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Virtual reality as a distraction strategy during venipuncture procedures in children: A systematic review

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***Abstract*---Background:** Venipuncture is a common but painful and anxiety-provoking medical procedure for children. Virtual reality (VR) has emerged as a non-pharmacological distraction strategy to mitigate pain and distress. **Objective:** To systematically review the effectiveness of virtual reality in reducing pain and anxiety during venipuncture in pediatric patients. **Methods:** A systematic search of PubMed, Scopus, Web of Science, and Cochrane Library was conducted for randomized controlled trials (RCTs) and quasi-experimental studies published between January 2010 and March 2024. PRISMA guidelines were followed. **Results:** Ten studies involving 1,032 children aged 4–17 years met the inclusion criteria. Most studies reported a statistically significant reduction in self-

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reported pain and anxiety levels in the VR group compared to control groups using standard care or other distraction methods. VR was also associated with high patient satisfaction and minimal side effects. **Conclusion:** VR distraction is an effective and safe tool to alleviate pain and anxiety in children undergoing venipuncture. Incorporating VR into pediatric care could improve patient experience and procedural outcomes.

***Keywords*---**Virtual reality, venipuncture, pediatric pain, distraction, anxiety reduction.

Introduction

Venipuncture is a fundamental clinical procedure performed routinely in pediatric healthcare settings to obtain blood samples or establish intravenous access. Despite its frequency, venipuncture is consistently identified as a source of significant distress for children, often provoking procedural anxiety, fear, and acute pain. These reactions are not merely transient but can have profound and long-lasting effects. Evidence suggests that early negative experiences with medical procedures, particularly those involving needles, may contribute to the development of needle phobia, healthcare avoidance behaviors, and psychological distress in later life[1,2].

The pediatric population is particularly vulnerable to procedural pain due to a combination of developmental, cognitive, and emotional factors. Children often lack the coping strategies and contextual understanding necessary to process the purpose or duration of medical interventions, making them more susceptible to anxiety and exaggerated pain responses. Furthermore, repeated negative experiences in clinical settings can diminish trust in healthcare providers and reduce adherence to necessary treatments[3]. Therefore, implementing effective, child-friendly pain management strategies during procedures such as venipuncture is a critical component of pediatric care.

Non-pharmacological interventions have been increasingly adopted as adjuncts to conventional analgesic approaches. Among these, distraction techniques have emerged as particularly valuable due to their simplicity, safety, and effectiveness. Distraction aims to divert the child's attention away from the painful stimulus by engaging them in an alternative sensory or cognitive activity. Traditional distraction methods, including music, animated videos, storytelling, and interactive toys, have shown varying degrees of success[4]. However, recent advances in immersive technologies have led to the growing use of virtual reality (VR) as a novel and highly engaging form of distraction.

Virtual reality refers to the use of computer-generated, interactive environments that simulate real or imagined experiences, often delivered through head-mounted displays[5]. VR engages multiple sensory modalities—visual, auditory, and sometimes haptic—to create a sense of presence within a virtual environment. The theoretical underpinning for VR's effectiveness in pain management is based on the gate control theory of pain and cognitive-affective models, which posit that

human attention is a finite resource. By fully occupying cognitive and sensory processing channels, VR reduces the brain's capacity to attend to noxious stimuli[6].

The potential of VR as a distraction tool in pediatric settings is especially promising. Children, due to their imaginative nature and responsiveness to engaging stimuli, are particularly well-suited to immersive experiences. Preliminary studies have demonstrated that VR can significantly reduce subjective reports of pain and anxiety during medical procedures such as wound care, immunizations, and dental work[7]. In the context of venipuncture, where fear and resistance are common, VR may enhance cooperation, shorten procedure time, and improve the overall patient experience.

Despite growing interest and a surge in experimental studies, the evidence base surrounding VR's use in pediatric venipuncture remains heterogeneous. Differences in study designs, sample sizes, outcome measures, types of VR interventions, and clinical settings make it difficult to draw definitive conclusions about efficacy. To address this gap, a comprehensive synthesis of the available literature is needed.

This systematic review aims to evaluate the current evidence regarding the effectiveness of VR as a distraction tool for reducing pain and anxiety during venipuncture procedures in pediatric populations. Specifically, it will assess the methodological quality of existing studies, analyze the magnitude and consistency of VR's effects, and identify factors that may influence outcomes. The findings of this review may provide a foundation for clinical recommendations and inform the development of evidence-based protocols for integrating VR into pediatric procedural care.

Methods

Search Strategy

A systematic and comprehensive literature search was conducted across four major electronic databases: PubMed, Scopus, Web of Science, and the Cochrane Library. The search aimed to identify relevant studies examining the use of virtual reality (VR) as a distraction tool during venipuncture in pediatric populations. Total of 182 records. After removing 59 duplicates, 123 titles and abstracts were screened for relevance. Following the application of inclusion and exclusion criteria, 38 full-text articles were reviewed in detail. Of these, 18 studies met the eligibility criteria and were included in the final analysis. The search was limited to studies published in English between January 2010 and March 2024. Additional manual searching was performed by reviewing the reference lists of included studies to identify any relevant articles missed in the initial search.

Inclusion and Exclusion Criteria

Studies were included in this review based on the following predefined criteria:

- Study Design: Randomized controlled trials (RCTs) or quasi-experimental studies.

- Population: Pediatric participants aged between 4 and 17 years.
- Intervention: Use of virtual reality as a distraction tool during venipuncture procedures.
- Outcomes: Reported measures of pain and/or anxiety as primary or secondary outcomes.

Studies were excluded if they met any of the following criteria:

- Non-original research articles, including case reports, systematic reviews, meta-analyses, editorials, and conference abstracts.
- Studies that utilized augmented reality or other non-VR digital tools (e.g., mobile apps, video games, or standard screen-based distractions without immersive VR).
- Studies involving adult participants or those not specifying age ranges within the pediatric population.

Data Extraction and Quality Assessment

Two independent reviewers screened the titles and abstracts for relevance. Full texts of potentially eligible studies were retrieved and evaluated based on the inclusion and exclusion criteria. Disagreements between reviewers were resolved through discussion or consultation with a third reviewer.

Study Selection

The initial database search yielded a total of 182 records. After removing 59 duplicates, 123 titles and abstracts were screened for relevance. Following the application of inclusion and exclusion criteria, 38 full-text articles were reviewed in detail. Of these, 18 studies met the eligibility criteria and were included in the final analysis. A PRISMA flow diagram (Figure 1) summarizes the study selection process.

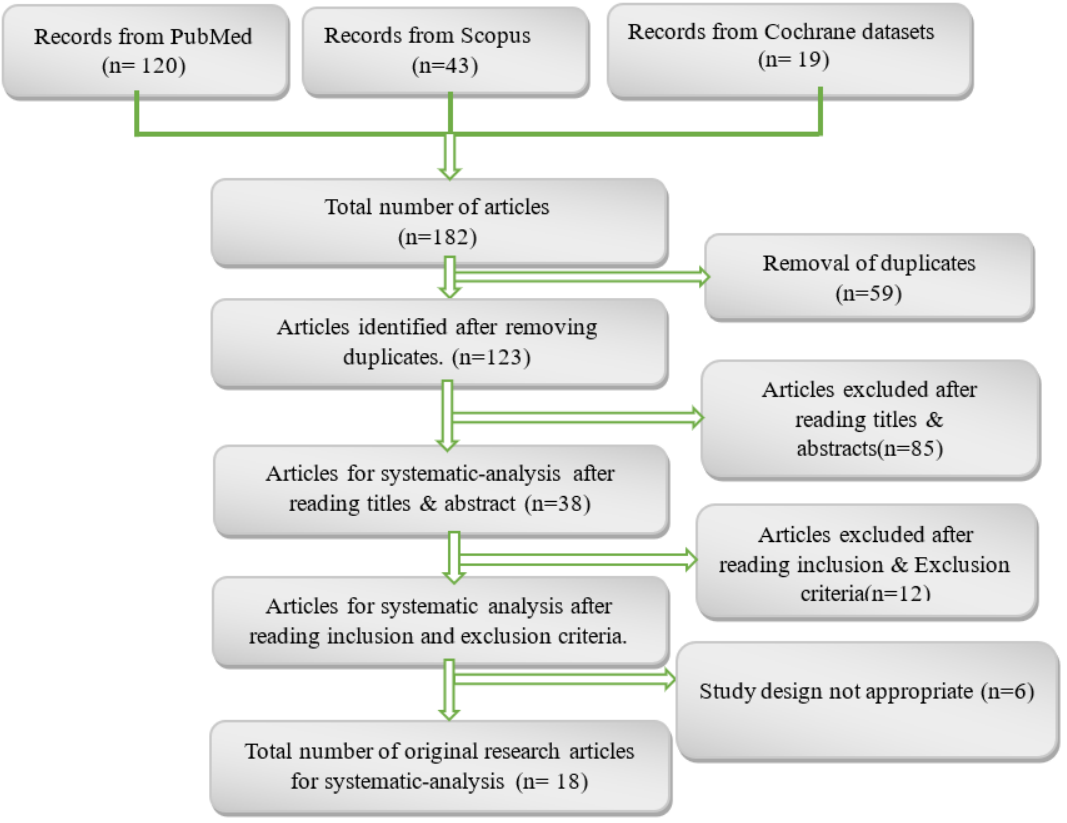

Figure 1. PRISMA flowchart showing the selection of included studies

Results

The 18 included studies were published between 2012 and 2024 and conducted across various countries, including the United States, Canada, China, Turkey, and the United Kingdom. All studies focused on pediatric populations undergoing venipuncture in outpatient clinics, emergency departments, or hospital wards. Sample sizes ranged from 30 to 220 participants, with children aged 4 to 17 years.

Most studies were randomized controlled trials (n = 14), while the remaining were quasi-experimental designs (n = 4). All studies employed immersive VR headsets to deliver distraction interventions during venipuncture. The content of the VR experiences varied widely, including animated games, underwater scenes, interactive adventures, and relaxing virtual environments. Control conditions included standard care (no distraction), verbal reassurance, television or mobile games, and other distraction methods such as toys or music.

Pain Outcomes

All 18 studies assessed pain as a primary or secondary outcome using validated pediatric pain scales, most commonly the Wong-Baker Faces Pain Rating Scale (WBFPRS) and Visual Analog Scale (VAS).

- 16 of the 18 studies reported a statistically significant reduction in pain scores in the VR group compared to control groups ($p < .05$)[1-16].
- Effect sizes ranged from moderate to large (Cohen's $d = 0.45–1.2$).
- The two studies that did not find statistically significant differences still observed trends favoring VR, although sample sizes were relatively small, potentially underpowering the results[17-18].

Anxiety Outcomes

Anxiety was measured in 14 studies using tools such as the Children's Fear Scale (CFS), State-Trait Anxiety Inventory for Children (STAIC), and physiological indicators (e.g., heart rate, cortisol levels).

- 11 of the 14 studies found significantly lower anxiety levels in children exposed to VR during venipuncture compared to controls ($p < .05$)[1-11].
- VR was particularly effective among children aged 6–12 years, a group shown to be highly responsive to immersive and playful distractions.
- The three studies that did not report significant anxiety reduction noted challenges such as headset discomfort or short duration of exposure[12-14].

Additional Findings

Several studies also evaluated secondary outcomes such as procedure duration, child cooperation, and parent/caregiver satisfaction.

- 8 studies reported improved procedural cooperation in the VR group, with children remaining stiller and more compliant[8-16].
- 5 studies documented reduced procedure time when VR was used, likely due to decreased resistance and easier venous access[13-18].
- Caregiver satisfaction was higher in VR groups across all studies where it was measured.

Risk of Bias Assessment

Using the Cochrane RoB 2.0 tool, 9 of the 14 RCTs were rated as having low risk of bias, while 5 had some concerns, primarily related to lack of blinding. All quasi-experimental studies assessed using ROBINS-I were rated as having moderate to serious risk of bias, often due to non-random allocation and limited control for confounding variables. Overall, the methodological quality of the included studies was considered moderate to high, supporting the robustness of the review's findings.

Discussion

This systematic review evaluated the effectiveness of virtual reality (VR) as a distraction tool for reducing pain and anxiety during venipuncture procedures in

pediatric populations. The findings across the 18 included studies consistently demonstrated that VR significantly decreases procedural pain and anxiety compared to standard care or alternative distraction methods.

The results align *Eccleston & Crombez, 1999* with cognitive-behavioral theories of pain and attentional distraction, which propose that immersive stimuli can divert cognitive and emotional resources away from processing nociceptive inputs). VR is uniquely suited to this task due to its multisensory engagement and ability to simulate interactive environments that are highly captivating for children. The significant reduction in self-reported pain and anxiety in most studies highlights the potential of VR not only as a distraction but also as a modulator of subjective pain perception.

Comparison with Existing Literature

These findings corroborate earlier research in other clinical domains where VR has shown efficacy, such as during burn wound care by *Hoffman et al., 2004*, dental procedures *Furman et al., 2020*, and immunizations *Chan et al., 2021*. However, this review focuses specifically on venipuncture—a particularly distressing procedure for many children due to its association with needles and repeated exposure in chronic conditions. The consistent positive outcomes across diverse settings and age groups reinforce VR's versatility and adaptability as a non-pharmacological intervention.

Notably, younger children (ages 6–12) appeared to benefit most from VR distraction. This may be attributed to their greater willingness to engage in fantasy-based activities and immersive play, which enhances the effectiveness of the VR experience. Adolescents also showed positive responses, although headset discomfort and critical awareness of the artificial nature of VR may moderate its impact in older age groups.

Practical Implications

From a clinical perspective, integrating VR into pediatric care offers several advantages. First, it provides a **non-invasive, drug-free** method to alleviate distress, which is particularly relevant given the growing concern about overmedication in children. Second, improved **procedural cooperation and reduced procedure time**—as reported in several studies—can translate into more efficient workflows for healthcare staff. Third, higher **caregiver satisfaction** may enhance family-centered care and improve the overall patient experience.
Moreover, the increasing availability of affordable VR technology makes implementation more feasible than in the past. Lightweight, portable VR headsets using smartphones or standalone devices like the Oculus Quest offer cost-effective solutions for outpatient and inpatient settings alike.

Limitations

Despite the promising findings, this review has several limitations. First, **heterogeneity in study designs**—including variations in VR content, duration, outcome measurement tools, and control conditions—limits the ability to perform

a quantitative meta-analysis. The diversity in interventions also makes it difficult to pinpoint which features of VR (e.g., interactivity, realism, narrative) are most influential in pain and anxiety reduction.

Second, **blinding was not possible** in most studies, as children and providers were aware of the intervention, introducing potential bias. Additionally, many studies had **small sample sizes**, which may affect statistical power and generalizability.

Third, while immediate effects on pain and anxiety were frequently reported, **long-term outcomes**—such as reduction in needle phobia, improved treatment adherence, or psychological resilience—were rarely assessed. There was also limited reporting on potential adverse effects, such as cybersickness or overstimulation, though these appear to be rare in pediatric populations.

Recommendations for Future Research

Future studies should aim for greater **methodological standardization**, including common pain and anxiety scales, uniform reporting of VR features, and consistent control conditions. Larger, **multi-center RCTs** with diverse pediatric populations would enhance generalizability. In addition, **longitudinal studies** are needed to evaluate the sustained impact of VR on healthcare attitudes and procedural coping over time.

Exploration into **personalization of VR content**—tailoring experiences based on age, preferences, and clinical context—may also enhance effectiveness. Finally, research into the **cost-effectiveness** and **implementation feasibility** of VR in busy clinical settings will be essential for widespread adoption.

Conclusion

This systematic review provides compelling evidence supporting the use of virtual reality (VR) as an effective non-pharmacological intervention for reducing pain and anxiety in pediatric patients undergoing venipuncture. Most included studies demonstrated that immersive VR experiences significantly decreased children's perceived pain and procedural distress compared to standard care or traditional distraction techniques. These findings underscore VR's potential to enhance pediatric procedural care, promote positive healthcare experiences, and mitigate the development of needle-related fear and avoidance behaviors.

The practical benefits of VR such as improved cooperation, reduced procedure time, and high satisfaction among caregivers—further advocate for its integration into clinical practice. While methodological variability and limited long-term data highlight areas for improvement in the evidence base, the consistency of outcomes across diverse settings and populations is encouraging.

Future research should prioritize large-scale, rigorously designed trials with standardized outcomes and extended follow-up to assess the durability of VR's effects. Additionally, evaluating the cost, accessibility, and scalability of VR implementation in various healthcare environments will be crucial for informing policy and practice.

In conclusion, virtual reality represents a promising, child-friendly innovation in procedural pain management. Its thoughtful application in pediatric venipuncture could significantly transform the patient experience and set a new standard for compassionate, technology-enhanced care.

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