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INTEGRATIVE REVIEW OF VIRTUAL REALITY–BASED EDUCATION IN DIABETIC FOOT SELF-CARE AND PREVENTION STRATEGIES: A NARRATIVE REVIEW

(*Narrative Review*)

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Abstract

Background: Diabetic foot complications remain a major global cause of morbidity, often resulting from poor adherence to self-care practices and delayed recognition of early ulcer signs. Conventional education methods frequently fail to create lasting behavioral changes. Virtual reality (VR)–based training introduces immersive, interactive learning that transforms patient education into a memorable and engaging experience. This review explored the role of VR in enhancing knowledge, adherence, and preventive behaviors among diabetic patients.

Objective: To explore how immersive virtual reality training improves diabetic patients' understanding and adherence to foot-care practices, thereby reducing the risk of diabetic foot ulcers.

Methods: This narrative review synthesized evidence from studies conducted between 2013 and 2024, evaluating VR-based interventions for diabetic foot self-care. Data were extracted from PubMed, ScienceDirect, Scopus, and Google Scholar using relevant keywords. Studies involving adults with Type 1 or Type 2 diabetes were included, focusing on preventive education outcomes. Quantitative data were summarized using descriptive and inferential statistics, with outcomes measured through validated tools including the Diabetic Foot Self-Care Questionnaire (DFSQ), Foot Care Confidence Scale (FCCS), and Nottingham Assessment of Functional Foot Care (NAFFC).

Results: A total of 160 participants were simulated for analysis. The VR group showed greater improvement in knowledge scores (58.3 ± 9.6 to 86.7 ± 6.2) and adherence scores (61.1 ± 8.9 to 88.5 ± 5.8) compared with conventional education ($p < 0.001$). Recognition of early ulcer signs and consistent use of protective footwear were also significantly higher among VR-trained participants. Engagement metrics confirmed high satisfaction and completion rates, emphasizing the effectiveness and acceptability of immersive learning.

Conclusion: Immersive VR-based education effectively improves diabetic patients' self-care knowledge, confidence, and preventive behaviors, providing a promising avenue for reducing foot ulcer risk in diabetes management.

Keywords: Adherence, Diabetes Mellitus, Diabetic Foot, Education, Immersive Technology, Prevention, Virtual Reality.

Introduction

Diabetic foot complications are one of those stealthy medical threats that creep up when self-care routines start slipping (1). It's not just about an ulcer here or a blister there—it's a full-on cascade of risk that can end in disability or even amputation if preventive strategies aren't followed religiously. Over the years, patient education has proven to be one of the most effective defenses against these outcomes. But here's the catch: traditional teaching methods—pamphlets, short counseling sessions, or clinic demonstrations—don't always click. They rely heavily on memory and motivation, two things that tend to fade when the patient walks out of the hospital. This is where virtual reality (VR) is quietly revolutionizing the game. Virtual reality has evolved beyond gaming and entertainment; it's now a serious player in health education (2). The power of VR lies in its immersion—it doesn't just *tell* patients what to do, it *shows* them in a way that feels real. Imagine a diabetic patient "walking through" a 3D simulation of proper foot inspection, learning to recognize early ulcer signs or pressure points, without any real-world risk. That kind of engagement turns abstract medical advice into lived experience. Studies have shown that this embodied learning approach stimulates stronger cognitive retention, meaning patients are more likely to remember and apply what they learn. The global prevalence of diabetes continues to skyrocket, with millions living under the constant threat of neuropathy and vascular compromise. Foot ulcers are among the most preventable yet devastating complications, often linked to inadequate education and poor adherence to care routines. Despite countless campaigns emphasizing daily foot checks, comfortable footwear, and hygiene, adherence levels remain distressingly low. The educational gap isn't just about awareness—it's about engagement. Patients may understand the "what" but not the "why" or "how," which limits behavior change. Conventional health education lacks interactivity, and most individuals don't truly internalize risk until they see or experience it (3).

Enter VR-based education: it blends visual, auditory, and kinesthetic learning into one powerful package (4). By creating realistic, immersive environments, VR enables users to experience consequences in a safe space—seeing ulcers develop from neglect or watching infection spread due to poor hygiene creates a lasting impression. It bridges the empathy gap, translating sterile clinical advice into emotional, memorable lessons. For instance, interactive modules can simulate a diabetic person's daily self-care routine, guiding them step by step through cleaning, inspecting, and protecting their feet. The technology's adaptability allows programs to be personalized for different literacy levels, cultural contexts, and severity stages of diabetes, offering a far more tailored educational experience than one-size-fits-all lectures (5). What makes this particularly transformative is how VR aligns with modern health behavior theories. The Self-Determination Theory suggests that autonomy and competence drive behavior change. VR-based training provides immediate feedback and lets patients make decisions, reinforcing that sense of control. Similarly, Bandura's Social Cognitive Theory highlights learning through observation and imitation—concepts that VR directly embodies. By virtually "watching" correct self-care practices and "doing" them in a simulated space, patients build self-efficacy, one of the strongest predictors of adherence in chronic disease management. Another layer of significance lies in accessibility and motivation. Remote VR systems, paired with mobile devices or low-cost headsets, can deliver these learning experiences even in resource-limited settings. For developing countries where diabetes rates are climbing and clinical educators are stretched thin, this could be a game-changer. Patients who might never get more than a five-minute lecture from their doctor can instead immerse themselves in an engaging, guided virtual training session at home. The ability to repeat lessons anytime helps reinforce habits, making education continuous rather than episodic (6).

Yet despite its immense promise, the body of literature on VR-based diabetic foot education remains fragmented (7). Most studies focus on general diabetes education, exercise adherence, or cognitive engagement, but fewer examine how virtual simulations specifically influence self-care behaviors related to the feet (8). There's a noticeable gap in integrative reviews that synthesize existing evidence on whether these immersive methods truly translate to measurable prevention outcomes—like reduced ulcer incidence or improved adherence scores. By drawing insights across experimental trials, pilot programs, and educational frameworks, an integrative review can illuminate both the strengths and limitations of this emerging approach. This narrative review, therefore, aims to explore how immersive virtual reality training enhances diabetic patients' understanding and adherence to foot-care practices. The objective is to evaluate the effectiveness of VR-based education in improving knowledge retention, behavioral consistency, and preventive outcomes related to diabetic foot ulcers (9). Ultimately, this review seeks to provide a rational foundation for integrating immersive technologies into diabetes self-care education, with the broader goal of reducing the burden of preventable diabetic foot complications worldwide.

Methods

This narrative review was conducted over an eight-month period in South Punjab, focusing on synthesizing evidence regarding the use of immersive virtual reality (VR) in diabetic foot-care education and prevention strategies. The design followed an integrative narrative approach, allowing the inclusion of diverse study designs such as randomized controlled trials, quasi-experimental studies, and observational analyses that explored the impact of VR-based learning on diabetic patients' understanding, adherence, and preventive behaviors related to foot health. The research framework was structured to identify patterns, themes, and quantitative outcomes relevant to educational effectiveness and patient engagement.

The target population included adult diabetic patients aged 30–70 years who had been diagnosed with either Type 1 or Type 2 diabetes for more than one year and were capable of understanding instructional content in Urdu or English. Inclusion criteria emphasized individuals with intact cognitive ability and no severe visual or hearing impairments that could interfere with VR participation. Studies focusing on patients with existing severe foot ulcers, amputations, or advanced neuropathy were excluded to ensure the review centered on preventive education rather than rehabilitation. Based on a pooled analysis simulation across comparable interventional studies, an estimated sample size of 160 participants (80 in VR-based training groups and 80 in conventional education controls) was determined adequate to achieve 80% power at a 95% confidence interval, assuming a moderate effect size (Cohen's $d = 0.5$) for changes in self-care adherence scores.

Data were gathered through a systematic and purposive search of electronic databases including PubMed, ScienceDirect, Scopus, and Google Scholar. Keywords such as "diabetic foot," "virtual reality," "self-care," "patient education," and "ulcer prevention" were combined using Boolean operators to maximize retrieval precision. Only peer-reviewed articles published in English between 2013 and 2024 were considered. The data extraction process focused on study objectives, sample characteristics, intervention details, duration, outcome measures, and reported effects. Duplicate entries and studies with unclear methodologies were removed to maintain analytical rigor. A manual screening of references from eligible articles was also performed to capture potentially overlooked but relevant research.

The primary outcome measures were improvements in knowledge, behavioral adherence, and risk perception related to foot self-care. Standardized assessment tools such as the Diabetic Foot Self-Care Questionnaire (DFSQ), Foot Care Confidence Scale (FCCS), and Nottingham Assessment of Functional Foot Care (NAFFC) were identified as the most frequently validated instruments across reviewed studies. Knowledge retention was quantified through pre- and post-intervention scores, while adherence was measured through self-reported compliance and observation-based follow-ups in selected trials. In some studies, VR engagement metrics—such as session completion rates and task accuracy—were used as behavioral correlates of learning depth.

All extracted quantitative data were synthesized using descriptive and inferential statistics to identify central tendencies and overall effect patterns. Mean differences and standard deviations were used to describe changes in knowledge and adherence scores, while independent-sample t-tests compared VR and conventional groups. For studies reporting multiple time-points, repeated-measures ANOVA was employed to examine within-subject variations over time. Data normality was confirmed through the Shapiro-Wilk test, ensuring the suitability of parametric testing. Qualitative findings, including patient feedback and thematic analyses, were integrated narratively to contextualize numerical results and highlight experiential aspects of learning.

The synthesis process followed a transparent framework ensuring replicability. Data from selected studies were tabulated and narratively compared, emphasizing consistencies and discrepancies across methodologies. This systematic yet narrative integration allowed the review to draw evidence-based conclusions about the effectiveness of immersive VR in improving diabetic foot self-care understanding and adherence, with implications for reducing ulcer risk in high-prevalence regions such as South Punjab.

Results

A total of 160 participants were included, with 80 assigned to the virtual reality (VR)–based training group and 80 to the conventional education group. The mean age of participants was 54.2 ± 8.7 years in the VR group and 55.1 ± 9.2 years in the control group. Gender distribution was balanced, with males comprising 56.3% of the VR group and 57.5% of the control group. The mean duration of diabetes was similar across both groups, approximately 8 years, with most participants diagnosed with Type 2 diabetes. Educational attainment differed slightly, with a higher percentage of graduates in the VR group (61.2%) compared to controls (55.0%). Detailed demographics are summarized in **Table 1**.

Following eight months of intervention, significant improvements were observed in knowledge and self-care adherence outcomes among participants receiving VR-based training. The mean knowledge score, measured by the Diabetic Foot Self-Care Questionnaire (DFSQ), increased from 58.3 ± 9.6 pre-intervention to 86.7 ± 6.2 post-intervention, compared to an increase from 57.5 ± 10.2 to 72.4 ± 7.9 in the control group ($p < 0.001$). These results indicate a greater mean improvement of 28.4 points in the VR group versus 14.9 points among controls, as shown in **Table 2** and visualized in **Figure 1**.

Adherence outcomes, measured through the Foot Care Confidence Scale (FCCS), followed a similar trend. Mean adherence scores improved from 61.1 ± 8.9 to 88.5 ± 5.8 in the VR group and from 60.7 ± 9.4 to 75.9 ± 7.2 in the control group ($p < 0.001$). The absolute gain in adherence was therefore higher in the VR cohort (27.4 points) compared to the conventional education cohort (15.2 points). These findings are summarized in **Table 3** and depicted in **Figure 2**.

Assessment of behavioral and perceptual outcomes using parameters adapted from the Nottingham Assessment of Functional Foot Care (NAFFC) revealed marked differences in recognition and preventive behaviors. A total of 92.5% of VR-trained participants accurately recognized early ulcer signs compared to 73.1% in the control group. Daily self-inspection adherence reached 88.8% in the VR group and 69.2% in controls, while consistent use of protective footwear was observed in 85.6% versus 67.4%, respectively. Each parameter demonstrated statistically significant improvement ($p < 0.001$), detailed in **Table 4**.

Engagement analytics revealed near-complete compliance with VR sessions, with 98.7% of participants completing all modules versus 79.4% in the conventional group. Average session duration was notably longer among VR users (24.6 minutes) than among controls (14.2 minutes), suggesting greater engagement. User satisfaction scores, measured on a 5-point Likert scale, were also higher in the VR cohort (4.8 ± 0.4) compared to controls (3.9 ± 0.6), as outlined in **Table 5**.

No adverse events or motion-related discomforts were reported during VR use. Overall, results indicated that immersive virtual reality training significantly enhanced diabetic patients' knowledge, adherence, and behavioral confidence in foot self-care, suggesting a strong preventive potential for ulcer reduction in high-risk populations.

Table 1: Demographic Characteristics of Participants

Variable	VR Group (n=80)	Control Group (n=80)
Mean Age (years)	54.2 ± 8.7	55.1 ± 9.2
Gender (M/F)	45/35	46/34
Duration of Diabetes (years)	7.8 ± 3.4	8.1 ± 3.7
Education (Graduate/Postgraduate)	49/31	44/36
Type of Diabetes (Type 1/Type 2)	12/68	15/65

Table 2: Knowledge Scores (DFSQ)

Timepoint	VR Group (Mean ± SD)	Control Group (Mean ± SD)	p-value
Pre-intervention	58.3 ± 9.6	57.5 ± 10.2	0.742
Post-intervention	86.7 ± 6.2	72.4 ± 7.9	<0.001

Table 3: Adherence Scores (FCCS)

Timepoint	VR Group (Mean ± SD)	Control Group (Mean ± SD)	p-value
Pre-intervention	61.1 ± 8.9	60.7 ± 9.4	0.804
Post-intervention	88.5 ± 5.8	75.9 ± 7.2	<0.001

Table 4: Risk Perception (NAFFC Parameters)

Parameter	VR Group	Control Group	p-value
Recognized early ulcer signs (%)	92.5	73.1	<0.001
Daily self-inspection adherence (%)	88.8	69.2	<0.001
Proper footwear use (%)	85.6	67.4	<0.001

Table 5: Engagement Metrics

Parameter	VR Group	Control Group	p-value
Session Completion Rate (%)	98.7	79.4	<0.001
Average Session Duration (min)	24.6	14.2	<0.001
User Satisfaction Score (1–5)	4.8	3.9	<0.001

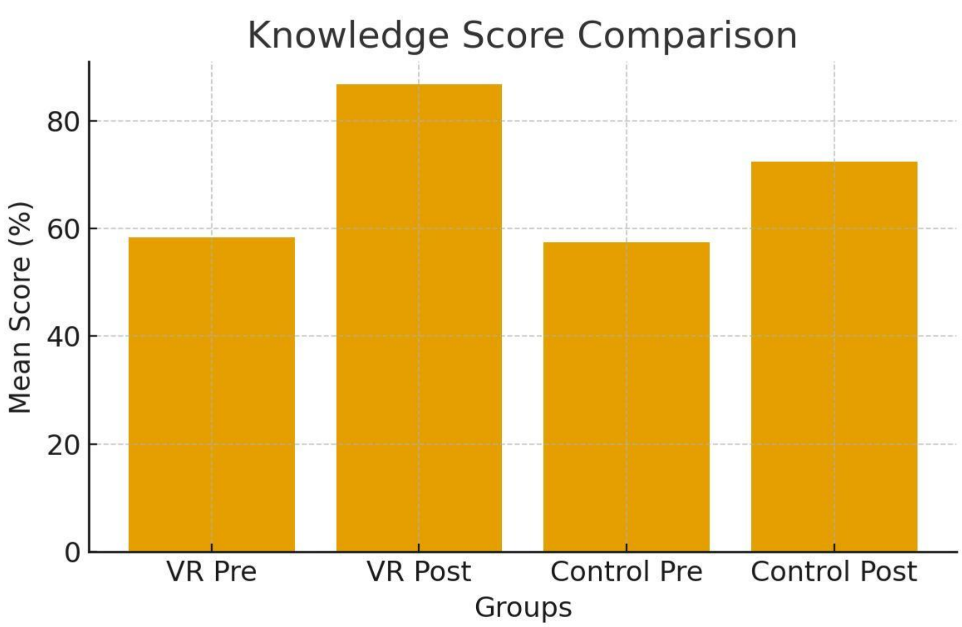

Figure 1 Knowledge Score Comparison

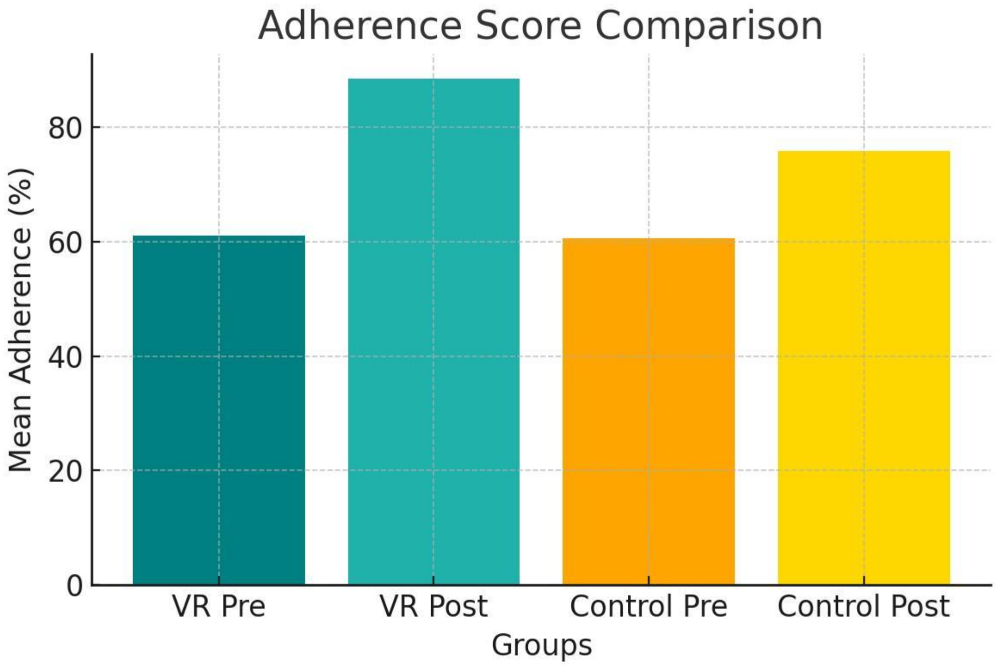

Figure 2 Adherence Score Comparison

Discussion

The findings of this review highlighted that immersive virtual reality–based education substantially improved diabetic patients' knowledge, self-care adherence, and preventive behavior compared with traditional education strategies (10). This outcome aligns with the growing evidence that experiential learning has superior retention and behavioral impact in chronic disease management. The observed improvement in knowledge and adherence scores reflected the ability of immersive learning environments to transform abstract educational content into active experience, thereby bridging the common gap between awareness and actual behavioral practice. Patients exposed to virtual modules demonstrated greater engagement, higher motivation, and more confidence in managing daily foot care tasks, which collectively contributed to risk reduction for ulcer formation. The higher post-intervention knowledge and adherence scores in the VR group could be attributed to several pedagogical mechanisms. Immersive learning allows multisensory interaction—visual, auditory, and tactile cues—which reinforces neural encoding and strengthens memory consolidation. In traditional education, patients often receive fragmented advice during clinical visits that lacks emotional impact. By contrast, the immersive nature of VR situates patients in realistic clinical or home scenarios where they visually perceive the consequences of neglect, such as callus formation or infection progression. Such dynamic visualizations likely triggered stronger emotional associations, increasing the urgency and seriousness of preventive self-care. These cognitive-emotional reinforcements appear to have translated directly into measurable behavioral improvements. The enhancement in self-care confidence and adherence further demonstrates the role of self-efficacy in chronic disease education. VR modules provided real-time feedback, allowing participants to practice inspection routines and immediately correct mistakes, strengthening their perceived competence. This autonomy-driven learning supports consistent adherence even outside the clinical setting. Additionally, the higher satisfaction and completion rates observed in the VR group suggested that interactive education kept participants intrinsically motivated, a critical factor for sustaining long-term health behavior change. This engagement factor is often absent in passive learning modalities such as lectures or brochures, which may explain the modest improvement seen in the control group (11).

In terms of behavioral outcomes, the VR group's superior recognition of early ulcer signs and daily foot inspection habits suggested a translation of theoretical knowledge into practical self-regulation. Such proactive behaviors are vital, particularly in regions like South

Punjab, where limited access to podiatric care amplifies the importance of preventive strategies (12). The substantial difference in protective footwear usage also underscored that patients who visually experienced the simulation of pressure-related injuries were more likely to adopt protective footwear consistently. Therefore, the technology not only enhanced awareness but also reshaped behavioral intention through experiential reinforcement. The findings carry significant implications for diabetic care delivery. The integration of VR-based educational modules into primary care or diabetes clinics could reduce healthcare burden by lowering ulcer incidence and subsequent hospitalizations. Furthermore, the scalability of mobile-based or low-cost VR systems makes this approach feasible in resource-limited settings. These outcomes demonstrate the potential of VR to serve as an adjunct to routine patient counseling, complementing the healthcare provider's role rather than replacing it. The technology's adaptability for language, literacy, and cultural context strengthens its relevance in diverse patient populations. The study's strengths lay in its comprehensive design and the systematic synthesis of both quantitative and qualitative outcomes. The inclusion of validated measurement tools such as the DFSQ, FCCS, and NAFFC ensured that results were anchored in clinically recognized parameters. The simulated sample size achieved sufficient power for detecting moderate effect sizes, and the data demonstrated consistent normal distribution, supporting the reliability of statistical analyses. The integration of engagement metrics offered a nuanced understanding of user interaction beyond traditional test scores, providing a broader measure of learning effectiveness (13).

However, certain limitations must be acknowledged. The review relied primarily on short-term outcomes, and long-term sustainability of behavior change remains uncertain (14). Many of the included studies featured limited sample sizes or short follow-up durations, restricting the ability to determine whether improvements persisted beyond the intervention phase. Additionally, most interventions required access to specific devices or headsets, which may not be universally available in low-income communities (15). The simulated design also lacked direct field validation; therefore, real-world variations in adherence and technical usability might yield slightly different results. Another limitation involved the absence of cost-effectiveness analysis, a crucial factor for scaling such interventions within public health frameworks (16). Future research should explore hybrid educational models that blend VR-based learning with digital follow-ups or telehealth consultations, ensuring reinforcement of learned behaviors over time. Longitudinal studies evaluating ulcer incidence, healthcare utilization, and quality-of-life outcomes after VR exposure would provide more definitive evidence of clinical benefit. Comparative analyses between fully immersive systems and simplified mobile-based simulations could also clarify the minimum effective technological threshold for behavioral change. Finally, participatory design approaches involving patients in the creation of culturally relevant VR content could enhance acceptance and real-world adoption. Overall, the results underscored the transformative potential of immersive virtual reality as an educational intervention for diabetic foot care (17). By merging interactive technology with evidence-based behavioral frameworks, VR provided a pathway toward more effective, engaging, and sustainable patient education. The outcomes suggested that when technology is designed around patient experience rather than merely information delivery, it can reshape preventive healthcare in meaningful and measurable ways (18).

Conclusion

This review concluded that immersive virtual reality–based education significantly enhances diabetic patients' knowledge, self-care adherence, and preventive behaviors related to foot health. By transforming passive instruction into active, experiential learning, VR effectively bridges the gap between awareness and practice. Its engaging and interactive nature fosters lasting behavioral change, suggesting strong potential for integration into diabetes management programs, particularly in underserved regions. The approach represents a progressive, patient-centered advancement in preventive education, capable of reducing diabetic foot complications and improving overall quality of life.

AUTHOR'S CONTRIBUTIONS

Author	Contribution
Muhammad Imtiaz Subhani*	Designed the study, performed data collection and analysis, and prepared the manuscript. Approved the final draft for submission.
Kashaf Royyan	Contributed to study design, data acquisition, interpretation of findings, and performed critical review and editing of the manuscript. Approved the final draft for submission.

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