

# Virtual Reality for Pain Management in Pediatric Phlebotomy: A Systematic Review

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## Abstract

Pediatric phlebotomy is a common invasive procedure frequently associated with pain, anxiety, and fear, which may negatively affect children's cooperation and overall healthcare experiences. Virtual reality (VR) has emerged as a promising non-pharmacological intervention capable of providing immersive distraction and emotional engagement during painful medical procedures. The aim of this systematic review was to evaluate the effectiveness of immersive VR in reducing pain perception and anxiety-related outcomes among pediatric patients undergoing phlebotomy procedures. This review was conducted in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines. The research question was developed using the PICO framework. Randomized controlled trials and comparative controlled studies published between January 2020 and September 2025 were identified through systematic searches of PubMed and the Cochrane Central Register of Controlled Trials (CENTRAL). Studies involving children and adolescents aged 4–17 years undergoing phlebotomy or venipuncture procedures were eligible for inclusion. A total of six studies comprising 557 pediatric participants were included in the review. The VR interventions involved immersive and interactive environments, including educational simulations, animated scenarios, and game-based experiences delivered through head-mounted displays. Four studies reported statistically significant reductions in pain and/or anxiety among participants exposed to VR compared with control groups, whereas two studies found no significant differences. Across the included studies, VR interventions were generally well accepted by children, parents, and healthcare professionals, with only mild and transient adverse effects reported. However, substantial heterogeneity was observed regarding clinical settings, VR technologies, intervention protocols, and outcome assessment methods. The current evidence suggests that immersive VR is a promising adjunctive strategy for reducing pain and anxiety during pediatric phlebotomy procedures. Nevertheless, the available evidence remains limited by methodological heterogeneity and relatively small sample sizes. Future research should focus on larger, well-designed randomized controlled trials using standardized intervention protocols and outcome measures to support evidence-based implementation of VR in pediatric clinical practice.



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**Keywords:** virtual reality; pediatric phlebotomy; venipuncture; pain management; anxiety; immersive technologies; pediatric care

## 1. Introduction

Painful and anxiety-provoking procedures are an unavoidable component of healthcare delivery, particularly in pediatric settings. Among these procedures, phlebotomy and venipuncture are among the most frequently performed interventions and represent a significant source of distress for children and adolescents. Exposure to needle-related procedures may generate negative sensory and emotional experiences, often characterized by pain, fear, anxiety, and anticipatory stress, which can adversely affect both immediate procedural outcomes and future healthcare interactions [1].

The impact of these experiences extends beyond temporary discomfort. In pediatric populations, poorly managed pain and anxiety during invasive procedures may reduce cooperation, increase procedural difficulty, prolong intervention time, and elevate the risk of technical failure. Furthermore, repeated negative healthcare experiences can contribute to the development of healthcare avoidance behaviors, decreased adherence to preventive care, and increased healthcare utilization costs over time [2,3]. Consequently, the implementation of effective, child-centered approaches to pain and anxiety management has become an important priority within contemporary healthcare systems.

In recent years, technological innovations have created new opportunities for improving patient experiences during medical procedures. Among these innovations, immersive virtual reality (VR) has emerged as a promising non-pharmacological intervention for pain and anxiety management. Delivered through head-mounted displays, immersive VR creates computer-generated three-dimensional environments that provide high levels of presence, engagement, and sensory immersion. By redirecting attentional resources toward virtual stimuli, VR may reduce awareness of painful procedures and improve emotional coping during healthcare interventions [4,5].

The potential benefits of VR extend beyond simple distraction. Neurophysiological research suggests that immersive VR may influence pain processing through cognitive, emotional, and attentional mechanisms. By integrating visual, auditory, and interactive stimuli, VR can alter the perception of nociceptive input and modulate activity in brain regions associated with pain processing, including the insular and somatosensory cortices [6]. Neuroimaging studies have demonstrated patterns of neural modulation comparable to those observed with certain pharmacological analgesic interventions, supporting the growing interest in VR as an adjunctive pain management strategy [5,7].

The use of VR has been investigated across a variety of healthcare contexts, including burn treatment, wound care, rehabilitation, perioperative anxiety management, and needle-related procedures. Several systematic and narrative reviews have reported encouraging results regarding the effectiveness of VR in reducing pain and anxiety in pediatric populations [1,3,8]. However, most previous reviews have examined broader categories of needle-related procedures or multiple clinical contexts, including vaccination, intravenous cannulation, wound care, and surgical settings. As a result, evidence specifically related to immersive VR interventions during pediatric phlebotomy and venipuncture procedures remains fragmented and has not been comprehensively synthesized within the context of recent technological developments in immersive VR systems.

Recent studies have continued to strengthen the evidence base regarding the use of immersive VR during pediatric needle-related procedures. Ferraz-Torres et al. [9] demonstrated that both passive and interactive VR interventions were effective in reducing pain and anxiety in pediatric patients, while a subsequent quasi-experimental study reported additional benefits for children and their parents during emergency care procedures [10]. Similarly, Gold et al. [11] highlighted the influence of individual patient characteristics and immersion levels on anxiety and pain outcomes during venipuncture, suggesting that intervention effectiveness may be partially moderated by participant-specific factors.

More recently, Gerçeker et al. [12] reported significant improvements in pain, anxiety, fear, and emotional behavior among children undergoing phlebotomy procedures using both active and passive VR distraction techniques. Collectively, these findings reinforce the growing interest in immersive technologies as supportive interventions for pediatric procedural care.

Nevertheless, considerable heterogeneity exists across studies regarding VR hardware, software content, intervention protocols, clinical settings, and outcome assessment methods. Differences in study design, participant characteristics, levels of immersion, and outcome measurement tools make it difficult to draw definitive conclusions regarding the effectiveness of VR specifically for pediatric phlebotomy procedures. These limitations highlight the need for a focused synthesis of the most recent evidence in this area.

Accordingly, the present systematic literature review aims to critically evaluate the effectiveness of immersive virtual reality in reducing pain perception and anxiety-related outcomes among pediatric patients undergoing phlebotomy procedures, compared with standard care without VR. By focusing exclusively on studies published between 2020 and 2025 and involving immersive VR technologies, this review seeks to provide an updated synthesis of the available evidence, identify current limitations in the literature, and support future research and clinical implementation efforts.

The remainder of this paper is organized as follows. Section 2 describes the methodological procedures adopted for systematic review, including the search strategy, eligibility criteria, study selection process, quality assessment, and data extraction procedures. Section 3 presents the results of the review. Section 4 discusses the findings considering the existing literature and methodological limitations. Finally, Section 5 summarizes the main conclusions and implications for future research and clinical practice.

## 2. Methods

This systematic literature review (SLR) was conducted and reported in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA 2020) guidelines [13]. The completed PRISMA 2020 checklist is provided in the Supplementary Materials (Table S1). To enhance methodological transparency and reproducibility, the review protocol was developed prior to study selection and subsequently registered in the Open Science Framework (OSF; <https://doi.org/10.17605/OSF.IO/F4x2Y>).

The review aimed to synthesize current evidence regarding the effectiveness of immersive virtual reality (VR) interventions for pain and anxiety management during pediatric phlebotomy procedures. The review process was guided by the PICO framework (Population/Problem, Intervention, Comparison, Outcome), which informed the development of the research question, eligibility criteria, search strategy, and data extraction procedures [14].

### 2.1. Research Question

The present systematic literature review was guided by a research question formulated using the PICO framework, which delineates four key components: Population/Problem, Intervention, Comparison, and Outcome. This structured approach not only facilitated the clear articulation of the research question but also informed the establishment of precise inclusion and exclusion criteria. Accordingly, the research question for this study was defined as follows (Table 1): “To what extent does virtual reality modulate pain perception and anxiety in pediatric patients undergoing phlebotomy procedures?”.

**Table 1.** PICO Question.

| <b>P (Population/Problem)</b>                              | <b>I (Intervention)</b>                                                                        | <b>C (Comparison)</b>                         | <b>O (Outcomes)</b>                                                        |
|------------------------------------------------------------|------------------------------------------------------------------------------------------------|-----------------------------------------------|----------------------------------------------------------------------------|
| Children and Adolescents Undergoing Phlebotomy Procedures. | Use of immersive virtual reality delivered through head-mounted displays during the procedure. | Procedure Without the Use of Virtual Reality. | Impact of Virtual Reality on Pain Perception and Anxiety-related Outcomes. |

## 2.2. Inclusion and Exclusion Criteria

Considering the research question structured according to the PICO framework, Eligibility criteria were established:

- Population/Problem (P): Children and adolescents aged 4 to 17 years undergoing phlebotomy or venipuncture procedures in hospital, outpatient, emergency department, or other clinical settings.
- Intervention (I): Use of immersive virtual reality delivered through head-mounted display devices during the procedure.
- Comparison (C): Standard care or procedures performed without VR, including routine clinical practice and other non-pharmacological approaches.
- Outcomes (O): Assessment of pain perception and/or anxiety-related outcomes using validated and age-appropriate measurement instruments, including the Wong–Baker FACES® Pain Rating Scale, Faces Pain Scale–Revised (FPS-R), Numerical Rating Scales, or equivalent validated tools.

To ensure methodological rigor and relevance to contemporary immersive technologies, only randomized controlled trials (RCTs) and controlled comparative studies published between 1 January 2020 and 30 September 2025 were considered. Studies were restricted to publications in English. The selected time frame was chosen to reflect recent advances in immersive VR hardware, software, and clinical implementation.

Conversely, studies were excluded if they involved adult-only populations; employed non-immersive technologies such as tablets, smartphones without immersive displays, standard video distraction techniques, or other two-dimensional screen-based interventions; used virtual reality systems that were not delivered through head-mounted displays; lacked a comparison or control group; or consisted of secondary research, including systematic reviews, meta-analyses, scoping reviews, and narrative reviews. Conference proceedings, editorials, opinion papers, letters, study protocols, and abstracts without full-text availability were also excluded. Additionally, duplicate publications and studies reporting overlapping datasets were removed from the review.

The eligibility criteria were applied independently during the screening and full-text assessment phases to ensure consistency and methodological transparency throughout the review process.

## 2.3. Research Strategy

The literature search was conducted in two electronic databases: PubMed® and the Cochrane Central Register of Controlled Trials (CENTRAL®). These databases were selected because of their extensive coverage of biomedical literature and randomized controlled trials, which are particularly relevant for evaluating the effectiveness of clinical interventions in healthcare settings.

The search strategy was developed using the PICO framework and combined controlled vocabulary terms, where applicable, with free-text search terms related to virtual reality and pediatric phlebotomy procedures. The principal search terms included “virtual reality”, “VR”, “phlebotomy”, “blood collection”, “venipuncture”, “pediatric”, “child”,

and “adolescent”. These search strings were combined using Boolean operators (AND/OR) to maximize the identification of potentially relevant studies.

The search was restricted to studies published between 1 January 2020 and 30 September 2025 and was limited to articles published in English. This period was selected to capture evidence generated using contemporary immersive VR technologies, reflecting recent advances in hardware capabilities, software development, and clinical implementation.

The study selection process was conducted in two sequential stages. First, titles and abstracts were screened to identify potentially eligible studies. Subsequently, full-text articles were assessed against the predefined eligibility criteria. Screening and eligibility assessment were independently performed by two reviewers. Any disagreements were resolved through discussion and consensus, following established recommendations for systematic reviews [15].

References were managed using Zotero® reference management software, version 9.0.5 (64-bit) (Corporation for Digital Scholarship, Vienna, VA, USA), which was used to organize records, support the screening process, and identify duplicate publications. The complete search syntax, database-specific search procedures, applied filters, and search outputs are presented in Table 2 to ensure methodological transparency and reproducibility.

Table 2. Research Strategy.

| Data Base                                                       | Search Formula                                                                                                                                                 | Filters            | Total Number of Studies |
|-----------------------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------|--------------------|-------------------------|
| PubMed®                                                         | Search terms all fields<br>("virtual reality" OR "VR") AND ("phlebotomy"<br>OR "blood collection" OR "venipuncture") AND<br>(pediatric OR child OR adolescent) | English; 2020–2025 | 26                      |
| Cochrane Central<br>Register of Controlled<br>Trials (Central)® | Same search syntax                                                                                                                                             | English; 2020–2025 | 75                      |

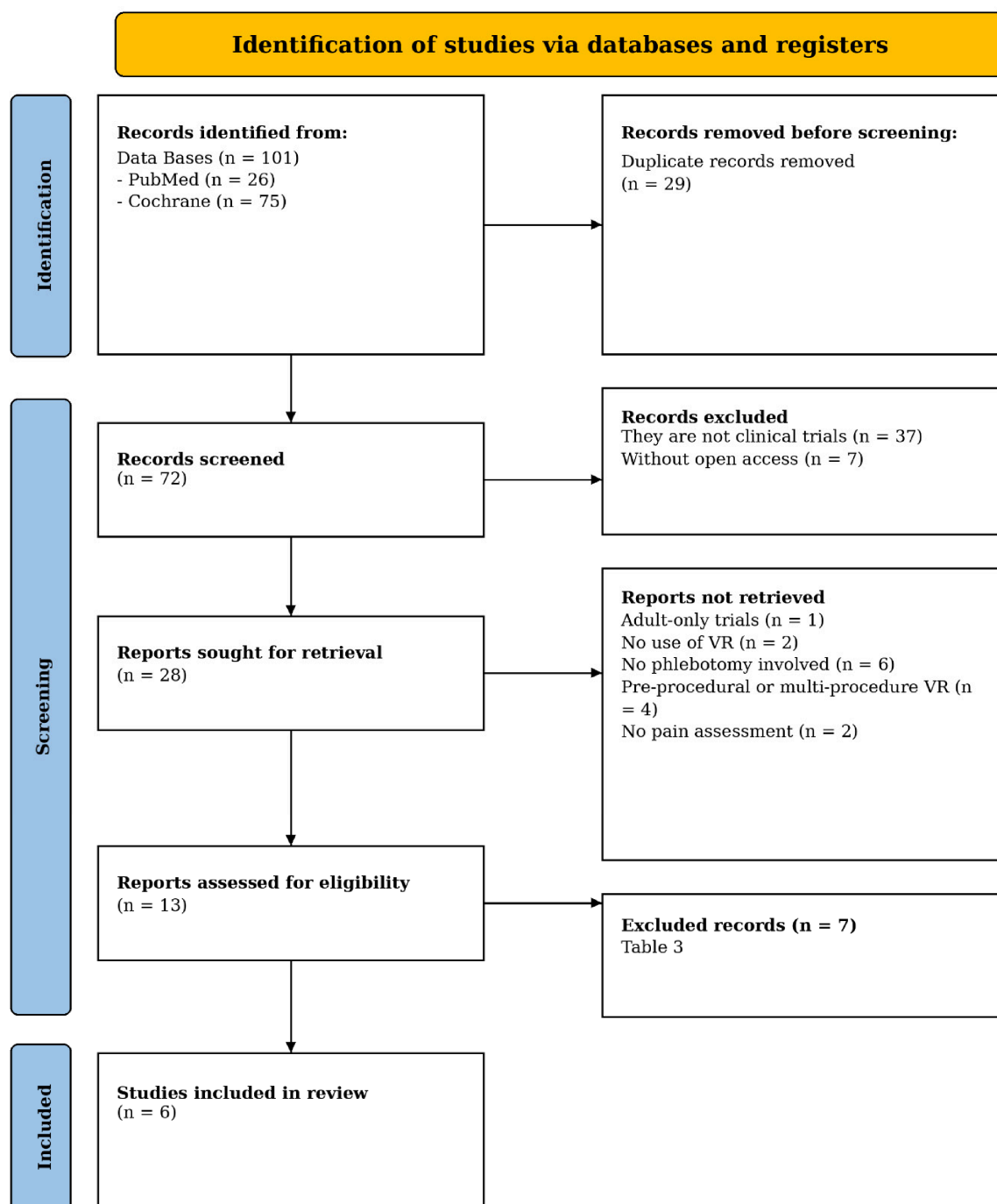
2.4. Study Selection

The study selection process was conducted in accordance with the PRISMA 2020 guidelines and is summarized in the PRISMA flow diagram presented in Figure 1 [13]. The flow diagram provides a transparent overview of the identification, screening, eligibility assessment, and inclusion stages of the review process.

A total of 101 records were identified through database searching, including 26 records retrieved from PubMed® and 75 from the Cochrane Central Register of Controlled Trials (CENTRAL®). Following the removal of 29 duplicate records, 72 unique studies remained for title and abstract screening.

During the initial screening stage, studies that clearly did not meet the predefined eligibility criteria were excluded. The remaining records were subsequently subjected to full-text assessment to determine their eligibility for inclusion in the review. Full-text evaluation was performed independently by two reviewers using the previously established inclusion and exclusion criteria.

Following the eligibility assessment, six studies met all selection criteria and were included in the final qualitative synthesis. Seven full-text articles were excluded at this stage for specific methodological or eligibility-related reasons, which are detailed in Table 3. The most common reasons for exclusion included the use of interventions that did not correspond to immersive virtual reality, the inclusion of populations outside the predefined age range, the absence of phlebotomy procedures, and study designs that did not meet the methodological requirements of the review.



**Figure 1.** PRISMA 2020 flow diagram illustrating the identification, screening, eligibility assessment, and inclusion of studies.

To ensure consistency, transparency, and methodological rigor throughout the study selection process, all records identified through the database searches were independently screened by two reviewers. Disagreements regarding study eligibility at either the title and abstract screening stage or the full-text assessment stage were resolved through discussion and consensus, with decisions guided by the predefined inclusion and exclusion criteria. This approach helped minimize the risk of selection bias and subjective judgment during the screening process. Complete agreement was ultimately achieved for all studies considered eligible for inclusion, and therefore the involvement of a third reviewer was not required.

Table 3. Excluded studies and reasons for exclusion.

| Studies                           | Reasons for Exclusion                                            |
|-----------------------------------|------------------------------------------------------------------|
| Study 1—Ali et al., 2022          | Simultaneous application of analgesia and VR                     |
| Study 2—Besirik et al., 2024      | Compares only two methodologies                                  |
| Study 3—Camacho-Cruz et al., 2023 | VR applied during vaccination                                    |
| Study 4—Canares et al., 2021      | Sample age range does not match the study’s established criteria |
| Study 5—Gold et al., 2024         | Sample age range does not match the study’s established criteria |
| Study 6—Mohamed et al., 2023      | Compares only two methodologies                                  |
| Study 7—Zavlanou et al., 2024     | Compares only two methodologies                                  |

2.5. Methodological Quality Assessment

The methodological quality of the included randomized controlled trials was assessed using the revised Risk of Bias 2 (RoB 2) tool developed by the Cochrane Collaboration [16]. This instrument is widely recommended for evaluating the internal validity of randomized studies and provides a structured assessment of potential sources of bias that may influence study findings.

In accordance with the RoB 2 framework, the methodological quality assessment examined five domains of potential bias, namely bias arising from the randomization process, deviations from intended interventions, missing outcome data, outcome measurement, and the selection of reported results [16].

Each domain was classified as presenting “low risk of bias,” “some concerns,” or “high risk of bias,” in accordance with RoB 2 guidance. The overall risk-of-bias judgment for each study was derived from the individual domain assessments.

Quality assessment was conducted independently by two reviewers. Any discrepancies in scoring were discussed and resolved through consensus to ensure consistency and methodological rigor.

Attention was given to outcome measurement, as pain and anxiety are predominantly assessed using self-reported instruments in pediatric populations. Consequently, limitations related to participant blinding and the subjective nature of outcome measures were considered when evaluating this domain.

Table 4 summarizes the risk-of-bias assessment for all included studies.

Table 4. Risk of bias assessment of the included studies.

| Study                                  | Atzori et al., 2022 [2] | Pérez-Moneo et al., 2024 [17] | Alonzi et al., 2022 [18] | Wong & Choi, 2023 [19] | Özalp Gerçeker et al., 2020 [20] | Osmanlliu et al., 2021 [21] |
|----------------------------------------|-------------------------|-------------------------------|--------------------------|------------------------|----------------------------------|-----------------------------|
| Domain                                 |                         |                               |                          |                        |                                  |                             |
| Randomization                          | Low                     | Low                           | Low                      | Low                    | Low                              | Low                         |
| Deviations from intended interventions | Some concerns           | Some concerns                 | Some concerns            | Some concerns          | Some concerns                    | Some concerns               |
| Incomplete outcome data                | Low                     | Low                           | Low                      | Low                    | Low                              | Low                         |
| Outcome measurement                    | High                    | High                          | High                     | Some concerns          | Some concerns                    | Some concerns               |
| Selective reporting                    | Low                     | Low                           | Low                      | Low                    | Low                              | Low                         |
| Overall judgment                       | Some concerns           | Some concerns                 | Some concerns            | Some concerns          | Some concerns                    | Some concerns               |

Overall, the included studies demonstrated an acceptable methodological quality. All studies presented a low risk of bias regarding the randomization process, missing outcome

data, and selective reporting. However, concerns were identified in the domains related to deviations from intended interventions and outcome measurement.

The most frequently observed limitation was the potential for measurement bias associated with self-reported pain and anxiety outcomes, which are inherently subjective and difficult to blind to in studies involving immersive VR interventions. Consequently, although the overall risk of bias was judged as “some concerns” across all included studies, the available evidence remains sufficiently robust to support qualitative synthesis while highlighting the need for future trials with enhanced methodological standardization and reporting practices.

2.6. Data Extraction

Data extraction was performed independently by two reviewers using a standardized data extraction form developed specifically for this review. The extraction process was designed to ensure consistency, completeness, and transparency in the collection of relevant study information.

The extracted data included: study identification (authors and year of publication), study design, country of origin, sample characteristics (sample size and participant age range), clinical setting, characteristics of the virtual reality intervention (hardware, software content, level of interactivity, and duration of exposure), comparator conditions, outcome measures used to assess pain and anxiety, timing of outcome assessments, and the main findings reported by the authors.

To minimize the risk of extraction errors, the extracted information was cross-checked between reviewers. Any discrepancies or uncertainties were discussed and resolved through consensus. The extracted data were subsequently synthesized narratively and summarized in tabular format to facilitate comparison across studies.

3. Results

A total of six randomized or controlled studies published between 2020 and 2024 met the eligibility criteria and were included in the qualitative synthesis. Together, these studies comprised 557 pediatric participants aged between 4 and 17 years and were conducted across diverse healthcare settings in Italy, Spain, the United States, China, Turkey, and Canada.

Table 5 summarizes the main characteristics of the included studies, including study design, sample characteristics, intervention features, and principal outcomes related to pain and anxiety management during phlebotomy or venipuncture procedures.

Table 5. Description of the studies included in the SLR.

| Author                  | Country | Type of Study     | Sample and Objective                                                                                                                                                                                                      | Intervention                                                                       | Results                                                                                                                                                                                                             |
|-------------------------|---------|-------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Atzori et al., 2022 [2] | Italy   | Exploratory Study | N = 82 (ages 7–17 years)<br>Intervention group (IG): N = 41; Control group (no VR) (CG): N = 41<br>Objective: To evaluate the analgesic efficacy of VR in pediatric patients with kidney disease undergoing venipuncture. | VR Device: Sony HMZ-T2<br>Software: SnowWorld—simulates an icy canyon environment. | Pain intensity was significantly lower in the intervention group (IG) compared to the control group (CG) in the sensory (−43%), emotional (−52%), and cognitive (−11%) components. No adverse events were observed. |

Table 5. Cont.

| Author                           | Country | Type of Study                               | Sample and Objective                                                                                                                                                                                                                                                      | Intervention                                                                                                                                             | Results                                                                                                                                                                                                                                                                                                                                                                                                                       |
|----------------------------------|---------|---------------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Pérez-Moneo et al., 2024 [17]    | Spain   | Randomized Clinical Trial                   | N = 78 (ages 5–12 years); Intervention group (IG): N = 39; Control group (CG): N = 39<br>Objective: To evaluate the effect of VR, during venipuncture, on pain perception, anxiety, and fear in children.                                                                 | VR device: Meta Quest® head-mounted display, featuring two immersive environments (nature walks and an underwater life simulation).                      | With respect to pain reduction, no statistically significant differences were observed between the intervention group and the control group (mean difference = $-0.85$ ; 95% CI: $-2.02$ to $0.33$ ; $p = 0.129$ ).                                                                                                                                                                                                           |
| Alonzi et al., 2022 [18]         | USA     | Randomized Clinical Trial                   | N = 49 (ages 6–17 years); Intervention group (IG): N = 26; Control group (CG): N = 23<br>Objective: To assess whether VR reduces pain, anxiety, and fear during phlebotomy procedures in pediatric patients.                                                              | VR device: Samsung Gear head-mounted display. Interactive applications were initiated 1 min prior to venipuncture.                                       | The intervention group exhibited significantly lower anxiety levels ( $1.75$ vs. $3.00$ ; $p = 0.05$ ), a greater reduction in fear over time ( $p = 0.049$ ), and lower pain intensity ( $2.33$ vs. $3.61$ ; $p = 0.040$ ) compared with the control group. Children's cooperation during the procedure was higher in the intervention group (mICC: $0.33$ vs. $1.44$ ; $p = 0.007$ ). Only one case of nausea was reported. |
| Wong & Choi, 2023 [19]           | China   | Randomized Clinical Trial                   | N = 149 (ages 4–12 years); Intervention group (IG): N = 75; Control group (CG): N = 74<br>Objective: To evaluate the effects of VR on reducing pain and anxiety in pediatric patients undergoing venipuncture.                                                            | VR intervention: Smartphone-adapted goggles. Software: An animated cartoon character that also undergoes the venipuncture procedure.                     | The results demonstrated a significantly smaller increase in pain in the intervention group at T2 (post-venipuncture) compared with T0 (10 min prior to venipuncture), relative to the control group ( $\beta = -0.78$ ; 95% CI: $-1.21$ to $-0.35$ ; $p < 0.001$ ).                                                                                                                                                          |
| Özalp Gerçeker et al., 2020 [20] | Turkey  | Randomized Clinical Trial                   | N = 136 (ages 5–12 years); Intervention group 1 (VR-Rollercoaster): N = 45; Intervention group 2 (VR-Ocean Rift): N = 45; Control group (CG): N = 46<br>Objective: To assess whether two VR applications reduce pain, fear, and anxiety during phlebotomy.                | VR device: Samsung Gear Oculus head-mounted display. Applications: Rollercoaster (dynamic environment) and Ocean Rift (relaxing underwater environment). | Significantly lower pain levels were observed in the groups using virtual reality compared with the control group ( $p < 0.001$ ). Fear and anxiety were also reduced after the procedure ( $p < 0.001$ ). No statistically significant differences were found between the two VR applications. No adverse effects were reported.                                                                                             |
| Osmanlliu et al., 2021 [21]      | Canada  | Pragmatic Randomized Controlled Pilot Trial | N = 63 (ages 7–17 years); Intervention group (IG): N = 31 (1 child excluded due to software error); Control group (CG): N = 31<br>Objective: To determine the feasibility and acceptability of VR distraction in managing pain and anxiety during intravenous procedures. | VR intervention: Rift® head-mounted display and Dreamland® game, which used head movements for aiming and a manual trigger for interaction.              | Self-reported pain levels were similar between the groups (median [IQR]: 3 [1–6] vs. 3 [1–5.5]; $p = 0.75$ ). High levels of satisfaction with the use of virtual reality were reported by patients, parents, and healthcare professionals. Mild side effects were recorded in five children (16.7%), including nausea, dizziness, and headaches.                                                                             |

### 3.1. Characteristics of the Included Studies

The included studies demonstrated considerable heterogeneity regarding sample size, clinical context, VR technology, intervention design, and outcome assessment methods. Sample sizes ranged from 49 participants [18] to 149 participants [19]. Five studies employed randomized controlled trial designs, while one was conducted as a pragmatic randomized controlled pilot trial.

The VR interventions were delivered using different immersive technologies, including Sony HMZ-T2, Samsung Gear Oculus, Meta Quest, Rift® head-mounted displays, and smartphone-adapted immersive goggles. Virtual environments ranged from interactive games and animated educational content to relaxing natural environments and immersive simulations specifically designed to distract participants during needle-related procedures.

### 3.2. Effects on Pain Perception

Four of the six included studies reported statistically significant reductions in pain intensity associated with immersive VR interventions. Atzori et al. [2] observed substantial reductions in sensory, emotional, and cognitive pain components among children undergoing venipuncture [2]. Similarly, Alonzi et al. [19] reported significantly lower pain scores in the VR group, while Wong and Choi [19] found a significantly smaller increase in pain following venipuncture among participants exposed to VR.

Özalp Gerçeker et al. [20] also demonstrated significantly lower pain levels in both VR intervention groups compared with standard care. Notably, no significant differences were observed between the two VR applications evaluated, suggesting that the beneficial effects may be associated with immersion itself rather than specific software content.

Conversely, Pérez-Moneo et al. [17] and Osmanlliu et al. [21] did not identify statistically significant differences in pain intensity between intervention and control groups. Nevertheless, both studies reported positive user experiences and high levels of acceptability.

### 3.3. Effects on Anxiety and Fear

Beyond pain reduction, several studies reported beneficial effects of VR on anxiety- and fear-related outcomes. Alonzi et al. [18] observed significantly lower anxiety levels and greater reductions in fear among participants receiving the VR intervention. Likewise, Özalp Gerçeker et al. [20] reported significant reductions in both anxiety and fear following phlebotomy procedures.

Although anxiety reduction was not consistently observed across all studies, the overall evidence suggests that immersive VR may contribute positively to the emotional experience of pediatric patients undergoing needle-related procedures.

### 3.4. Acceptability and Adverse Events

Overall, immersive VR interventions demonstrated high levels of acceptability among children, parents, and healthcare professionals. Osmanlliu et al. [21] reported particularly high satisfaction levels despite the absence of significant differences in pain outcomes.

Adverse effects were generally mild and infrequent. Atzori et al. [2] and Özalp Gerçeker et al. [20] reported no adverse events. Alonzi et al. [18] documented a single case of nausea, whereas Osmanlliu et al. [21] reported mild symptoms, including nausea, dizziness, and headache in a small proportion of participants. No serious adverse events were identified across the included studies.

### 3.5. Outcome Assessment Methods

Considerable variability was observed in the instruments used to assess pain and anxiety outcomes. Pain intensity was measured using several validated pediatric scales,

including the Numerical Rating Scale (NRS), the Wong–Baker FACES® Pain Rating Scale, and the Faces Pain Scale–Revised (FPS-R). Furthermore, assessment timing differed substantially across studies, with measurements performed before, during, immediately after, and up to 30 min following the procedure.

This methodological heterogeneity limits direct comparisons across studies and precluded quantitative synthesis through meta-analysis.

Overall, the findings suggest that immersive virtual reality may be an effective non-pharmacological intervention for reducing pain and anxiety during pediatric phlebotomy procedures. However, differences in VR technologies, intervention protocols, participant characteristics, clinical settings, and outcome assessment methods contribute to variability in the reported effectiveness and should be considered when interpreting the results.

## 4. Discussion

### 4.1. Principal Findings

The present systematic literature review examined the effectiveness of immersive virtual reality as a non-pharmacological strategy for reducing pain and anxiety during pediatric phlebotomy procedures. Overall, the findings suggest that immersive VR has considerable potential to improve the procedural experience of children and adolescents undergoing needle-related interventions. Four of the six included studies reported statistically significant reductions in pain and/or anxiety, whereas two studies did not identify significant differences compared with standard care.

The positive effects observed across most studies support the growing body of evidence indicating that immersive VR can function as an effective distraction and emotional regulation tool during painful medical procedures. In particular, the studies by Atzori et al. [2], Alonzi et al. [18], Wong and Choi [19], and Özalp Gerçeker et al. [20] consistently demonstrated improvements in pain-related outcomes and, in several cases, reductions in anxiety and fear.

### 4.2. Comparison with Previous Literature

The findings of the present review are broadly consistent with previous systematic reviews and meta-analyses investigating the use of virtual reality interventions in pediatric healthcare settings. Earlier reviews have reported beneficial effects of VR in reducing pain, anxiety, fear, and procedural distress across a range of clinical contexts, including needle-related procedures, burn care, wound management, rehabilitation, and perioperative settings [1,3,8]. These studies collectively suggest that immersive technologies can serve as valuable non-pharmacological tools for improving the experience of pediatric patients undergoing painful medical procedures.

However, unlike previous reviews that examined multiple clinical contexts and diverse procedural applications, the present review focused specifically on immersive VR interventions during pediatric phlebotomy and venipuncture procedures. This narrower scope enabled a more detailed analysis of the effectiveness, feasibility, and implementation challenges associated with VR within a specific and frequently performed pediatric intervention. By concentrating on studies published between 2020 and 2025, this review also reflects recent advances in immersive VR hardware and software, providing an updated perspective on contemporary clinical applications.

The findings are further supported by recent studies that have expanded the evidence base for VR use in pediatric needle-related procedures. The effectiveness of immersive VR in pediatric care is further supported by the work of Ferraz-Torres et al. [9], who reported significant reductions in pain and anxiety using both passive and interactive VR modalities. Their later study also highlighted beneficial effects on the overall procedural experience

of children and their parents in emergency care settings [10]. Similarly, Gold et al. [11], in a secondary analysis of a randomized controlled trial, highlighted the importance of individual patient characteristics and levels of immersion in influencing anxiety and pain outcomes during venipuncture, suggesting that intervention effectiveness may be partially moderated by participant-specific factors.

More recently, Gerçeker et al. [12] compared active and passive VR distraction techniques during pediatric phlebotomy and reported significant reductions in pain, anxiety, fear, and negative emotional responses compared with standard care. Notably, their findings suggest that different forms of immersive VR may be effective, reinforcing the broader conclusion that engagement and immersion play an important role in the modulation of procedural distress.

Taken together, the findings from the studies included in this review and the more recent evidence available in the literature consistently support the potential of immersive VR as a safe, acceptable, and effective adjunctive intervention for managing pain and anxiety during pediatric needle-related procedures. This interpretation is further reinforced by recent publications from 2026. Sanad et al. [22] reported significant reductions in pain, fear, and distress during pediatric venipuncture following the use of immersive virtual reality interventions, while Jing et al. [23], in a systematic review of needle-related procedures, concluded that virtual reality represents an effective non-pharmacological strategy for reducing pain, anxiety, and fear in children. These recent findings further strengthen the growing evidence base supporting the integration of immersive technologies into pediatric procedural care.

#### *4.3. Potential Mechanisms of Action*

Several mechanisms may explain the beneficial effects observed across the included studies. Immersive VR environments compete with nociceptive stimuli for attentional resources, reducing the cognitive processing of pain signals. In addition, VR promotes emotional engagement, positive affect, and cognitive reappraisal, which may contribute to reductions in anxiety and fear.

Neurophysiological evidence further suggests that immersive VR influences neural activity in regions associated with pain perception and emotional processing, supporting its role as more than a simple distraction technique. The combination of attentional, emotional, and sensory mechanisms likely explains the multidimensional benefits observed across studies.

#### *4.4. Sources of Heterogeneity*

Despite encouraging findings, substantial heterogeneity was observed across studies. Variability existed in participant age ranges, clinical settings, VR hardware, software content, intervention duration, and outcome assessment methods.

Differences in immersion levels may be particularly relevant. Some interventions relied on highly immersive head-mounted displays with interactive content, whereas others employed simpler or less interactive systems. These differences may partly explain why certain studies reported significant benefits while others did not.

Furthermore, pain and anxiety were assessed using different instruments and at varying time points, limiting direct comparability between studies and preventing quantitative synthesis through meta-analysis.

#### *4.5. Clinical Implications*

Beyond pain reduction, several studies reported improvements in anxiety, fear, cooperation, and overall procedural satisfaction. These findings suggest that the clinical value of VR may extend beyond analgesia alone.

From a practical perspective, immersive VR appears to be a safe and acceptable intervention, with only mild and transient adverse effects reported. Consequently, VR may represent a useful adjunctive strategy for healthcare professionals seeking to improve pediatric patient experiences during phlebotomy procedures.

An important consideration for future implementation relates to infection prevention and device management. Only one included study explicitly described infection control procedures. Future clinical protocols should therefore address device sanitation, disposable components, and workflow integration to ensure safe and scalable implementation.

#### 4.6. Limitations

Several limitations should be considered when interpreting the findings of this review.

First, only six studies met the eligibility criteria, reflecting the limited number of high-quality clinical trials specifically focused on immersive VR during pediatric phlebotomy procedures. Second, substantial methodological heterogeneity was observed across studies, including differences in VR technologies, intervention protocols, outcome measures, and clinical settings.

Third, the review was restricted to studies published in English and searched within PubMed and CENTRAL, which may have limited the identification of additional relevant studies. Finally, a quantitative meta-analysis was not feasible due to the clinical and methodological heterogeneity of the included studies.

#### 4.7. Future Research

Future research should prioritize large-scale randomized controlled trials employing standardized VR protocols, harmonized outcome measures, and comprehensive reporting of implementation procedures. Additional investigation is also needed to determine the influence of immersion level, content design, patient characteristics, and clinical context on intervention effectiveness.

Furthermore, future studies should address practical implementation factors, including cost-effectiveness, infection control procedures, user training, and long-term acceptability within routine clinical practice.

### 5. Conclusions

The present systematic literature review aimed to evaluate the effectiveness of immersive virtual reality as a non-pharmacological intervention for reducing pain and anxiety during pediatric phlebotomy procedures. Based on the analysis of six randomized and controlled studies published between 2020 and 2024, the available evidence suggests that immersive VR has the potential to improve the procedural experience of children and adolescents undergoing needle-related interventions.

Overall, most of the included studies reported beneficial effects of VR on pain perception and anxiety-related outcomes, while also demonstrating high levels of acceptability among patients, parents, and healthcare professionals. Beyond its analgesic potential, immersive VR appears to provide psychological and cognitive benefits by enhancing emotional regulation, reducing fear and distress, and increasing engagement during medical procedures. Furthermore, the intervention was generally well tolerated, with only mild and transient adverse effects reported.

Despite these promising findings, the current evidence base remains limited by methodological heterogeneity across studies, including differences in participant characteristics, clinical settings, VR technologies, intervention protocols, and outcome assessment methods. Consequently, the findings should be interpreted with appropriate caution.

Nevertheless, the results support the growing role of immersive technologies as complementary tools for pediatric pain and anxiety management. The integration of VR into clinical practice may contribute to more positive healthcare experiences, improved patient cooperation, and enhanced quality of care during invasive procedures.

Future research should focus on large-scale, rigorously designed randomized controlled trials employing standardized intervention protocols, harmonized outcome measures, and comprehensive implementation frameworks. Additional research is also needed to address practical considerations such as infection control, cost-effectiveness, staff training, and long-term adoption in healthcare settings. Strengthening the evidence base in these areas will be essential to support the development of clinical guidelines and the broader implementation of immersive VR interventions in pediatric care.

**Supplementary Materials:** The following supporting information can be downloaded at <https://www.mdpi.com/article/10.3390/future4030021/s1>, Table S1: PRISMA 2020 Checklist.

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