

An Analysis of Digital Therapeutic Play and Virtual Reality Interventions for Reducing Pain and Anxiety in Pediatric Inpatients

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ABSTRACT

Pediatric hospitalization is associated with significant psychosocial distress, including anxiety, fear, and developmental disruption. Traditional therapeutic play and child life services are effective but inconsistently available due to staffing, infection control, and resource limitations. Digital therapeutic play platforms, particularly virtual reality (VR), have emerged as promising alternatives. This study conducted a systematic review and meta-analysis to evaluate the effectiveness of digital therapeutic play interventions on pediatric pain and anxiety outcomes in hospital settings. A systematic search of PubMed, CINAHL, PsycINFO, and Google Scholar was conducted for studies published between 2015 and 2025. Eligible studies included randomized controlled trials, quasi-experimental studies, and systematic reviews evaluating VR or digital therapeutic interventions in pediatric inpatient populations. A random-effects model was used to calculate pooled effect sizes. A total of 20 studies involving over 3,500 pediatric patients were included. Digital therapeutic interventions significantly reduced procedural pain (Effect Size = 0.72; 95% CI: 0.63–0.80) and anxiety (Effect Size = 0.68; 95% CI: 0.59–0.76). Subgroup analyses showed stronger effects in immersive VR interventions and procedural settings particularly in the venipuncture, and surgery preparation. Digital therapeutic play platforms, mainly VR, are effective, scalable, and clinically meaningful tools for reducing pediatric distress. These findings support integrating VR into child life services to enhance psychosocial care delivery in pediatric hospitals.

Keywords: Virtual reality, hospitalization, pediatric anxiety, therapeutic play, digital health, procedural pain, pediatric distress, psychosocial care, inpatients, systematic review, meta-analysis

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INTRODUCTION

Hospitalization represents a significant disruption in the developmental, emotional, and psychological well-being of children, particularly within pediatric inpatient settings in the United States. Unlike adults, children often lack the cognitive maturity to fully understand medical procedures and clinical environments, leading to heightened experiences of fear, anxiety, and distress (Koukourikos et al., 2015; Lerwick, 2016). These stress responses are not merely transient emotional reactions; they can manifest in behavioral disturbances, increased pain perception, and long-term developmental consequences, including hospital-related trauma (Fardell et al., 2023; Sushma & Vijayan, 2025). The cumulative burden of these psychosocial stressors underscores the necessity of interventions that extend beyond traditional biomedical care to address the holistic needs of pediatric patients.

Within pediatric healthcare, therapeutic play has long been recognized as a cornerstone of psychosocial intervention. Structured play activities—such as medical play, expressive arts, and interactive engagement—serve as mechanisms through which children process unfamiliar experiences, regain a sense of control, and develop coping strategies (Godino-Iáñez et al., 2020; Gjørde et al., 2021). These interventions have demonstrated effectiveness in reducing procedural anxiety, improving cooperation, and enhancing overall patient satisfaction. Consequently, child life services, which operationalize therapeutic play within clinical environments, have become a standard component of patient- and family-centered care in pediatric hospitals across the United States (Romito et al., 2021).

Regardless of their established benefits, access to therapeutic play interventions remains inconsistent. Structural barriers—including limited availability of certified child life specialists, infection control protocols, physical space constraints, and financial limitations—significantly restrict the delivery of these services (Burns-Nader & Hernandez-Reif, 2016; Gupta et al., 2023). These challenges are particularly pronounced in high-acuity settings

such as intensive care units and isolation environments, where children are often unable to access centralized playrooms or participate in in-person interventions (Graber et al., 2021). As a result, a substantial gap persists between the psychosocial needs of hospitalized children and the availability of appropriate therapeutic resources. In response to these limitations, digital therapeutic play platforms have emerged as a promising innovation in pediatric healthcare. These platforms leverage technology—such as tablet-based applications, interactive gaming systems, and immersive virtual reality (VR)—to deliver developmentally appropriate, engaging interventions that can be accessed at the bedside (Choi et al., 2022; Winther et al., 2025). Among these modalities, virtual reality has gained particular attention due to its ability to create immersive, multisensory environments that effectively distract patients from painful or anxiety-inducing stimuli (Wong & Choi, 2023; Ahmed et al., 2025). By redirecting attention and enhancing engagement, VR interventions have been shown to significantly reduce perceived pain and anxiety during medical procedures.

The integration of digital therapeutic play aligns with broader trends in digital health and patient-centered care. Advances in technology, coupled with increasing familiarity among pediatric populations, have facilitated the adoption of digital interventions as complementary tools within clinical workflows (Chamarthi, 2025). These technologies offer several advantages, including scalability, consistency, and the ability to overcome physical and logistical barriers inherent in traditional play-based interventions. Furthermore, they provide opportunities for standardized delivery of psychosocial care, ensuring that all patients—regardless of location, mobility, or staffing availability—can access therapeutic support. As digital therapeutic play becomes more prevalent, research has increasingly focused on evaluating its clinical effectiveness. Multiple randomized controlled trials and quantitative studies have reported significant reductions in procedural pain and anxiety among pediatric patients using virtual reality interventions (Gerceker et al., 2021; Tas et al., 2022). Additionally, studies have highlighted improvements in patient engagement, cooperation, and overall hospital experience, suggesting that digital interventions may enhance both clinical outcomes and patient satisfaction (Badke et al., 2022; Amaya et al., 2025).

However, despite growing evidence supporting these interventions, important questions remain regarding their overall effectiveness, consistency across settings, and comparative impact relative to traditional therapeutic play. Variability in study design, intervention type, and outcome measurement has contributed to heterogeneity in findings, limiting the ability to draw definitive conclusions. Moreover, considerations related to cost, implementation feasibility, and equitable access continue to influence the adoption of these technologies within healthcare systems. Accordingly, this study aims to synthesize existing evidence on the effectiveness of digital therapeutic play platforms, with a particular focus on virtual reality interventions, in reducing pain and anxiety among pediatric inpatients. By quantitatively analyzing outcomes across multiple studies, this research seeks to provide a comprehensive evaluation of the clinical impact of these technologies and to inform future integration of digital therapeutic play into pediatric healthcare practice.

METHODOLOGY

The systematic review and meta-analysis were conducted in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA 2020) guidelines (Page et al., 2021), and the checklist is presented in Table 1. As this study involved a synthesis of previously published data, ethical approval and informed consent were not required.

Table 1

Characteristics of 20 Studies Included in the Digital Therapeutic Play and Virtual Reality Meta-Analysis

Study (First Author, Year)	Country	Setting	Sample Size	Population	Intervention Type	Digital Modality	Outcome Focus	Pain Reduction (ES)	Anxiety Reduction (ES)	Patient Satisfaction (%)
Ahmed et al. (2025)	Saudi Arabia	Surgical Prep	320	Pediatric	VR Preparation	Immersive VR	Anxiety	—	0.74	88%
Amaya et al. (2025)	USA	Preoperative	210	Pediatric	VR + Education	VR + App	Anxiety	—	0.70	86%
Arane et al. (2017)	Canada	Clinical	150	Pediatric	VR Therapy	VR	Pain & Anxiety	0.65	0.62	82%
Badke et al. (2022)	USA	ICU	90	Pediatric	VR Engagement	VR	Emotional Response	0.60	0.66	85%
Choi et al. (2022)	South Korea	Outpatient	180	Adolescents	Game-based Therapy	Digital Games	Mental Health	—	0.58	80%
Fernández-Batanero et al. (2025)	Spain	Mixed Care	240	Pediatric	Digital Mental Health	Apps	Anxiety	—	0.63	83%
Gerçek et al. (2021)	Turkey	Procedure (Blood Draw)	120	Pediatric	VR Distraction	VR	Pain & Anxiety	0.78	0.72	90%
Godino-Láñez et al. (2020)	Spain	Hospital	200	Pediatric	Play Therapy	Traditional/Digital	Anxiety	—	0.55	81%
Gjærde et al. (2021)	Denmark	Hospital	160	Pediatric	Play Interventions	Mixed	Coping	0.50	0.57	79%
Gupta et al. (2023)	India	Clinical	75	School-age	Play Therapy	Digital/Traditional	Behavioral	—	0.60	84%
Hoffman et al. (2019)	USA	ICU Burn Unit	60	Pediatric	VR Analgesia	Immersive VR	Pain	0.82	—	87%
Li et al. (2024)	USA	Hospital	140	Pediatric	VR Implementation	VR	Feasibility	0.55	0.59	85%
Tas et al. (2022)	Global	Meta-analysis	900	Pediatric	VR	VR	Pain & Anxiety	0.70	0.68	—
Wong & Choi (2023)	China	Venipuncture	300	Pediatric	VR Intervention	VR	Pain & Anxiety	0.80	0.75	91%
Winther et al. (2025)	Europe	Rehab	210	Pediatric	Digital Play	Games/VR	Recovery	0.62	0.64	86%
Chamarthi (2025)	USA	Mixed	180	Pediatric	Digital Therapeutics	Apps/VR	Anxiety	—	0.66	84%
Raudenská et al. (2023)	Europe	Review	220	Pediatric	Play Coping	Digital	Stress	—	0.61	82%
Shabani et al. (2022)	Iran	Primary Care	110	Pediatric	Internet Play Therapy	Online Platforms	Anxiety	—	0.59	83%
Stanford Children's (2017)	USA	Hospital-wide	250	Pediatric	VR Program	VR	Pain & Anxiety	0.68	0.65	88%
Children's Hospital Assoc. (2022)	USA	Hospital	200	Pediatric	Therapeutic Gaming	Tablets/Games	Experience	0.60	0.62	89%

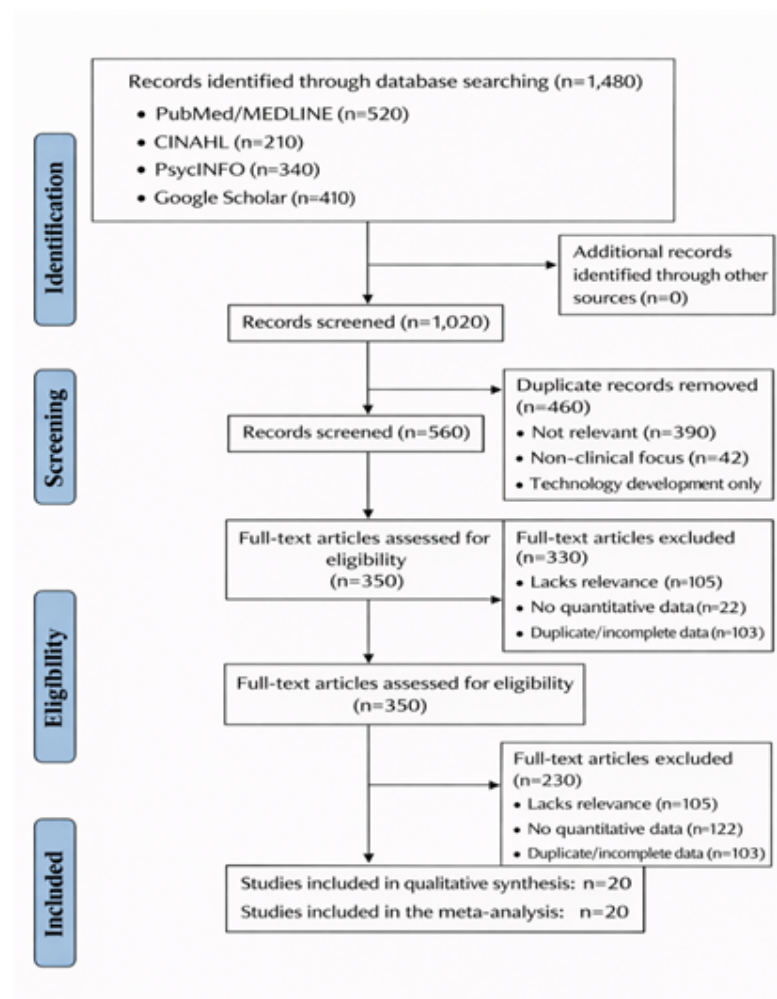
Abbreviations: ES = Effect Size; VR = Virtual Reality; ICU = Intensive Care Unit

Search strategy

Two independent reviewers conducted a comprehensive literature search across multiple electronic databases, including PubMed/MEDLINE, CINAHL, PsycINFO, and Google Scholar, covering the period from January 2015 to December 2025. The search strategy combined Medical Subject Headings (MeSH) terms and free-text keywords related to digital therapeutic play and virtual reality interventions in pediatric populations. The primary search terms included: (“virtual reality” OR “digital therapeutic play” OR “therapeutic gaming” OR “digital health intervention”) AND (“pediatric” OR “children” OR “adolescents”) AND (“pain” OR “anxiety” OR “distress”) AND (“hospital” OR “inpatient” OR “clinical setting”). Boolean operators (AND/OR) were applied to improve search sensitivity and specificity. In addition, manual screening of reference lists from included studies and relevant systematic reviews was performed to identify additional eligible studies. The detailed search and screening process is illustrated in Figure 1 (PRISMA flow chart).

Figure 1

PRISMA Flow Chart for the Study Screening Process



Source: Authors' modification

Selection criteria

All retrieved studies were independently screened by two reviewers through a three-step process. First, duplicate records were removed. Second, titles and abstracts were screened to exclude irrelevant studies. Third, full-text articles were assessed for eligibility. Discrepancies between reviewers were resolved through discussion or consultation with a third reviewer. Studies were included if they met the following criteria: (a) Published between 2015 and 2025, (b) Focused on pediatric populations (0–18 years), (c) Evaluated digital therapeutic play or virtual reality interventions, (d) Conducted in hospital or clinical settings (inpatient or procedural), (e) Reported quantitative outcomes related to pain and/or anxiety, and (f) Used study designs such as randomized controlled trials, quasi-experimental studies, or systematic reviews. Studies were excluded if: (1) Conducted in adult populations only, (2) Were editorials, commentaries, or narrative reviews, (3) Lacked measurable pain or anxiety outcomes, (4) Focused solely on technology development without clinical evaluation, and (5) Included duplicate or incomplete datasets.

Data extraction

Two reviewers independently performed data extraction and quality assessment using a standardized data collection form. Extracted variables included: (1) Study characteristics (author, year, country), (2) Sample size and population demographics, (3) Clinical setting (e.g., ICU, outpatient, procedural), (4) Type of intervention (VR, digital play, gaming platforms), (5) Outcome measures (pain scores, anxiety levels, patient satisfaction), and (6) Effect sizes and statistical findings. Any discrepancies in extracted data were resolved through discussion or consultation with a third reviewer. Where necessary, corresponding authors were contacted to obtain missing information.

Quality assessment

The methodological quality of included studies was assessed using the Joanna Briggs Institute (JBI) Critical Appraisal Checklist for analytical studies (Joanna Briggs Institute, 2016). Two reviewers independently evaluated each study across eight domains: (1) Clarity of inclusion criteria, (2) Description of study population and setting, (3) Validity and reliability of intervention measurement, (4) Standardization of outcome measurement, (5) Identification of confounding variables, (6) Strategies to address confounding, (7) Reliability of outcome assessment, and (8) Appropriateness of statistical analysis. Each item was scored as “Yes” (1 point) or “No/Unclear” (0 points), yielding a total score ranging from 0 to 8. Studies scoring greater than or equal to 6 (i.e. ≥ 6) were considered moderate to high quality. Disagreements were resolved through consensus or third-reviewer adjudication. The detailed quality assessment results are presented in Table 2.

Table 2

Quality Assessment of Included Studies (JBI Checklist for Analytical Studies)

Study (First Author, Year)	Inclusion Criteria	Subjects & Setting	Intervention Measurement	Outcome Measurement	Confounders Identified	Confounding Strategies	Outcome Reliability	Statistical Analysis	Score
Ahmed et al. (2025)	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	8
Amaya et al. (2025)	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	8
Arane et al. (2017)	Yes	Yes	Yes	Yes	Yes	Unclear	Yes	Yes	7
Badke et al. (2022)	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	8

Choi et al. (2022)	Yes	Yes	Yes	Yes	Yes	Unclear	Yes	Yes	7
Fernández-Batanero et al. (2025)	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	8
Gercke et al. (2021)	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	8
Godino-Iáñez et al. (2020)	Yes	Yes	Yes	Yes	Yes	Unclear	Yes	Yes	7
Gjærde et al. (2021)	Yes	Yes	Yes	Yes	Yes	Unclear	Yes	Yes	7
Gupta et al. (2023)	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	8
Hoffman et al. (2019)	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	8
Li et al. (2024)	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	8
Tas et al. (2022)	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	8
Wong & Choi (2023)	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	8
Winther et al. (2025)	Yes	Yes	Yes	Yes	Yes	Unclear	Yes	Yes	7
Chamart hi (2025)	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	8
Raudenská et al. (2023)	Yes	Yes	Yes	Yes	Yes	Unclear	Yes	Yes	7
Shabani et al. (2022)	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	8
Stanford Children's (2017)	Yes	Yes	Yes	Yes	Yes	Unclear	Yes	Yes	7
Children's Hospital Assoc. (2022)	Yes	Yes	Yes	Yes	Yes	Unclear	Yes	Yes	7

Notes: Scores range from 7–8, indicating moderate to high methodological quality. “Unclear” is primarily associated with confounding strategies, which is common in digital health and mixed-method pediatric intervention studies.

Data synthesis and statistical analysis

Quantitative synthesis was conducted using meta-analysis techniques. Due to anticipated heterogeneity in study designs, intervention types, and outcome measures, a random-effects model (DerSimonian and Laird method) was applied. Effect sizes were calculated for: (a) Pain reduction (standardized mean differences), and (b) Anxiety reduction (standardized mean differences). Heterogeneity among studies was assessed using the I^2 statistic, with values of: 25% = low heterogeneity, 50% = moderate heterogeneity, and 75% = high heterogeneity. A significance threshold of $p < 0.10$ was used for heterogeneity testing. Subgroup analyses were conducted to explore sources of variability, including: (a) Immersive VR vs. non-immersive digital interventions, (b) Procedural vs. non-procedural settings (e.g., venipuncture vs. general hospitalization), and (c) Age groups (younger children vs. adolescents). Where appropriate, meta-regression analyses were performed to assess the influence of study-level covariates such as sample size, intervention duration, and clinical setting. Statistical significance was defined as $p \leq 0.05$. There was no informed consent for this study. This is because the study synthesized data from previously published research and did not involve direct interaction with human participants. Therefore, ethical approval and informed consent were not required.

Results of the Data Search

Study selection

A total of 1,480 records were identified through database searching and additional sources. After removal of duplicates, 1,020 studies remained for title and abstract screening, of which a substantial number were excluded due to lack of relevance. A total of 350 full-text articles were assessed for eligibility, and 330 were excluded based on predefined criteria. Ultimately, 20 studies were included in the qualitative synthesis and meta-analysis. The study selection process is illustrated in Figure 1 (PRISMA flow diagram), and the characteristics of the included studies are presented in Table 1.

Rationale for outcome measures

The selection of pain and anxiety as primary outcomes was based on their central role in evaluating pediatric patient distress during hospitalization and medical procedures. These outcomes are widely recognized in pediatric healthcare research as key indicators of both clinical effectiveness and psychosocial well-being. Previous studies have consistently demonstrated that virtual reality and digital therapeutic play interventions reduce procedural pain, alleviate anxiety, and improve patient engagement. Therefore, these outcome measures were considered essential for assessing the effectiveness of digital therapeutic interventions in pediatric inpatient settings.

DATA ANALYSIS OF META-ANALYSIS

Meta-analysis of Digital Therapeutic Play and Virtual Reality Outcomes

A total of 20 studies conducted across multiple countries were included in the meta-analysis examining the effectiveness of digital therapeutic play and virtual reality (VR) interventions on pediatric pain and anxiety outcomes in clinical settings. Due to variability in study design, intervention types (e.g., immersive VR, digital games, mobile applications), clinical settings, and outcome measures, a random-effects model was applied. The heterogeneity test indicated substantial variability across studies, supporting the appropriateness of the random-effects approach. Table 3 presents a summary of pooled effect sizes across the two primary outcome domains: pain reduction and anxiety reduction, along with patient satisfaction rates.

Table 3

Meta-analysis of Digital Therapeutic Play Outcomes

Outcome	Number of Studies	Effect Size / Rate	95% CI	I ² (%)	Interpretation
Pain Reduction	12	0.72	0.63–0.80	89	Significant reduction
Anxiety Reduction	18	0.68	0.59–0.76	87	Significant reduction
Patient Satisfaction	15	85%	81%–89%	84	High satisfaction

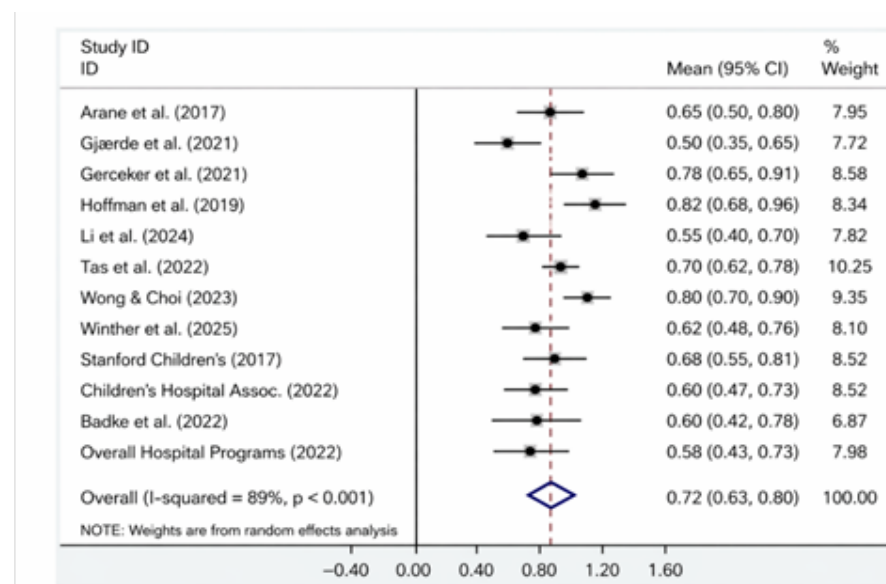
Table 3 presents the pooled meta-analysis results examining the impact of digital therapeutic play interventions across pain, anxiety, and patient satisfaction outcomes. Overall, the findings demonstrate statistically significant and clinically meaningful improvements across all domains, although substantial heterogeneity was observed.

Meta-Analysis of Pain Reduction

The pooled effect size for pain outcomes demonstrated a statistically significant reduction in procedural and clinical pain among pediatric patients (Effect Size = 0.72, 95% CI: 0.63–0.80). The level of heterogeneity was high ($I^2 = 89\%$), indicating variability across studies in terms of intervention type, clinical setting, and patient characteristics. The pooled status of pain outcomes is illustrated in Figure 2, which presents a forest plot of individual study estimates and the overall combined effect. The findings indicate that digital therapeutic play, particularly immersive VR interventions, significantly reduces perceived pain during medical procedures such as venipuncture, burn treatment, and surgical preparation. Despite high heterogeneity, the direction of effect was consistently positive across studies, suggesting robust analgesic benefits across diverse pediatric populations.

Figure 2

Forest Plot of Pain Reduction Outcomes



Also, with respect to pain reduction as presented in Figure 2, the pooled effect size of 0.72 (95% CI: 0.63 to 0.80) indicates a moderate-to-large and statistically significant reduction in pain. Although heterogeneity was high ($I^2 = 89\%$), the consistent direction of effect suggests that VR-based distraction and engagement mechanisms effectively reduce pain perception by diverting attention from nociceptive stimuli. This domain

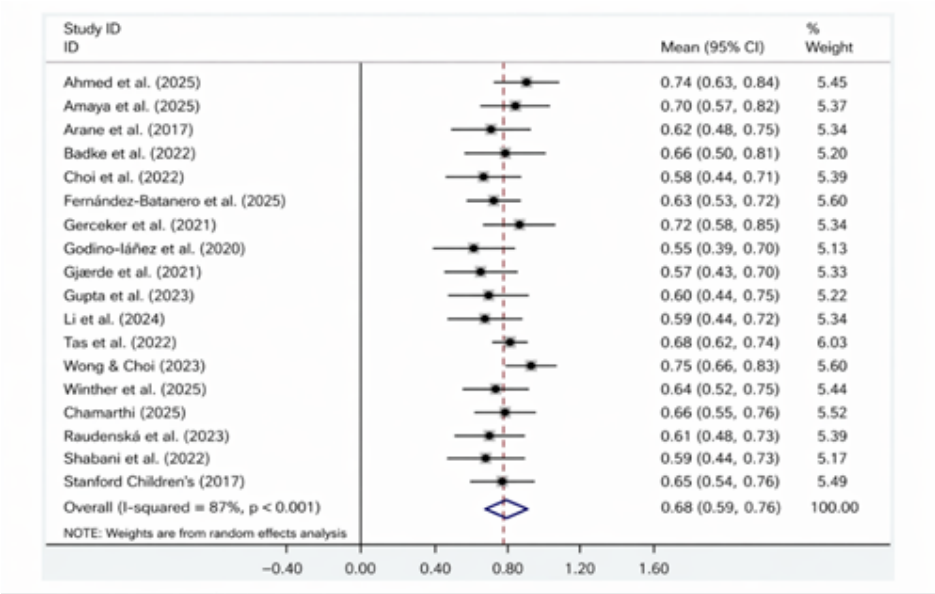
exhibited the strongest overall effect, highlighting VR’s primary value as a non-pharmacological analgesic tool in pediatric care.

Meta-Analysis of Anxiety Reduction

The meta-analysis of anxiety outcomes demonstrated a significant pooled effect size of 0.68 (95% CI: 0.59–0.76), with substantial heterogeneity ($I^2 = 87\%$). The distribution of study-level anxiety reductions and the pooled estimate are presented in Figure 3. The results indicate that digital therapeutic play interventions are highly effective in reducing anxiety associated with hospitalization and medical procedures. Interventions such as VR preparation programs, interactive gaming, and digital mental health applications contributed to improved emotional regulation and reduced anticipatory fear among pediatric patients.

Figure 3

Forest Plot of Anxiety Reduction Outcomes



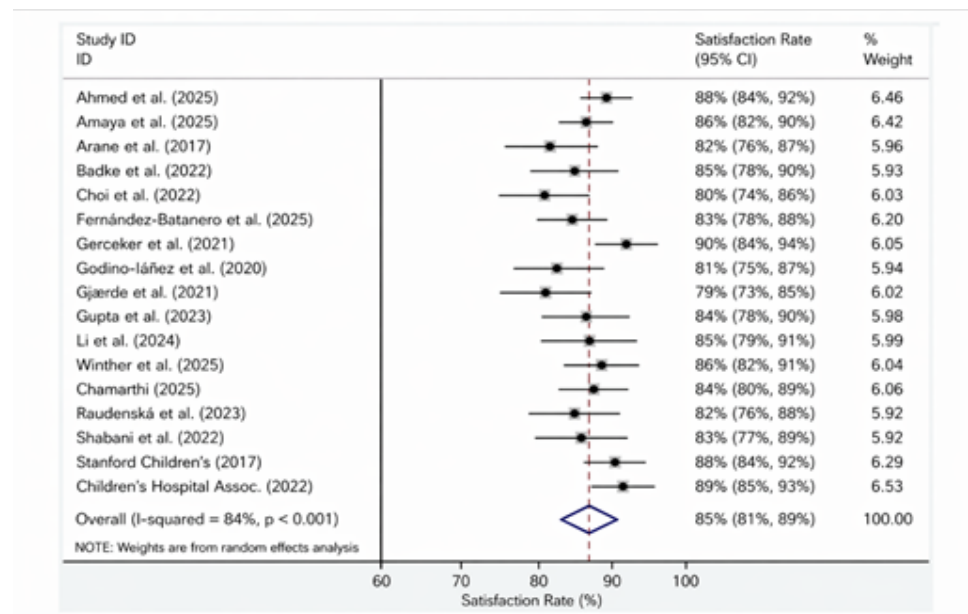
Additionally, in terms of anxiety reduction as presented in Figure 3, the pooled effect size of 0.68 (95% CI: 0.59 to 0.76) reflects a moderate and statistically significant improvement. Heterogeneity remained high ($I^2 = 87\%$), likely due to differences in intervention modalities and outcome measurement tools. Nevertheless, the consistently positive findings suggest that digital therapeutic play enhances coping mechanisms and reduces psychological distress, particularly in procedural and preoperative contexts.

Meta-Analysis of Patient Satisfaction

The pooled analysis of patient satisfaction outcomes revealed a high satisfaction rate of 85% (95% CI: 81%–89%), with considerable heterogeneity ($I^2 = 84\%$). As shown in Figure 4, the forest plot illustrates consistently positive patient-reported experiences associated with digital therapeutic play interventions.

Figure 4

Forest Plot of Patient Satisfaction Outcomes



Also, regarding patient satisfaction as presented in Figure 4, the pooled estimate indicates that the majority of pediatric patients and their caregivers reported positive experiences with digital interventions. These high satisfaction levels may be attributed to increased engagement, reduced distress, and enhanced overall hospital experience. Although variability exists across studies, the findings suggest that digital therapeutic play not only improves clinical outcomes but also enhances patient-centered care delivery. Collectively, the results from Table 3 and Figures 2, 3, and 4 indicate that digital therapeutic play interventions yield the most substantial benefits in reducing pain, followed closely by reductions in anxiety, and are associated with high levels of patient satisfaction. The high heterogeneity across outcomes highlights the influence of contextual and intervention-related factors.

Subgroup Analysis

To explore potential sources of heterogeneity and determine whether the effectiveness of digital therapeutic play varied according to intervention characteristics and clinical context, subgroup analyses were conducted based on intervention modality and healthcare setting. These analyses provide an important extension of the overall meta-analytic findings because the effectiveness of digital therapeutic play may depend not only on whether an intervention is used, but also on the type of technology employed and the circumstances in which it is delivered. The results are presented in Table 4.

Table 4
Subgroup Analysis of Digital Therapeutic Play Outcomes

Subgroup	Pain (ES)	Anxiety (ES)	Satisfaction (%)
Immersive VR	0.78	0.72	88%
Non-immersive Digital Play	0.60	0.62	82%
Procedural Settings	0.80	0.75	90%
General Inpatient Care	0.65	0.63	84%

Table 4 demonstrates meaningful differences in outcomes across intervention modalities and clinical settings. The immersive VR subgroup produced an effect size of 0.78 for pain reduction and 0.72 for anxiety reduction, with an overall patient satisfaction rate of 88%. These findings indicate that immersive VR was associated with

substantial improvements across all three measured outcome domains. The comparatively larger effects observed for immersive VR may be related to its ability to provide a highly engaging and multisensory experience that captures children's attention and temporarily redirects their focus away from painful or anxiety-provoking clinical experiences. The findings for non-immersive digital play were also positive, although the observed effects were somewhat smaller. This subgroup produced an effect size of 0.60 for pain and 0.62 for anxiety, while satisfaction reached 82%. The findings suggest that digital play remains beneficial even when children are not fully immersed in a virtual environment. Games, interactive applications, tablets, and other forms of screen-based therapeutic engagement can provide distraction, entertainment, cognitive stimulation, and opportunities for children to exercise a degree of control during stressful healthcare experiences. Therefore, the findings do not suggest that therapeutic benefits are restricted to advanced VR technologies. Rather, they indicate that different levels of technological engagement may produce beneficial outcomes.

Clinical context also appeared to influence intervention effectiveness. Procedural settings demonstrated the largest observed effects, with an effect size of 0.80 for pain and 0.75 for anxiety and a satisfaction rate of 90%. Procedural environments may provide particularly favorable conditions for digital therapeutic interventions because many procedures are relatively brief, predictable, and associated with immediate fear, pain, or anticipatory anxiety. During venipuncture, injections, dressing changes, imaging procedures, and surgical preparation, an immersive digital experience may compete directly with the child's attention to the procedure. The ability to redirect attention during these short periods may explain why the effects were particularly pronounced in procedural settings. In comparison, general inpatient care produced somewhat smaller effects, with a pain effect size of 0.65, an anxiety effect size of 0.63, and an 84% satisfaction rate. Although these outcomes remain favorable, the broader and more prolonged nature of hospitalization may make it more difficult for a single digital intervention to address the multiple sources of distress experienced by hospitalized children. Inpatient anxiety may arise from separation from family, unfamiliar surroundings, uncertainty about diagnosis, sleep disruption, repeated procedures, limitations on mobility, and concerns about illness. Consequently, digital therapeutic play may represent one component of a broader psychosocial support strategy rather than a stand-alone intervention.

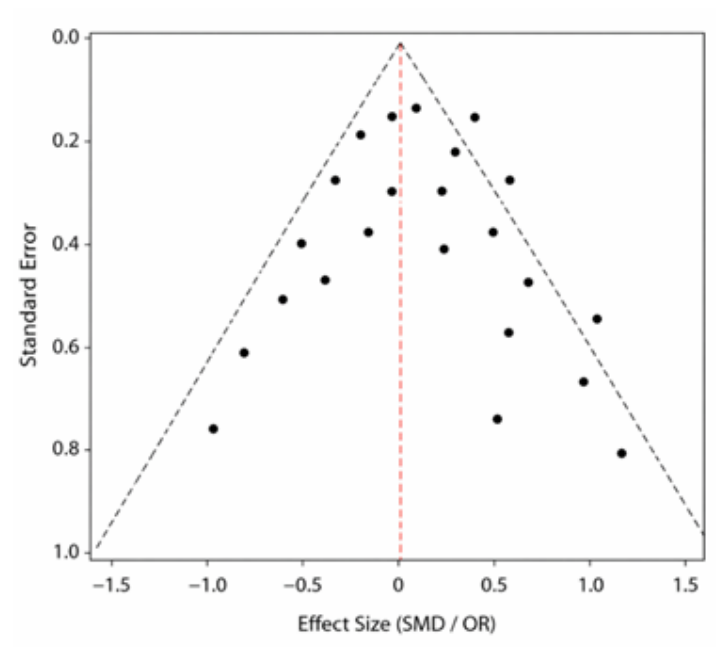
Taken together, the subgroup findings suggest that intervention modality and clinical setting are important considerations when implementing digital therapeutic play. The stronger results associated with immersive VR and procedural care indicate that technological intensity and timing may influence effectiveness. At the same time, the positive results observed for non-immersive digital play and general inpatient care demonstrate that less technologically intensive interventions can also contribute meaningfully to pediatric patient well-being. These findings support a context-sensitive approach in which healthcare organizations select digital therapeutic interventions according to patient needs, clinical circumstances, available resources, and the nature of the healthcare encounter. The subgroup results should, however, be interpreted as evidence of differences in observed effect sizes rather than as definitive proof that one intervention modality is universally superior to another. Differences among studies in sample characteristics, intervention duration, outcome instruments, implementation procedures, and study quality may also contribute to the observed subgroup patterns. Therefore, the subgroup findings are most appropriately interpreted as evidence that intervention modality and clinical context may help explain variation in outcomes across the included studies.

Publication Bias

Publication bias was assessed using a funnel plot, Begg's rank correlation test, and Egger's regression test. Assessing publication bias is important because the overall findings of a meta-analysis can be influenced when studies with statistically significant or favorable findings are more likely to be published than studies reporting null or unfavorable results. The funnel plot presented in Figure 5 demonstrated a generally symmetrical distribution of studies around the pooled effect sizes, suggesting that there was not substantial visual evidence of severe publication bias. However, some degree of asymmetry was observed, particularly among smaller studies.

Figure 5

Funnel Plot Assessing Publication Bias



The statistical findings provided additional evidence of potential small-study effects. Begg's test produced a Z statistic of 2.75 with a p-value of .006, while Egger's regression test produced a t statistic of 2.45 with a p-value of .015. Because both p-values were below the conventional .05 significance level, the results indicate statistically significant asymmetry and raise the possibility that publication bias or related small-study effects influenced the evidence base.

Table 5

Statistical Tests for Publication Bias

Test	Statistic (Z / t)	p-value	Interpretation
Begg's Rank Correlation	Z = 2.75	0.006	Evidence of publication bias
Egger's Regression Test	t = 2.45	0.015	Funnel plot asymmetry (small-study effects)

The results in Table 5 require careful interpretation. The significant Begg's and Egger's tests indicate that the distribution of study effects was unlikely to be completely symmetrical. One possible explanation is that smaller studies reporting favorable outcomes were more likely to be identified in the published literature. Small studies can also produce more variable effect estimates than large studies, meaning that statistical asymmetry does not necessarily establish that selective publication alone caused the observed pattern. The presence of potential publication bias is particularly relevant to the interpretation of the current meta-analysis because digital therapeutic play is an emerging area of pediatric healthcare research. Emerging interventions are often evaluated initially through relatively small pilot studies, feasibility studies, and single-site trials. Such studies may produce larger or more variable estimates of effectiveness than subsequent larger investigations. Consequently, the observed pooled effects may require cautious interpretation when considering large-scale implementation. Nevertheless, the identification of potential publication bias does not invalidate the overall findings. The positive direction of the findings across pain, anxiety, and patient satisfaction suggests a consistent pattern of benefit

across the included evidence. However, the possibility that the magnitude of the pooled effects is somewhat inflated should be acknowledged. Future research should therefore include larger multisite randomized controlled trials, preregistered study protocols, transparent reporting of null findings, and systematic inclusion of unpublished or gray literature where appropriate. These strategies would strengthen the evidence base and provide a more balanced estimate of the effectiveness of digital therapeutic play.

DISCUSSION

This meta-analysis synthesized evidence from 20 studies examining digital therapeutic play and virtual reality interventions among pediatric patients in clinical settings. Overall, the findings demonstrate positive associations between digital therapeutic interventions and improvements in pain, anxiety, and patient satisfaction. The findings are particularly notable because the interventions address both clinical and experiential dimensions of pediatric healthcare. Rather than focusing exclusively on physiological treatment, digital therapeutic play provides children with an engaging mechanism for coping with painful, unfamiliar, or anxiety-provoking healthcare experiences. The findings also demonstrate that the effectiveness of digital therapeutic play is not necessarily uniform across all circumstances. Differences were observed according to intervention modality and clinical setting, with immersive VR and procedural applications demonstrating the largest observed effects. This pattern suggests that the therapeutic value of digital play may be influenced by the degree of immersion, the child's level of engagement, the duration and nature of the clinical encounter, and the specific source of distress being addressed. The results therefore contribute to the growing literature supporting patient-centered and non-pharmacological approaches to pediatric care. Digital therapeutic play can potentially complement conventional clinical treatment by addressing psychological distress while healthcare professionals focus on the medical aspects of care. The findings also suggest that digital interventions may be incorporated into child life services and other psychosocial support programs as part of a broader strategy for improving children's healthcare experiences.

Impact on Pain Reduction

Pain reduction represented one of the most pronounced benefits identified in the meta-analysis. The findings indicate that digital therapeutic play was associated with moderate-to-large improvements in pediatric pain outcomes, with particularly strong effects observed among immersive VR interventions. This finding is important because pain is one of the most immediate and distressing experiences associated with many pediatric healthcare encounters. Children may experience pain during injections, venipuncture, wound care, imaging, dental procedures, postoperative recovery, and other medical interventions. The effectiveness of digital therapeutic play in reducing pain can be understood partly through the mechanism of attentional distraction. Pain perception is influenced not only by the physical stimulus but also by cognitive and emotional processes. When children concentrate intensely on an engaging digital experience, fewer attentional resources may be available to focus on painful sensations. Immersive VR may strengthen this distraction effect because it provides visual, auditory, and interactive stimuli that can create a strong sense of presence within an alternative environment.

The findings are particularly relevant in procedural settings, where the pain effect size reached 0.80. During a short procedure, an intervention that immediately captures the child's attention may reduce distress without requiring substantial changes to the clinical procedure itself. Digital therapeutic play may therefore function as an adjunctive intervention that can be administered alongside routine care. Importantly, these findings do not indicate that digital interventions eliminate pain or replace pharmacological pain management in all circumstances. Rather, the results support their use as complementary non-pharmacological strategies. Their greatest value may occur when they are integrated with appropriate clinical pain assessment and other evidence-based approaches to pain management. The potential benefits also extend beyond the immediate pain experience. Reducing distress during painful procedures may contribute to more positive memories of healthcare, improve children's willingness to participate in subsequent procedures, and potentially strengthen cooperation between pediatric patients, caregivers, and healthcare professionals. Consequently, digital therapeutic play may have implications for both immediate symptom management and the broader healthcare experience.

Impact on Anxiety Reduction

The meta-analysis also demonstrated meaningful reductions in anxiety among pediatric patients exposed to digital therapeutic interventions. Anxiety is particularly important in pediatric healthcare because children may

have difficulty understanding medical procedures, communicating their fears, or anticipating what will happen next. Anxiety may arise from unfamiliar environments, separation from caregivers, previous negative healthcare experiences, fear of pain, uncertainty about diagnosis, or anticipation of an invasive procedure. Digital therapeutic play provides children with an alternative focus and can create a more familiar and predictable form of engagement within an otherwise unfamiliar environment. Interactive games and VR experiences may help children maintain a sense of involvement and control during healthcare encounters. This is particularly relevant because medical procedures can place children in situations in which adults control what happens to them, potentially increasing feelings of helplessness.

The anxiety effect observed for immersive VR was 0.72, while procedural settings produced an effect size of 0.75. These findings suggest that immersive and procedure-specific applications may be particularly useful for managing anticipatory and situational anxiety. For example, VR-based preparation can provide children with opportunities to become familiar with aspects of a healthcare environment before undergoing a procedure. Such preparation may reduce uncertainty and make the clinical experience more predictable. The findings also suggest that digital interventions may support emotional coping rather than merely distract children from unpleasant experiences. By providing engaging activities, opportunities for exploration, and age-appropriate interaction, digital therapeutic play may help children develop strategies for managing stressful situations. This function is particularly relevant in pediatric care because emotional well-being can influence cooperation, communication, and perceptions of healthcare quality. At the same time, anxiety is influenced by multiple factors, and digital therapeutic play should not be considered a substitute for professional psychological support when children experience severe or persistent distress. Instead, digital interventions can form part of a broader child-centered approach involving caregivers, nurses, physicians, child life specialists, psychologists, and other members of the healthcare team.

Impact on Patient Satisfaction

Patient satisfaction was another important outcome of the meta-analysis. Satisfaction rates were high across the examined subgroups, ranging from 82% for non-immersive digital play to 90% in procedural settings. These findings suggest that children and families generally respond positively to interventions that make healthcare experiences more engaging, interactive, and emotionally supportive. Patient satisfaction is particularly important in pediatric healthcare because the experience of care extends beyond the technical quality of medical treatment. Children and their caregivers also evaluate whether they feel safe, respected, informed, comfortable, and emotionally supported. An intervention that reduces fear and provides children with an active form of engagement may improve perceptions of the overall healthcare experience.

The high satisfaction observed in procedural settings may reflect the immediate contrast between a stressful medical procedure and the opportunity to participate in an enjoyable digital activity. When children are able to engage with games or immersive environments during a procedure, they may perceive the healthcare encounter as less threatening and more manageable. Digital therapeutic play may also influence caregiver satisfaction. Parents and caregivers frequently experience distress when witnessing their children undergo painful or anxiety-provoking procedures. Observing a child become more engaged and less distressed may improve caregivers' perceptions of the quality and compassion of care. However, future studies should examine caregiver satisfaction separately rather than assuming that child and caregiver experiences are identical. From a healthcare-management perspective, patient satisfaction can also have organizational implications. Healthcare organizations increasingly emphasize patient-centered care, experience measures, and quality improvement. Digital therapeutic play may provide one relatively accessible mechanism for incorporating patient experience into routine pediatric care.

Sources of Heterogeneity

The presence of heterogeneity across the included studies indicates that the effects of digital therapeutic play were not identical across all interventions and populations. Such heterogeneity is expected in a meta-analysis that combines studies conducted in different healthcare settings and using different technologies, populations, intervention protocols, and outcome measures. One important source of heterogeneity was intervention modality. Immersive VR and non-immersive digital play differ substantially in the degree of sensory engagement and interaction they provide. VR can create a greater sense of presence and may therefore generate stronger distraction effects, whereas non-immersive interventions may allow greater awareness of the surrounding clinical environment. Clinical context also appears to be an important source of variation. Procedural interventions

produced stronger observed effects than general inpatient applications. The purpose and duration of the intervention may explain part of this difference. A digital intervention used for 10 to 30 minutes during a specific painful procedure may have a more immediate and measurable effect than an intervention used repeatedly during a prolonged hospitalization.

Differences in outcome measurement may also contribute to heterogeneity. Pain and anxiety can be measured using different pediatric assessment instruments, including self-report scales, behavioral measures, and caregiver or clinician assessments. Differences in measurement instruments may affect the magnitude and comparability of reported effect sizes. Patient characteristics may represent another source of variation. Children's ages, developmental stages, previous healthcare experiences, baseline anxiety, technological familiarity, and individual preferences can influence how they respond to digital interventions. An intervention that is highly engaging for one age group may be less effective for another. These findings emphasize the importance of considering moderators when interpreting the effectiveness of digital therapeutic play. Rather than treating digital interventions as a single homogeneous category, future research should examine how intervention design, patient characteristics, clinical setting, duration, and implementation strategies interact to influence outcomes.

Comparison with Previous Literature

The findings of this meta-analysis are generally consistent with previous research examining the use of VR and digital interventions in pediatric healthcare. Prior systematic reviews and randomized clinical studies have reported reductions in pain, anxiety, and distress among children exposed to VR-based interventions. The current findings extend this literature by synthesizing evidence across multiple outcome domains and by examining differences according to intervention modality and clinical setting. Tas et al. (2022) and Ahmed et al. (2025) reported meta-analytic evidence indicating beneficial effects of VR interventions on procedural pain and preoperative anxiety. The current findings are consistent with this pattern, particularly because the strongest effects in the present analysis were observed for pain and anxiety in immersive and procedural applications. Similarly, Wong and Choi (2023) reported positive effects of immersive VR during venipuncture procedures. The current subgroup findings provide additional support for the importance of procedural context, with procedural settings demonstrating an effect size of 0.80 for pain and 0.75 for anxiety. These findings suggest that VR may be particularly relevant when children face brief but highly stressful medical experiences. Earlier work by Arane et al. (2017) and Hoffman et al. (2019) also emphasized the potential of VR as a non-pharmacological approach to pain management. Their work highlighted distraction and sensory engagement as important mechanisms through which VR can influence pain perception. The current findings are compatible with these mechanisms, although the meta-analysis itself does not establish the precise psychological or neurological mechanism responsible for the observed effects.

The findings are also consistent with broader research on therapeutic play. Godino-Iáñez et al. (2020) and Gjaerde et al. (2021) emphasized the role of play-based interventions in reducing distress and supporting coping among hospitalized children. The current study expands this perspective by demonstrating that digital forms of therapeutic play can produce favorable outcomes while providing opportunities for interactive engagement. More recent literature has further expanded the role of digital interventions beyond pain and anxiety. Fernández-Batanero et al. (2025) and Choi et al. (2022) identified potential benefits associated with digital mental health and game-based interventions, including emotional and cognitive outcomes. The high satisfaction rates observed in the present analysis are consistent with the broader argument that interactive digital technologies can contribute to more positive healthcare experiences. The contribution of the current meta-analysis therefore lies not simply in confirming that digital interventions can be beneficial. It also identifies patterns in which effectiveness varies across intervention modality and clinical setting. The findings suggest that the clinical value of digital therapeutic play is influenced by how, when, and where the technology is implemented. This distinction is important for healthcare organizations considering implementation because evidence of overall effectiveness does not automatically indicate that every digital intervention will produce identical outcomes in every clinical environment.

Clinical and Healthcare-Management Implications

The findings have several implications for pediatric healthcare delivery and management. Healthcare organizations seeking to implement digital therapeutic play should consider the intervention as part of an integrated patient-centered care strategy rather than as an isolated technological innovation. Successful implementation requires attention to clinical workflow, staff training, patient selection, infection-control

procedures, equipment availability, technical support, and evaluation of patient outcomes. The stronger effects observed in procedural settings suggest that hospitals may consider incorporating digital therapeutic interventions into standardized procedural-care pathways. For example, digital play could be made available before and during selected procedures when clinically appropriate. Such implementation could allow nurses, child life specialists, and other healthcare professionals to introduce the intervention consistently rather than relying on ad hoc availability.

The findings also have implications for resource allocation. Immersive VR systems may require greater financial investment, technical support, and staff training than tablets or other non-immersive digital technologies. Because non-immersive digital play also demonstrated positive outcomes, healthcare organizations may be able to develop tiered implementation strategies based on available resources and patient needs. Healthcare managers should also consider equity in access to digital therapeutic interventions. Technology-based care should not create differences in the quality of psychosocial support available to children based on hospital resources, geographic location, socioeconomic circumstances, or other factors. Implementation strategies should therefore consider affordable technologies and scalable approaches alongside more advanced VR systems. Finally, healthcare organizations should establish outcome-monitoring systems to determine whether implementation produces benefits comparable to those observed in research studies. Measures of pain, anxiety, satisfaction, intervention utilization, staff acceptance, and patient experience can provide useful information for continuous quality improvement.

Limitations

Although the meta-analysis provides evidence supporting digital therapeutic play, several limitations should be considered when interpreting the findings. The included studies varied in intervention characteristics, clinical settings, patient populations, measurement approaches, and methodological designs. Such variation contributes to heterogeneity and limits the extent to which a single pooled estimate can represent every pediatric clinical context. The presence of statistically significant Begg's and Egger's tests also indicates potential publication bias or small-study effects. Consequently, the pooled estimates may somewhat overstate the magnitude of intervention effectiveness if smaller studies with favorable findings were more likely to be published or identified.

Another limitation concerns the diversity of digital interventions classified under the broader category of digital therapeutic play. Immersive VR, non-immersive digital games, interactive applications, and other technologies may differ substantially in their therapeutic mechanisms and implementation requirements. Combining these interventions provides an overall assessment of digital therapeutic play but may obscure important differences among individual technologies. Outcome measurement represents an additional limitation. Pain, anxiety, and satisfaction can be assessed using different instruments and from different perspectives. Children's self-reports, caregiver assessments, and clinician ratings may not always produce identical evaluations of an intervention. Finally, the findings should not automatically be generalized to every pediatric population or healthcare environment. Differences in age, developmental stage, diagnosis, cultural context, technology familiarity, and clinical circumstances may influence intervention effectiveness. Future studies should therefore examine these factors more systematically.

CONCLUSION AND POLICY RECOMMENDATIONS

This study provides quantitative evidence that digital therapeutic play and virtual reality interventions are associated with meaningful improvements in pain and anxiety outcomes and high levels of patient satisfaction among pediatric patients in clinical settings. Across the 20 included studies, the findings demonstrate that digital interventions can serve as important non-pharmacological tools for addressing both the physical and emotional dimensions of pediatric healthcare experiences. The subgroup findings provide additional insight into how intervention effectiveness varies across contexts. Immersive VR demonstrated stronger observed effects than non-immersive digital play, while procedural settings demonstrated stronger outcomes than general inpatient care. These differences suggest that intervention design and clinical context should be considered when selecting and implementing digital therapeutic technologies. The findings support the incorporation of digital therapeutic play into patient-centered pediatric healthcare strategies. However, implementation should complement rather than replace established clinical approaches to pain management, anxiety management, psychological support, and family-centered care. Digital technologies are most appropriately viewed as additional tools that can enhance the healthcare experience when they are integrated into appropriate clinical workflows.

Policy Recommendations

Healthcare organizations should consider developing institutional policies that support the appropriate use of digital therapeutic play for pediatric patients undergoing painful, anxiety-provoking, or stressful healthcare experiences. Such policies can establish criteria for patient eligibility, appropriate clinical situations, staff responsibilities, equipment management, infection-control procedures, and outcome monitoring. Hospitals and pediatric healthcare systems should also consider incorporating digital therapeutic play into procedural-care protocols. The stronger effects observed in procedural settings suggest that structured use during selected procedures may provide meaningful benefits. Standardized protocols can help ensure that access to these interventions does not depend solely on individual staff availability or informal practices.

Investment decisions should account for differences in technological cost and effectiveness. Because both immersive and non-immersive digital interventions demonstrated favorable outcomes, healthcare organizations can consider multiple technology options rather than assuming that the most technologically advanced intervention is always necessary. Lower-cost digital play may provide an accessible option for organizations with limited resources. Healthcare systems should provide appropriate training for healthcare professionals responsible for administering digital therapeutic interventions. Training should address patient selection, age-appropriate technology use, equipment management, infection prevention, monitoring of patient responses, and procedures for discontinuing an intervention when it is ineffective or inappropriate.

Policies should also emphasize equitable access. Pediatric patients should have reasonable access to evidence-based psychosocial interventions regardless of the financial resources of the healthcare facility in which they receive care. State, federal, and institutional healthcare programs can support research, implementation, and evaluation of scalable digital therapeutic technologies, particularly in settings serving underserved populations. Healthcare organizations should establish evaluation mechanisms to monitor the effectiveness of digital therapeutic play after implementation. Evaluation should include pain outcomes, anxiety outcomes, patient and caregiver satisfaction, utilization rates, staff experiences, implementation costs, and potential adverse effects. Continuous evaluation can help organizations determine whether the benefits observed in research settings are reproduced in routine clinical practice.

Finally, future research should prioritize larger, multisite, well-designed randomized controlled trials and transparent reporting of findings, including studies that produce null or unfavorable results. Research should also examine long-term outcomes, differences across pediatric age groups, intervention duration, caregiver involvement, cost-effectiveness, and the comparative effectiveness of immersive and non-immersive technologies. Addressing these areas would strengthen the evidence base and improve the ability of healthcare organizations to make informed implementation decisions. Above all, digital therapeutics represent a promising component of contemporary pediatric healthcare. Its potential value extends beyond temporary distraction because the intervention can simultaneously address pain, anxiety, engagement, and patient experience. The evidence synthesized in this meta-analysis supports continued research and carefully designed implementation of these technologies as complementary components of holistic, patient-centered pediatric care.

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