stimulus density. The integrated difficulty management enables systematic progression of training demands across sessions, thereby supporting incremental skill development.

The development of "Wegfest" followed an iterative, user-centered design approach. From early stages, older adults were involved through pretests and feedback sessions. This allowed continuous optimization of usability, navigation, and interaction design. Particular attention was paid to aspects such as tolerability (e.g., minimization of motion sickness), clarity of instructions, and emotional acceptance of the virtual scenes. An integrated tutorial at the beginning of the application introduces users to the VR system and familiarizes them with basic movement and interaction patterns, ensuring that all participants meet the prerequisites to safely engage in the training.



Figure 1: Screenshot of a daytime street scene with a white circular target marker (own depiction)



Figure 2: Screenshot of a nighttime street scene with an e-scooter and a cyclist (own depiction)

## Integration into prevention and education

The VR application “Wegfest” was primarily developed for preventive health interventions targeting older adults, but it also holds significant potential as a tool for the training and education of healthcare professionals. In primary prevention, the VR training addresses key risk factors associated with age-related insecurity and vulnerability in public spaces. Through realistic simulations of hazardous situations, older adults can specifically train perception, reaction capability, and

movement planning—critical aspects for accident prevention and maintaining everyday mobility.

The virtual training allows for repeated, safe, and anxiety-free engagement with potentially threatening traffic scenarios. Studies show that such exposure training in VR significantly reduces anxiety responses and enhances confidence in one’s abilities (Cheng et al., 2025; Carl et al., 2019). In older age, where fear often leads to withdrawal and avoidance of movement, this can contribute significantly to quality of life and independence.

## STUDY DESIGN AND METHODOLOGY

To scientifically evaluate the effectiveness of the virtual reality application “Wegfest,” an exploratory intervention study was conducted with older adults using a pre–post design. The primary aim was to analyze both objective and subjective effects of the VR training on traffic safety, mobility, and participants’ perceived sense of safety. The study was designed as a pilot project and carried out at multiple locations in North Rhine-Westphalia, including a physiotherapy practice and a church community. Participants were recruited through information material and personal contact in a physiotherapy practice in Düsseldorf. Eligibility required individuals aged 70 or older, living independently and physically fit, while those with health conditions or impairments likely to interfere with VR use or compromise safety were excluded. The study was approved by the ethics committee of the German Sport University Cologne (No. 095/2022).

The initial sample comprised 29 participants aged 71–81 years ( $M = 74.95$ ,  $SD = 3.17$ ). After applying the predefined criteria (e.g., significant cognitive impairment, high fall risk, severe visual impairment) and accounting for a dropout rate of 31.03% due to incomplete participation (fewer than six of eight sessions), the final analysis included 20 participants.

The intervention comprised a total of eight training sessions over four weeks, with each session lasting approximately 20 to 30 minutes. The frequency of two sessions per week was chosen in accordance with the American College of Sports Medicine (ACSM, 2006) to ensure adequate recovery periods.

Each training session included seven individually configured virtual street scenarios that progressively increased in complexity (e.g., traffic density, lighting conditions, road types; cf. Napetschnig, 2024). The application was delivered through a head-mounted display (Meta Quest 2), and participants interacted with the VR environment through actual walking and gesture-based hand tracking. During the study, qualitative observations and informal feedback from participants regarding their



engagement and satisfaction with the VR system were continuously collected by the supervising staff.

To assess the intervention's effects, the following standardized instruments—established in geriatric research—were used:

- Functional mobility was measured using the Timed Up and Go Test (TUG), a validated tool for assessing everyday mobility and fall risk in older adults. Completion times under 20 seconds are considered indicative of age-appropriate mobility (Podsiadlo & Richardson, 1991).
- Fear of falling was assessed with the German version of the Falls Efficacy Scale – International (FES-I). This scale measures participants' perceived risk of falling during everyday activities and is a reliable indicator of fall-related self-efficacy (Cronbach's  $\alpha = 0.96$ ; Dias et al., 2006).
- Subjective sense of safety was directly assessed within the VR environment. After each scene, participants rated how safe they felt while crossing the virtual street using an integrated four-point response scale (1 = very unsafe to 4 = very safe). These VR-based safety ratings were collected and analyzed across two measurement points (first vs. eighth session).
- Cognitive performance was evaluated using the Montreal Cognitive Assessment (MoCA), an internationally recognized screening tool for assessing cognitive functions such as attention, memory, executive functioning, and visuospatial ability. A score of  $\geq 26$  points indicates unimpaired cognitive functioning.
- Collision events, defined as actual or near-virtual accidents, were automatically recorded by the application and served as an objective indicator of risk-related behavior. The total number of collisions per session was analyzed quantitatively to assess training effects.

### Data collection and analysis

All standardized measurements (Timed Up and Go Test [TUG], Falls Efficacy Scale – International [FES-I], Montreal Cognitive Assessment [MoCA]) were collected at two measurement points: immediately before the start of the first VR training session (baseline) and immediately after completion of the eighth/last VR training session (post).

The Subjective Sense of Safety was recorded within the VR application after each scene using a response system integrated into the system (four-point scale: 1 = very unsafe to 4 = very safe). For the group statistical analysis, the ratings from the first session (first complete runs within the application; baseline VR assessment) were compared with the aggregated ratings from the eighth session (post assessment).

The number of collisions (actual collisions and near misses within the virtual scenes) was automatically logged by the system. The total number of collisions in the first complete run (baseline) and the total number of collisions in the eighth session (post) were used as comparison values.

In total, each participant completed eight sessions over four weeks (two sessions per week). Each session contained seven configured road scenarios. The baseline measurement was taken before or during the first complete run; the post measurement was taken after the eighth session.

Statistical analysis was conducted using IBM SPSS Statistics (version 22) for Windows. Due to the small sample size and the predominantly non-normally distributed data, non-parametric tests were primarily employed. Changes between pre- and post-intervention were analyzed using the Wilcoxon signed-rank test for dependent samples. For normally distributed variables (e.g., TUG), paired-sample *t*-tests were also used. The alpha level for significance was set at  $\alpha = .05$  for all tests. Effect sizes were reported using Cohen's *d* (for *t*-tests) or *z*-values and *p*-values (for Wilcoxon tests).

This methodological approach enabled a nuanced evaluation of both quantitative performance metrics and subjective perceptions of safety and allowed for conclusions regarding the effectiveness of “Wegfest” as a VR intervention for mobility enhancement in older adults.

## RESULTS

### Functional and subjective effects

As part of the intervention study, the effects of the VR training “Wegfest” on participants' mobility, fear of falling, cognitive performance, and perceived safety were examined.

- Timed up and go test: Participants' mobility improved significantly following the VR training. The time required to complete the Timed Up and Go Test decreased significantly after the intervention,  $t(19) = 3.50$ ,  $p = .002$ ,  $d = 0.78$ , indicating enhanced functional mobility.
- Fear of falling (FES-I): Scores on the Falls Efficacy Scale – International (FES-I) showed a significant reduction in fear of falling,  $T = 4$ ,  $z = -2.82$ ,  $p = .005$ . Following the intervention, participants reported greater confidence and fewer concerns about potential falls in daily life.
- Subjective sense of safety (VR): The VR-integrated assessment revealed a significant increase in perceived safety when crossing virtual streets,  $T = 5134$ ,  $z =$



Table 1: Functional and subjective effects of VR training

| Parameter                       | Time Point   | Mean (SD)                 | Test Statistic         | Significance |
|---------------------------------|--------------|---------------------------|------------------------|--------------|
| Timed Up and Go Test (TUG)      | Pre vs. Post | 12.3 (2.1) vs. 10.8 (1.9) | $t=3.50$<br>$d = 0.78$ | $p = .002$   |
| Fear of Falling (FES-I)         | Pre vs. Post | 22.1 (3.4) vs. 19.8 (3.0) | $z = -2.82$            | $p = .005$   |
| Cognitive Performance (MoCA)    | Pre vs. Post | 25.2 (2.8) vs. 25.5 (2.7) | $z = 0.58$             | $p = .56$    |
| Subjective Safety (total score) | Pre vs. Post | 18.5 (4.2) vs. 23.7 (3.9) | $z = 7.16$             | $p < .001$   |

7.16,  $p < .001$ . Mean ratings on the four-point scale improved from the first to the final session, suggesting an enhanced sense of security within the simulated environment.

- Cognitive performance (MoCA): No significant changes were observed in cognitive performance, as measured by the Montreal Cognitive Assessment (MoCA),  $T = 18$ ,  $z = 0.58$ ,  $p = .56$ , indicating that the training did not produce measurable differences in overall cognitive function across the two time points.

The results for both functional and subjective parameters are summarized in Table 1.

### Analysis of collisions (hazardous situations/accidents)

Prior to statistical analysis, the distribution of collision data was tested for normality. The null hypothesis ( $H_0$ : the population's collision data are normally distributed) was rejected for both measurement points, indicating non-normal distribution. Therefore, the Wilcoxon signed-rank test was used for analysis.

Descriptive statistics indicated a clear reduction in the number of collisions over the course of the training. The Wilcoxon test revealed a highly significant difference between the two time points ( $z = -3.373$ ,  $p < .001$ ). The negative  $z$ -score indicates that the number of collisions was significantly lower after the training than before. Participants caused significantly fewer hazardous situations and virtual accidents following the eight training sessions.

## DISCUSSION

### “Wegfest” training outcomes

The results of this study demonstrate that VR-based training applications such as “Wegfest” can significantly contribute to improving mobility, strengthening subjective feelings of safety, and preventing falls among older adults. The improvements observed in the Timed Up and Go Test ( $p = .002$ ,  $d = 0.78$ ) indicate that the VR training

enhanced not only mental but also motor abilities. The significant reduction in fear of falling (FES-I,  $p = .005$ ) is especially noteworthy, as fear of falling often leads to avoidance behavior, which in turn further limits mobility. The significant increase in perceived safety during street crossing ( $p < .001$ ,  $z = 7.16$ ) is considered an important predictor of independence and quality of life in older age. Participants reported feeling more secure and confident after the training—an effect that could potentially transfer to real-life situations.

The objective reduction in collisions ( $p < .001$ ,  $z = -3.37$ ) underscores that the training improved not only subjective perceptions but also actual behavior in hazardous scenarios. These findings indicate an immediate training effect and increased competence in dealing with complex traffic situations immediately after completion of the program. Statements about the persistence of these effects over longer periods of time cannot be made based on the available short-term measurements and require follow-up measurements. The significant decrease in hazardous situations and virtual collisions points to a learning effect that may also be transferable to real-world traffic environments. Enhanced subjective safety, in turn, is a crucial predictor of maintained mobility and autonomy in older age, helping reduce the risk of social isolation and physical inactivity.

### Interdisciplinary development and user involvement in digital health applications

The development of digital prevention applications requires an interdisciplinary approach that integrates expertise from health sciences, technology design, and user experience research. Collaboration between software developers, healthcare professionals, and target users ensures that digital tools are evidence-based, user-oriented, and applicable in everyday contexts (Pfannstiel, 2024; Lie et al., 2022). Iterative user involvement during design and testing supports usability optimization and ecological validity, particularly when adapting interfaces and interaction methods to the needs of older adults (Nauerth et al., 2023).

Interdisciplinary development processes, however, are not without challenges. Differences in professional



language, methodological priorities, and project goals may complicate communication and coordination among disciplines. Balancing technological innovation with pedagogical and health-related objectives therefore requires structured dialogue, mutual understanding, and iterative adjustment. Effective digital prevention tools can emerge only when these diverse perspectives are systematically integrated into the design process (Mühling et al., 2023; Nauerth et al., 2023).

### **Benefits of VR and digital tools for patients and prevention**

Virtual reality and related digital tools provide new opportunities for prevention and health promotion, especially for older adults. VR enables users to engage in realistic yet risk-free training of critical everyday situations such as balance control or street crossing. Evidence indicates that VR-based serious games and exergames can enhance both cognitive and motor performance (Anderson-Hanley et al., 2012; Kustanovich et al., 2023). The immersive and interactive nature of VR fosters user motivation and adherence, supporting sustained participation in preventive programs.

Digital prevention tools can also mitigate inequalities in healthcare access. Remote delivery and telehealth formats enable participation in training and prevention programs regardless of location, which is particularly relevant for individuals in rural or underserved regions (Kyaw et al., 2019; Pfannstiel, 2024). Moreover, digital applications contribute to the development of digital health literacy by familiarizing older adults with technology and promoting self-efficacy in health management (Lie et al., 2022).

By providing controlled, repeatable scenarios, VR training can also strengthen users' confidence in their physical abilities and personal safety—factors crucial for maintaining autonomy and quality of life in later years. Consequently, digital prevention tools combine functional, psychological, and social benefits and support active aging within an increasingly digital healthcare environment (Pfannstiel, 2024).

### **Implications for health professionals: education, competence, and practice**

The integration of VR and other digital technologies into education and practice represents a central element of the digital transformation in healthcare (Pfannstiel, 2024). In professional education, simulation-based learning enables the safe and realistic exploration of complex clinical and preventive scenarios (Mühling et al., 2023; Lie et al., 2022). This approach promotes experiential and reflective learning while reducing risks to real patients.

VR-based education also contributes to the development of digital competencies, which are essential for future healthcare professionals (Nauerth et al., 2023). Through interactive simulations, learners can analyze safety-critical situations, test preventive interventions, and refine communication and ethical decision-making skills (Mühling et al., 2023).

In professional practice, digital competence has become a prerequisite for effective patient care. Health professionals must be able to assess, implement, and critically evaluate digital tools such as VR applications, telehealth systems, and sensor-based feedback technologies (Pfannstiel, 2024; Schwarz, 2023). Familiarity with these technologies supports evidence-based, patient-centered prevention and fosters reflective engagement with the potentials and limitations of technology-supported care.

Overall, the inclusion of VR and similar tools in health education and practice strengthens digital readiness across the workforce and contributes to the sustainable advancement of prevention and healthcare delivery (Lie et al., 2022; Pfannstiel, 2024).

### **Limitations**

Despite the promising results, several limitations must be acknowledged:

- Sample size and study design: The study is based on a small sample size and employed a pre–post design without a control group, limiting the generalizability and causal interpretation of the findings.
- Short-term effects: Effects were measured immediately following the intervention. Whether and to what extent the training effects persist over the long term and transfer to real-world scenarios remains unclear.
- Self-selection and motivation: Participants may have been highly self-motivated or technology-inclined, which could have positively influenced acceptance and effectiveness.
- Technical requirements: Using VR requires a certain level of openness and physical ability. Individuals with significant balance or vision impairments may be excluded. Additionally, some users may experience discomfort such as motion sickness.
- Subjective assessments: The measurement of perceived safety relied on self-reports, which could be influenced by social desirability or placebo effects.

These limitations should be considered when interpreting the results. Future studies should include larger and more diverse samples, use control groups, extend observation periods, and examine the real-world transferability of the training more systematically.



## OUTLOOK AND PRACTICAL IMPLICATIONS

The integration of VR applications such as “Wegfest” into prevention programs for older adults offers diverse opportunities and perspectives for healthcare:

- Promotion of physical activity and accident prevention: VR-based training provides a motivating and safe environment in which older individuals can practice realistic hazardous situations without risk. This can make a significant contribution to reducing falls and accidents.
- Enhancement of digital competencies: The use of digital technologies fosters media literacy among both healthcare professionals and patients, supporting the digital transformation in healthcare. The willingness to adopt new technologies is strengthened and can extend to other areas of life.
- Potential for telemedicine and remote care: VR applications could prospectively be employed within telemedicine frameworks to offer training and preventive measures flexibly and independent of location—particularly for individuals with limited mobility or those living in rural areas.
- Expansion of educational curricula: The incorporation of practice-oriented, technology-supported learning formats into healthcare education can sustainably improve the quality of prevention and rehabilitation work. VR simulations enable safe training of complex situations and thus strengthen action competence.

In light of the digital transformation in healthcare, technologies such as virtual reality should be established not merely as supplementary tools but as integral components of education and practice. VR offers the possibility to train fundamental nursing tasks—such as mobilization and movement promotion—in a realistic, safe, and adaptive manner. This allows healthcare professionals to gain practical experience, reflect on movement sequences, and systematically develop their competencies under controlled conditions.

Future research should particularly focus on examining the long-term effects and the actual transferability of training outcomes to everyday life. This requires randomized controlled trials with larger sample sizes and extended follow-up periods. The development of adaptive, individually tailored training programs and the integration of feedback mechanisms for continuous difficulty adjustment also appear promising.

## CONCLUSION

Virtual reality represents a promising and innovative complement to accident prevention and the promotion of physical activity in older adults. The “Wegfest” application demonstrates that VR training can not only enhance safety and mobility but also foster acceptance of digital technologies in older age. The findings underscore the significance of digital transformation in health prevention and education, providing valuable impulses for the further development of digitally supported prevention concepts. To fully exploit the potential of these technologies, however, further research, interdisciplinary collaboration, and close integration of science, practice, and technology development are required. To harness the full potential of VR in healthcare, this technology should be systematically integrated into education and professional practice—for example, in nursing and physiotherapy—where mobility, safety, and functional independence are central domains of action.

## Ethical considerations / registration

The approved ethics application (No. 095/2022) was submitted to the Institute of Pedagogy and Philosophy at the German Sport University Cologne.

## Conflicts of interest

None.

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