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Effect of Technology-Based Psychological Empowerment Interventions on Psychological Well-Being of Parents of Pediatric Cancer Patients: A Meta-Analysis of Randomized Controlled Trials

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ABSTRACT

Background: In recent years, technology-based interventions have emerged as effective approaches to provide psychological support for the parents of children with cancer. Despite their increasing use, evidence on the effectiveness of technology-based empowerment interventions remains limited, largely due to the heterogeneity in intervention designs and measured outcomes.

Aim: This meta-analysis aims to evaluate the effectiveness of technology-based psychological empowerment interventions on the psychological well-being of parents of pediatric cancer patients.

Methods: A comprehensive literature search was conducted databases including Scopus, Medline, PubMed, Embase, Cochrane Library, Web of Science, APA PsycINFO, CINAHL Complete, and the Ovid Nursing Database Scopus, Medline, and PubMed identified 8020 studies, from which 9 RCTs involving 698 parents of children with cancer were included. The risk of bias was assessed using the revised Cochrane Risk of Bias (RoB 2) tool. Data analysis was assessed using a random effects model with standardized mean difference (SMD) using Review Manager Version 5.4. Heterogeneity was assessed using the chi-square test and I^2 statistic. Subgroup analyses and sensitivity analyses were performed.

Results: The meta-analysis revealed significant improvements in psychological outcomes, including decreases in distress (SMD: −0.42, 95% CI [−0.70, −0.13], $p = 0.005$), depression (SMD: −0.92, 95% CI [−1.56, −0.27], $p = 0.005$) and anxiety (SMD: −1.47, 95% CI [−2.50, −0.44], $p = 0.005$) immediately after the intervention. Follow-up analyses showed maintained decreases in depression (SMD: −0.39, 95% CI [−0.61, −0.17], $p = 0.005$) and anxiety (SMD:-0.32, 95% CI [−0.58, −0.07], $p = 0.01$). Additionally, significant increases were observed coping (SMD: 4.31, 95% CI [1.19, 7.44], $p = 0.007$) and resilience (SMD: 4.68, 95% CI [1.23, 8.13], $p = 0.008$) immediately after the intervention. However, no significant effect was found on health-related quality of life (SMD: 0.02, 95% CI [−0.25, 0.29], $p = 0.88$).

Conclusion: This meta-analysis provides evidence that technology-based psychological empowerment interventions dramatically improve the psychological well-being of parents of children with cancer. By effectively decreasing distress, depression, and anxiety while enhancing coping skills and resilience, these interventions are emerging as essential components of psychosocial

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support programs. These findings underscore the transformative potential of technology-driven approaches in addressing the unique and multifaceted needs of families, paving the way for more accessible and personalized support systems.

1 | Introduction

A childhood cancer diagnosis profoundly affects not only the affected child, but also their parents, who serve as primary caregivers and emotional anchors throughout the treatment journey. These parents face significant psychological and emotional challenges, including increased anxiety, depression and distress, as they navigate the complexities of pediatric oncology care [1]. The demands extend beyond typical parenting challenges, including uncertain prognoses, intensive treatment regimens and the daily emotional toll of managing their child's illness [2, 3]. Although advances in medical care have improved survival rates, the psychological impact on parents remains significant, highlighting the critical need for effective interventions to support their psychosocial well-being [4–6].

Recently, psychological empowerment has emerged as a key framework for enhancing the psychological well-being of parents of children with cancer [7, 8]. In the context of pediatric oncology, psychological empowerment refers to the process of equipping parents with the necessary resources, skills, and support to increase their sense of control, pro-active coping strategies, enhancing resilience promotion, and enhance their capacity to manage caregiving challenges [3, 9–11]. This concept encompasses multiple dimensions, including reducing distress, anxiety, and depression, as well as enhancing resilience, coping skills, and quality of life, which collectively aim to strengthen parents' psychological well-being and their ability to navigate the complexities of their child's cancer treatment journey [12]. Psychological empowerment interventions differ from traditional psychosocial interventions by taking a broader and more proactive approach. While resilience-based interventions primarily focus on helping parents adapt to adversity, psychological empowerment interventions aim to foster a sense of agency and control by addressing multiple dimensions of psychological well-being at the skills level. These interventions typically include structured components such as enhancing resilience promoting, problem-solving skills, pro-active coping strategies, stress management, and self-efficacy enhancement, offering a holistic framework for supporting parents of children with cancer [11–13]. In this meta-analysis study, psychological empowerment is conceptualized as the core mechanism of the interventions evaluated. Psychological empowerment, as defined in the literature, involves processes that enhance individuals' sense of control, build resilience, strengthen coping skills, and improve self-efficacy. These processes aim to increase parents' capacity to manage caregiving challenges and, in turn, support their psychological well-being. Technology-based psychological empowerment interventions, as examined in this study, are designed to develop these skills and capacities in parents through structured programs [3, 9–11]. Psychological well-being, on the other hand, is used in this study as the outcome framework to evaluate the effects of these interventions. Psychological well-being, as defined, is a multidimensional construct encompassing life satisfaction, the experience of positive emotions, and the ability to cope with negative emotions. In this study, psychological well-being is assessed through specific outcomes; reducing distress, anxiety, and depression, which reflect improvements in the negative dimensions of psychological well-being; enhancing resilience, coping skills, and quality of life, which represent improvements in the positive dimensions of psychological well-being [7, 14]. Thus, in this study, psychological empowerment serves as the mechanism through which the interventions operate, while psychological well-being is the framework used to evaluate their effects. This theoretical framework highlights the complementary yet distinct roles of these two concepts, providing a comprehensive understanding of how technology-based interventions can support parents of children with cancer.

The integration of technology into psychosocial support has transformed the implementation of psychological empowerment interventions by providing more accessible, flexible and personalized solutions for parents of children with cancer [15, 16]. Technology-based empowerment interventions encompass a wide range of digital tools and platforms, including mobile health (m-health) applications such as mobile apps, messaging services, wearable technologies and social media, as well as electronic health (e-health) applications such as web-based platforms, digital programs and virtual reality [17, 18]. These interventions are designed to address parents' unique needs and circumstances by providing specialized support that overcomes traditional barriers, such as time constraints and caregiving responsibilities that often limit access to face-to-face psychosocial services [14]. By utilizing these digital interventions, technology-based empowerment interventions aim to enhance parents' psychological well-being through structured programs that include components such as stress management, pro-active coping strategies, resilience training, and self-efficacy building [19]. These interventions not only provide timely and flexible support, but also foster a sense of connection and empowerment by enabling parents to access resources, skills and peer support networks in real time. This holistic approach ensures that interventions are adaptable to the diverse and dynamic challenges parents face throughout their child's cancer treatment journey [15, 16, 19].

Phiri et al.'s meta-analysis study evaluating the effectiveness of psychoeducational interventions (PEIs) in carers of children with cancer found evidence that PEIs effectively reduce negative psychological outcomes and improve coping skills in carers of children with cancer [20]. Despite the increasing interest in technology-based interventions in pediatric oncology, evidence on the effectiveness of technology-based empowerment interventions in improving parents' psychological well-being is limited due to the heterogeneity of the implemented technology-based empowerment interventions [21]. Therefore, further research is needed to improve the quality of evidence on psychological empowerment interventions for parents of children with cancer [22, 23]. This meta-analysis aims to evaluate the effectiveness of technology-based psychological empowerment interventions on the psychological well-being of parents of pediatric cancer patients by synthesizing data from randomized controlled trials (RCTs) to address the existing gap in the literature. The results from this meta-analysis may provide insight into the development and implementation of evidence-based, technology-based interventions that empower parents, decrease psychological distress and optimize psychologically supportive care for parents throughout the cancer treatment journey.

1.1 | Research Questions

1. What are the characteristics of technology-based psychological empowerment interventions in terms of content, duration, delivery method, and follow-up period?
2. What are the significant findings from each study regarding the effect of technology-based psychological empowerment interventions on the psychological well-being of parents of children with cancer, as compared to control groups?
3. How do technology-based psychological empowerment interventions effect specific psychological outcomes such as distress, depression, anxiety, health-related quality of life, coping, and resilience among parents of children undergoing cancer treatment?
4. Are there differences in the effectiveness of technology-based psychological empowerment interventions across different subgroups (e.g., follow-up period)?

2 | Methods

2.1 | Study Design

This meta-analysis aims to evaluate the effectiveness of technology-based psychological empowerment interventions on the psychological well-being of parents of pediatric cancer patients. By synthesizing data from randomized controlled trials (RCTs), the meta-analysis quantifies the overall effect sizes of these interventions. This approach provides a comprehensive understanding of their impact on psychological outcomes such as anxiety, depression, stress, coping, quality of life, and resilience among parents of children undergoing cancer treatment. The meta-analysis follows the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) guidelines to ensure a rigorous and transparent process in identifying, selecting, and synthesizing evidence [24]. This meta-analysis was registered at the International Prospective Register of Systematic Reviews (PROSPERO Registration ID: CRD4202456 3797). As the data were obtained from previously published studies, the study did not require ethical approval or informed consent.

2.2 | Search Strategy

A comprehensive literature search was conducted across multiple electronic databases, including Scopus, Medline, PubMed, Embase, Cochrane Library, Web of Science, APA PsycINFO, CINAHL Complete, and the Ovid Nursing Database. The search strategy included keywords and MeSH terms related to the target population (e.g., "parents," "caregivers," "childhood cancer"), intervention type (e.g., "technology-based," "digital," "empowerment intervention"), and outcomes (e.g., "distress," "depression," "anxiety," "quality of life," "coping," "resilience") Boolean operators were used to combine terms, and search strategies were adapted for each database. Reference lists of included studies were also manually screened to identify additional eligible studies. These terms were customized to the specific requirements of each database, and filters were applied based on the eligibility criteria defined using the PICOS framework.

2.2.1 | Population

Parents or primary caregivers of children (0–18 years) diagnosed with any type (solid or hematological malignancies) or stage of cancer.

2.2.2 | Intervention

Technology-based empowerment interventions, defined as psychosocial interventions delivered through digital platforms (e.g., mobile applications, online support groups, virtual counseling, educational platforms, hybrid interventions) aimed at improving psychological well-being.

2.2.3 | Comparison

Control groups receiving standard care, waitlist, active control, or other interventions as comparisons.

2.2.4 | Outcomes

The primary outcomes of interest include psychological well-being indicators such as distress, depression, anxiety, quality of life, coping, and resilience.

2.2.5 | Study Design

Randomized controlled trials (RCTs) that evaluate the effect of technology-based psychological empowerment interventions.

The eligibility criteria for this meta-analysis;

- Participants had to be parents or primary caregivers of children (0–18 years) diagnosed with any type (solid or hematological malignancies) or stage of cancer.
- The intervention had to be a technology-based empowerment intervention (either single-component focusing exclusively on empowerment or multi-component interventions incorporating empowerment alongside

other supportive strategies or technology-based hybrid interventions).

- The research included studies published between 2014 and 2024. This time period was chosen because technology-based empowerment interventions have developed rapidly over the last decade. Especially since 2014, digital health technologies (e.g., mobile apps, online support groups, virtual reality) have been more widely integrated into psychosocial interventions. This period reflects systematic reporting of both technological innovations and their integration into clinical practice. The inclusion of studies published before 2014 may create heterogeneity in terms of both the nature of interventions and the technological underpinnings present at that time.
- Only randomized controlled trials (RCTs) published in English were included.

The excluded criteria for this meta-analysis;

- Studies were excluded if they were review articles, observational studies, quasi-experimental designs, noninferiority trial, case reports/series, or focused on survivor-caregiver dyads where the child had completed active cancer treatment.
- Gray literature such as opinion essays, editorials, commentaries, expert consensus reports, conference proceedings, and graduate theses were also excluded.

2.3 | Study Selection and Search Outcomes

The initial search of the databases yielded a number of potentially relevant articles. These articles were imported into Endnote Software Version 21.5 to review all citations and remove duplicates. After eliminating duplicates, two researchers independently performed study selection using data extraction form, reviewing the titles and abstracts of the retrieved reports to exclude studies not meeting the eligibility criteria.

Two independent reviewers screened titles and abstracts for initial eligibility. Full-text articles of potentially eligible studies were then retrieved and assessed based on the predefined inclusion and exclusion criteria. Any discrepancies between reviewers were resolved through discussion or resolved with a third reviewer. The study selection process was documented in a PRISMA flow diagram, detailing the number of studies identified, screened, assessed for eligibility, and included in the final analysis. The last searching was performed in November 2024.

Search strategy

Population

#1 “family” [Mesh] OR “parents” [Mesh] OR fami* OR parent * OR “caregivers” [Mesh] OR carers OR carer* OR “family caregivers” OR “informal caregivers” OR “spouse caregivers” OR fathers* OR mothers* OR “parents of children with cancer” OR “family of children with cancer”

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OR “parents of cancer children” OR “parents of childhood cancer”

Intervention

#2 “app” [Mesh] OR apps OR application OR mobile OR “mobile application” [Mesh] OR phone OR multi*media OR web OR internet OR website OR “web site” OR e-health OR m-Health OR online OR digital OR email OR “social network” OR “electronic communication” OR facebook OR technology OR WeChat OR “mHealth interventions” OR “information technology” OR “digital device” OR e-mail OR telehealth OR “smartphone” OR “smartphone app” OR “digital health interventions” OR “connected health interventions” OR “technology based interventions” OR “telehealth support” OR “videoconference-based interventions” OR “technology-based resilience interventions” OR “technology-based hybrid interventions” OR “web based supportive interventions” OR “web based psychological interventions” OR “technology based psychosocial interventions” OR “tele psycho-oncology” OR “online psychosocial support” OR “mobile psychosocial support” OR “web based empowerment program”

Outcomes

#3 psychological OR psychosocial OR distress OR depression OR anxiety OR fear OR “well-being” OR “psychological well-being” OR “psychosocial well-being” OR “emotional well-being” OR “psychological resilience” OR “family resilience” OR “resilience enhancing” OR “resilience promoting” OR “quality of life” OR “social support” OR coping OR “psychological empowerment”

Study design

#4 “ randomized controlled trials” [Mesh] OR “pilot randomized controlled trials

#5 #1 AND #2 AND #3 AND #4

2.4 | Data Extraction

A comprehensive data extraction form was developed by a single author, incorporating input from co-authors to enhance its clarity and usability. Researchers then extracted the following data from the included studies [1]: Study Information: Authors, year and place of publication, and study design [2]. Sample Characteristics: Sample size and mean age of the parents [3]. Intervention Details: Description of the intervention, duration of the intervention, sessions and frequency of sessions, and mode of delivery of the intervention (e-Health based, m-Health based, etc.) [4]. Control Group: Details on the control group procedures and any additional supportive measures provided [5]. Outcome Measures: Tools and scales used to assess psychological well-being (e.g., measures of anxiety, depression, quality of life, coping, and resilience) [6]. Primary Findings: Specific statistical findings (mean values, standard deviations, and mean differences) [7]. Assessment Time and Follow up: Assessment time points and stating the follow-up periods in the study [8]. Theory Guided: Statement of the theory guiding the study.

Data extracted from the included trials were recorded by two independent researchers using the data extraction form. Any discrepancies identified during this process were resolved through discussion and consensus within the research team, ensuring the accuracy and reliability of the collected data.

2.5 | Quality Assessment of the Included Studies

We used the Cochrane Risk of Bias version 2.0 (RoB 2) tool to assess the methodological quality of the included studies [25]. This tool assesses potential biases in five domains [1]: randomization process [2], deviations from intended interventions [3], missing outcome data [4], measurement of outcomes, and [5] selection of reported results. Each domain was rated as low, high, or unclear risk of bias. The studies' quality was independently evaluated by two reviewers (HOK and EK), and disagreements were resolved by discussion with a third author. This process increased the objectivity and consistency of the review process. For the overall assessment, a study is judged to have a “low risk of bias” if all domains are found to present a low risk of bias. A study was judged to have “some concerns” if at least one domain raised some concerns, provided that no domain showed a high risk of bias. A study was judged to have a “high risk of bias” if at least one domain showed a high risk of bias or if more than one domain revealed some concerns.

2.6 | Data Synthesis and Analysis

A statistical meta-analysis of the pooled data was conducted using Review Manager Version 5.4, Cochrane Collaboration. The inverse variance method was used with a random effects model to account for both within-study and between-study variations. As the evaluated outcomes were assessed with different measurement tools, standardized mean differences (MDs) were adopted [26, 27]. The heterogeneity of the studies was assessed using the standard chi-square test and I^2 statistic. A p-value of less than 0.05 via the chi-square test indicated statistical heterogeneity among the included studies. I^2 values of 25%, 50%, and 75% indicated low, moderate, and high heterogeneity, respectively [28]. The standard mean difference and a 95% confidence interval were used to determine the effect of technology-based interventions considering that outcomes were measured differently among the included studies. The forest plots were used to present the results of the meta-analysis visually [26].

To assess publication bias, funnel plot is created by plotting the effect sizes of studies against their standard errors [25, 26, 29]. In the absence of publication bias, the distribution of studies should be funnel-shaped and symmetrical [29]. However, when the number of studies is small, the funnel plot may appear asymmetrical due to random variation rather than publication bias. The Egger test is a regression analysis assesses funnel plot asymmetry [30]. However, for this test to provide reliable results, it is generally recommended to include at least 10 studies. Analyses conducted with fewer studies may have low power and could yield false positive results. This aligns with the recommendation that these tests should generally include at least 10 studies to evaluate publication bias effectively [26]. This test could not be applied because the number of studies included in the meta-analysis varied between three and six, in line with the recommendation that these tests should generally include at least 10 studies to effectively assess publication bias.

2.7 | Subgroup Analysis and Sensitivity Analysis

Subgroup analyses were performed to explore differences in outcomes across intervention formats (different measurement times post-intervention vs. 6 months after the intervention on the study outcomes). A Leave-One-Out sensitivity analysis was performed to determine the reliability and robustness of the meta-analysis results. A Leave-One-Out sensitivity analysis is performed by sequentially removing each study to assess how much the overall results of the meta-analysis are affected by each study. This approach systematically removes one study at a time to assess the impact of individual studies on the overall results. When the number of studies is small (2–3 studies), removing a study can significantly alter the results of the meta-analysis [26, 27, 31]. The Leave-One-Out analysis indicated that no single study disproportionately affected the pooled effect sizes for the meta-analysis for depression and anxiety, supporting the stability of the findings.

3 | Results

3.1 | Study Selection

A systematic literature search of several databases initially identified 8020 studies. After removing 1742 duplicate records, 6278 studies remained for screening. Titles and abstracts of these studies were screened and 6154 studies (6047 based on title and 107 based on abstract) were excluded. Afterward, 124 reports were tried to be reached and 32 reports could not be retrieved. A total of 92 reports were assessed for eligibility and 83 were excluded for various reasons: study sample [30], study design [20], study intervention [1], study outcome [8] and study comparator [7]. As a result, 9 studies met the inclusion criteria and were included in the meta-analysis, as shown in the PRISMA flow diagram (Figure 1).

3.2 | Study Characteristics

This meta-analysis included nine randomized controlled trials (RCTs) that investigated the effect of technology-based psychological empowerment interventions on the psychological well-being of parents of children and adolescents with cancer. The included studies were published from 2017 to 2024 and conducted in various countries, including South Korea, China, Türkiye, the USA, Sweden, Hong Kong, and the Netherlands [32–40]. In total, the nine studies included 698 parents of children with cancer. The individual sample sizes of the included studies ranged from 40 participants to 146. In seven studies, parents of children with cancer participated, but the majority were mothers. In one study, only mothers of children with cancer participated. The mean age of the parents ranged between 32 and 43 years. The characteristics of the included studies are shown in Table 1.

3.3 | Intervention Characteristics

The interventions included in this meta-analysis varied in their content and type of intervention, the way the intervention was delivered, theoretical based and reflected a comprehensive approach to psychological empowerment of parents of children with cancer.

The content of the interventions varied but generally included components such as relaxation training, stress management techniques, coping skills training and psychological support. For example, Duan et al. used a WeChat-based education and care program including meditation and deep breathing exercises [33], while Cernvall et al. focused on relaxation training and coping with distressing thoughts through an internet-based guided self-help intervention [32].

The interventions were delivered through various modes, including internet-based platforms, mobile health (mHealth) applications, and face-to-face and online sessions. For example, Park et al. used an internet-based family resilience support program [38], while Luo et al. implemented a mobile device-based resilience training program [36]. Ozturk and Katikol delivered a mobile health-based relaxation program [37], while Rosenberg et al. provided both face-to-face and online sessions through the PRISM-P program [39].

The duration and frequency of interventions also differed between studies. Sessions typically ranged from 30 min to 4 h and interventions lasted between 4 weeks and 6 months. Most interventions were delivered weekly, with some studies including follow-up sessions to reinforce learning and support.

The studies used a variety of theoretical frameworks to guide the development of their interventions, including Cognitive Behavioral Theory (CBT), Smith's Attentional Behavioral Cognitive (ABC) Relaxation Theory, Stress and Coping Theory and, Acceptance and Commitment Therapy (ACT) and resilience frameworks. All included studies had control groups.

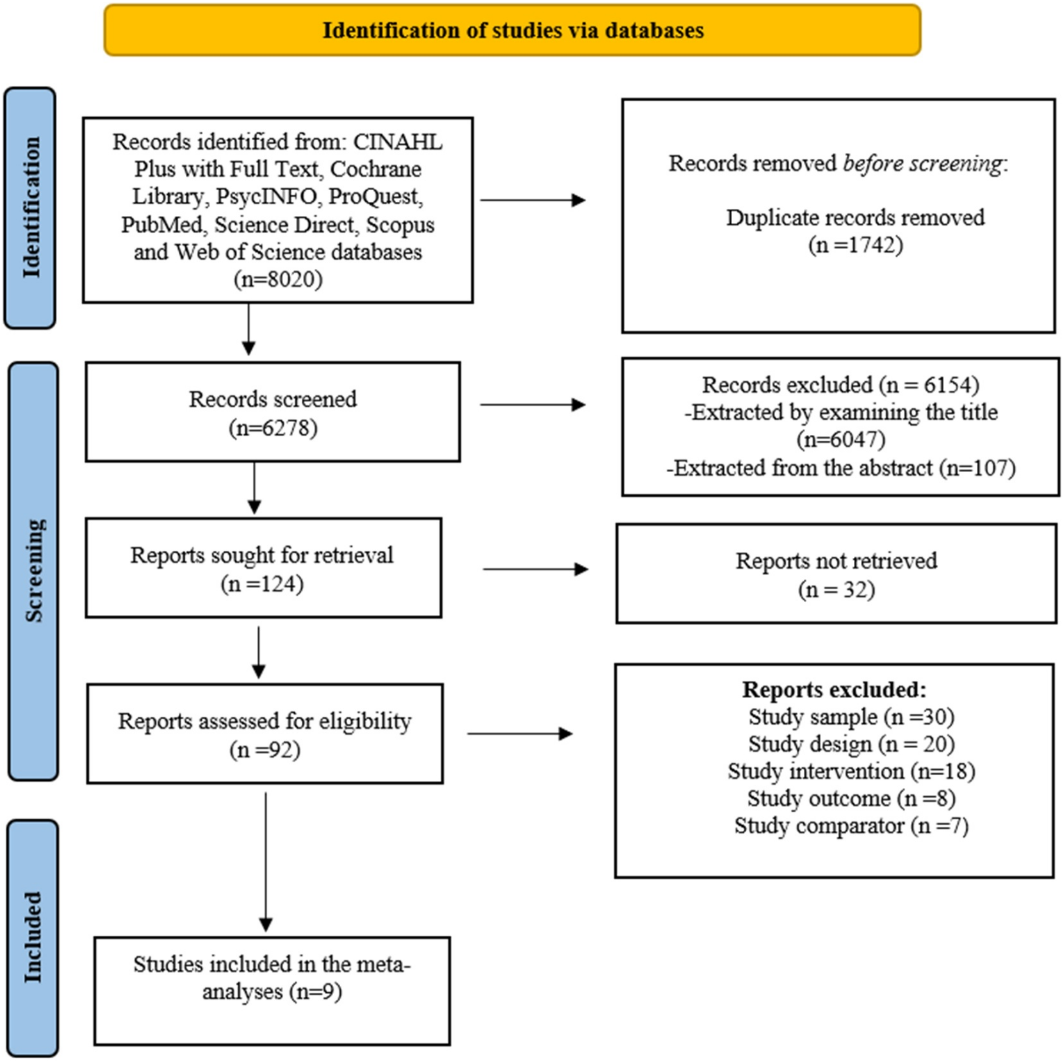


FIGURE 1 | Flow diagram of the studies included in the meta-analysis.

TABLE 1 | Characteristic of included studies.

Author/ year Country	Study design	Participants characteristics	Intervention	Control	Outcome measures	Primary findings	Assessment time	Theoretical frameworks
Park et al. (2023) [38] South Korea	Randomized controlled trial	41 parents of children with cancer Intervention group mean age: 43.0 ± 4.2 years Control group mean age: 41.5 ± 4.8 years	Intervention group: $n = 21$ *Intervention content*: Session 1, the motivation to participate in the program was enhanced Session 2, was to encourage the belief system in the domain of Walsh's family resilience framework Session 3, was to encourage the organization process in the domain of Walsh's family resilience framework Session 4, was to encourage the communication process in the domain of Walsh's family resilience framework *Duration*: Each session is 70 min in total *Frequency*: Once a week *Sessions*: Four sessions *Mode of delivery*: Internet-based (e-health) family resilience-promoting program	Control group: $n = 20$ Standard care	– Family Resilience Scale – Beck Depression Scale – Family Function Scale	Family resilience ($\beta = 13.21$; $p = 0.003$) Depression ($\beta = 2.13$; $p = 0.18$) Family function ($\beta = 1.25$; $p = 0.018$)	– Baseline before randomization – After the intervention – 4 weeks after the intervention (*follow up*)	Walsh's Family Resilience Framework
Luo et al. (2021) [36] China	Randomized controlled trial	103 parents of children with cancer Intervention group mean age: 33.92 ± 5.4 years Control group mean age: 33.22 ± 5 years	Intervention group: $n = 52$ *Intervention content*: Introduction, relaxation, problem-solving skills, character strength training, cognitive strategies, parent-child and communication, gratitude practice *Duration*: 15 min *Frequency*: Once a week *Sessions*: Eight sessions	Control group: $n = 51$ Standard care	– Connor Davidson Resilience Scale – Zung Self-Rating Depression Scale – Short Form 6-Dimension Health Survey	Compared with the participants in the control group in the intervention group, showed higher levels of resilience at 2 months (61.90 ± 14.6; 69.35 ± 13.4; $p = 0.005$) and 6 months (58.27 ± 19.0, 67.96 ± 15.8; $p < 0.001$) Depressive symptoms at 2 months (44.66 ± 8.0, 40.40 ± 9.1; $p = 0.009$) and 6 months	– Baseline before randomization – After the intervention – 6 months after the intervention (*follow up*)	Resilience Model

(Continues)

TABLE 1 | (Continued)

Author/ year Country	Study design	Participants characteristics	Intervention	Control	Outcome measures	Primary findings	Assessment time	Theoretical frameworks
			Mode of delivery: Mobile device-based (mHealth) resilience training program for parents of children with cancer			(46.04 ± 10.9 40.17 ± 9.9; $p < 0.001$) Quality of life in the control group 2 months (0.75 ± 0.1 0.77 ± 0.2; $p = 0.11$) and 6 months (0.76 ± 0.3, 0.79 ± 0.2; $p = 0.07$)		
Ozturk and Katikol (2024) [37] Türkiye	Randomized controlled trial	50 mothers of children with cancer Intervention group mean age: 37.00 ± 5.73 years Control group mean age: 36.76 ± 5.07 years	Intervention group: $n = 25$ *Intervention content*: The mothers in the intervention group participated in a mHealth-based relaxation program for 8 weeks (including progressive muscle relaxation, guided imagery, and the four-leaf clover of mindfulness). Videos of the relaxation program were sent to mothers' WhatsApp accounts *Duration*: NI *Frequency*: One a week *Sessions*: Eight sessions *Mode of delivery*: Mobile health (mHealth) based relaxation-coping program	Control group: $n = 25$ Standard care	– State-Trait Anxiety Inventory – Stress Coping Scales	Anxiety mean scores in the control group after the program were higher compared to the intervention group (45.72 ± 0.99; 44.56 ± 0.84; $Z = -4.382$, $p < 0.05$) Stress coping mean scores higher in the intervention group) than in the control group (91.04 ± 1.57; 58.16 ± 2.55; $t = 11.365$; $p < 0.05$)	– Baseline before randomization – After the intervention	Smith's Attentional Behavioral Cognitive (ABC) Relaxation Theory
Rosenberg et al. (2019) [39] USA	Randomized controlled trial	62 parents of children with cancer Intervention group median (IQR) ages: 35 to (31–41) years Control group median (IQR) ages: 36 (32–44) years	Intervention group: $n = 32$ *Intervention content*: Promoting resilience in stress management for parents (PRISM-P) programs brief intervention targeting 4 skills; these resources included (1) stress management, including relaxation and mindfulness exercises; (2) goal-setting skills, including strategies to set "SMART" (specific, measurable, actionable, realistic, and time-dependent) goals and track forward	Control group: $n = 30$ Standard care	– Connor Davidson Resilience Scale – Benefit Finding Scale – Hope Scale – Medical Outcomes Study 36-item short-form health survey	PRISM-P delivery was associated with improvement compared with standard care in parent-reported outcomes for resilience (β, 2.3; 95% CI, 0.1–4.6; $p = 0.04$) and for benefit finding (β, 0.5; 95% CI, 0.2–0.8; $p = 0.001$) No significant associations were detected between other parent-reported outcomes	– Baseline – 3 months after enrollment	Resilience and Stress and Coping Theories

(Continues)

TABLE 1 | (Continued)

Author/ year Country	Study design	Participants characteristics	Intervention	Control	Outcome measures	Primary findings	Assessment time	Theoretical frameworks
			progress; (3) cognitive reframing, including skills in recognizing negative self-talk and reappraising experiences realistically, if not optimistically; and (4) benefit finding, including identifying gratitude, meaning, and purpose despite adversity *Duration*: 30–60 min *Frequency*: One a week *Sessions*: Four sessions *Mode of delivery*: Face-to-face or online (skype/phone) promoting resilience in stress management for parents (PRISM-P) programs		– Perceived Stress Scale – The 6-item Kessler Psychological Distress Scale			
Duan et al. (2024) [33] China	Randomized controlled trial	146 parents of children with cancer Intervention group median (IQR) ages: 31.0 (25.0–44.0) years Control group median (IQR) ages: 33.0 (26.0–44.0) years	Intervention group: $n = 74$ *Intervention content*: Parents in the WeChat education and care program (WECP) divided into different groups (8-10 parents per team) and received WeChat-based mental and physical health education. This education including training materials articles and training videos (instructional videos on meditation and deep breathing). Parents via WeChat group can add the nurse's account and if can communicate one-to-one with the nurse when they have problems. Also, parents communicated with each other in the WeChat group	Control group: $n = 72$ Standard care	– Self-rating anxiety scale (SAS) score – Self-rating depression scale (SDS) score – 12-item general health questionnaire (GHQ-12) score	SAS scores at T3 (44.8 ± 10.1; 48.8 ± 12.3; $p = 0.041$) and T6 (43.3 ± 9.3 vs. 47.3 ± 12.1; $p = 0.032$) were decreased in the WECP group in comparison with the SC group SDS score at T6 WECP group compared to the SC group (42.7 ± 9.1; 46.5 ± 10.0; $p = 0.024$). Groups (all $p > 0.05$) General state of health of parents, the GHQ-12 scores at T3 (4.4 ± 1.7; 5.3 ± 2.0; $p = 0.007$) and M6 (4.1 ± 1.8; 5.2 ± 1.8; $p = 0.001$) were reduced in the WECP group in comparison with the SC group	– Baseline (T0) – At the first (T1), third (T3), and sixth (T6) months after the intervention (*follow up*)	—

(Continues)

TABLE 1 | (Continued)

Author/ year Country	Study design	Participants characteristics	Intervention	Control	Outcome measures	Primary findings	Assessment time	Theoretical frameworks
			Duration: 60 min *Frequency*: One a week *Sessions*: 6 months *Mode of delivery*: Mobile device-based (mHealth) WeChat education and care program (WECP)					
Cernvall et al. (2017) [32] Sweden	Randomized controlled trial	58 parents of children with cancer Intervention group mean age: 40 ± 7.4 years Control group mean age: 36 ± 6.6 years	Intervention group: $n = 31$ *Intervention content*: Relaxation training, coping with distressing thoughts and feelings, behavioral experiments, problem-solving Structured emotional writing, values and goal setting, general self-care, and maintenance of behavioral change *Duration*: 4 h/session *Frequency*: Weekly *Sessions*: 10 weeks *Mode of delivery*: Internet-based guided self-help intervention for parents of children on cancer treatment	Control group: $n = 27$ Wait list	– Self-reported PTSS with the PCL-C – Beck Depression Inventory – Beck Anxiety Inventory	PTSS, with large between-group effect sizes at after the intervention ($d = 0.89$; 95% CI 0.35–1.43) and at 12-month follow-up ($d = 0.78$; 95% CI 0.25–1.32). Significant effects in favor of the intervention on the anxiety and depression ($d = 0.12$, $p \leq 0.001$; $d = 0.52$ $p \leq 0.001$, respectively)	– Baseline before randomization – After the intervention – 12 months	Cognitive Behavioral Theory
Jin et al. (2022) [34] Hong Kong, China	Randomized controlled trial	40 parents of children with cancer Intervention group mean age: 34 ± 4.34 years Control group mean age: 36.40 ± 4.72 years	Intervention group: $n = 20$ *Intervention content*: Session 1: Generate creative hopelessness and build acceptance Session 2: Create space for your thought Session 3: Focus on here and now Session 4: Commit actions in line with the value	Control group: $n = 20$ Standard care	– Depression Anxiety Stress Scales-21 – PedsQL Parent HRQL Scale – Parent Experience of Child Illness – Acceptance and Action Questionnaire-II	The parents in the ACT group reported significant improvement in psychological flexibility with a medium effect size ($d = 0.75$; $p = 0.033$) and fewer negative experiences of child illness with a large effect size (i.e., guilt and worry: $d = 0.88$; $p = 0.010$) than those in the control group. Changes in psychological distress, QoL and experiential avoidance	– Baseline before randomization – 1 week after the intervention	Acceptance and Commitment Therapy (ACT)

(Continues)

TABLE 1 | (Continued)

Author/ year Country	Study design	Participants characteristics	Intervention	Control	Outcome measures	Primary findings	Assessment time	Theoretical frameworks
			Duration: 45–60 min *Frequency*: Weekly *Sessions*: 4 weeks *Mode of delivery*: Session 1: face-to-face sessions 2–4: Internet-based with the synchronized videos		– Comprehensive Assessment of Acceptance and Commitment Therapy Processes	between groups were nonsignificant		
Joosten et al. (2024) [35] Netherlands	Randomized controlled trial	86 parents of children with cancer Intervention group mean age: 41.6 ± 6.9 years Control group mean age: 42.2 ± 8.0 years	Intervention group: n = 42 *Intervention content*: Op Koers intervention is to teach active coping skills in order to reduce and/or prevent problems in psychosocial wellbeing. The sessions focus on different themes: CBT-principles, the hospital (strengths and difficulties in coping with the medical treatment), the family (impact of child's illness on the family, siblings, partner relationship), taking care of yourself (managing your roles as parent, partner, friend), environment/society (support figures), and looking back. In between sessions, parents are provided with in-depth reading material and homework assignments. *Duration*: 90 min *Frequency*: Weekly *Sessions*: 6 weeks and a booster session 5 months after the start of the intervention	Control group: n = 44 Wait list	– PROMIS Anxiety and depression were measured using item banks of the Patient-reported Outcomes Measurement Information System – Distress Thermometer for Parents – Situation-Specific Emotional Reaction Questionnaire – Cognitive Coping Strategies Scale Parent Form	The intervention had a beneficial effect on anxiety ($\beta = -0.35$; $p < 0.05$), depression ($\beta = -0.33$; $p < 0.05$), distress ($\beta = -0.46$; $p < 0.05$) and feelings of loneliness ($\beta = -0.25$; $p < 0.05$) at T1, and on anxiety ($\beta = -0.40$; $p < 0.05$) and feelings of uncertainty ($\beta = -0.32$; $p < 0.05$) at T2 The intervention had a beneficial effect on the use of coping skill relaxation at T1 ($\beta = 0.35$; $p < 0.05$) and at T2 ($\beta = 0.32$; $p < 0.05$)	– Baseline before randomization (T0) – After the intervention (T1) – 6 months	Cognitive Behavioral Theory (CBT) and Acceptance and Commitment Therapy (ACT)

(Continues)

TABLE 1 | (Continued)

Author/ year Country	Study design	Participants characteristics	Intervention	Control	Outcome measures	Primary findings	Assessment time	Theoretical frameworks
			Mode of delivery: Session 1: face-to-face sessions 2–4: Internet-based with the synchronized videos					
Wang et al. (2024) [40] China	Randomized controlled trial	112 parents of childhood lymphoma patients Intervention group mean age: 37.0 (30.0–51.0) years Control group mean age: 39.0 (26.0–52.0) years	Intervention group: $n = 56$ *Intervention content*: Parents in the WeChat education, relaxation and care program (WERC) group were provided with; the WERC program, including routine procedures; WeChat public account support where articles and videos related to education, relaxation and care could be found; WeChat group support where parents could contact the researchers or other parents at any time to share experiences and discuss issues; and routine psychological and physiological relaxation support through WeChat where parents could send meditation, deep breathing and muscle relaxation videos to the researchers *Duration*: NI *Frequency*: NI *Sessions*: 12 weeks *Mode of delivery*: Mobile device-based (mHealth) WeChat education and care program (WERC)	Control group: $n = 56$ Standard care	– Self-rating anxiety scale (SAS) score – Self-rating depression scale (SDS) score – Insomnia scale (AIS) – Impact of events scale-revised (IES-R)	The WERC group showed a lower SAS score at ($p = 0.045$) and greater change in SAS score ($p < 0.001$) than the control group. The SDS score a was not different ($p = 0.119$), while SDS score change was numerically greater ($p = 0.076$) in the WERC group than the control group Compared with the control group, the WERC group tended toward a decreased AIS score at ($p = 0.054$) and a greater AIS score change ($p < 0.001$). The IES-R score at was lower ($p = 0.040$), and the IES-R score change was greater ($p = 0.013$) in the WERC group than the control group	– Baseline before randomization – After the intervention	—

Most included studies had a control group receiving usual care. Only two studies had a waiting list control group [32, 35].

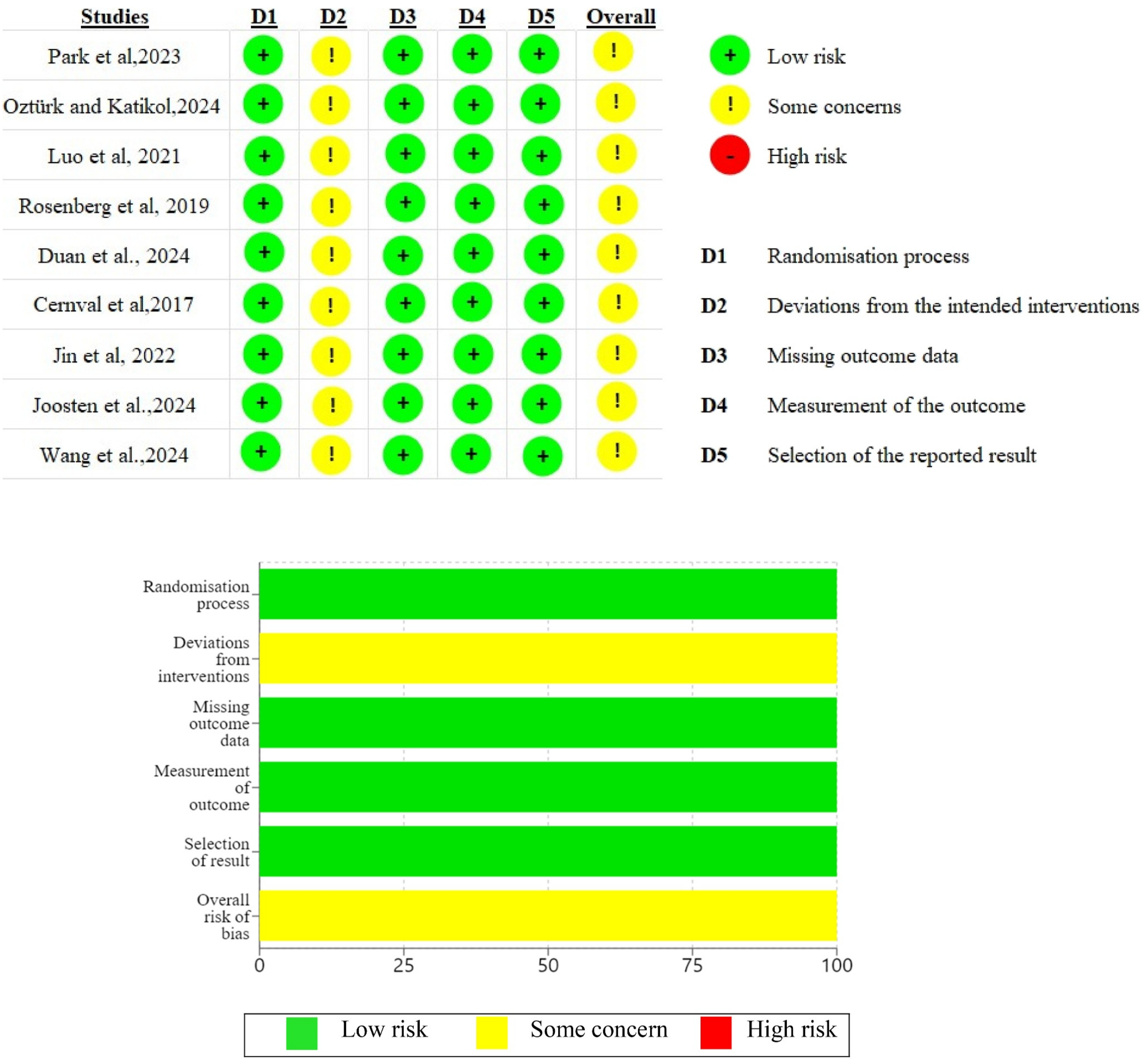
3.4 | Risk of Bias

The risk of bias of the included studies was assessed using Cochrane revised Risk of Bias 2 (RoB 2) tool is summarized in Figure 2. For most domains, nine studies were identified as presenting a low risk of bias. However, in domain 2 (risk of bias due to deviations from intended interventions—effect of assignment to the intervention), some concerns were identified due to the inability to blind intervention providers (nurses) due to the nature of the interventions. After comprehensive judgment and consensus among researchers, it was determined that this potential bias was an unavoidable nature of the intervention rather than a methodological flaw. Although this led to "some concerns" in the overall bias assessment, the research team considered the robust methodology in all other areas and the inherent nature of the interventions, with all nine studies eventually judged to have a low risk of bias and high methodological quality.

3.5 | Effect of Technology-Based Psychological Empowerment Interventions on Psychological Well-Being of Parents of Children and Adolescents With Cancer

3.5.1 | Distress

Three studies were included to evaluate the impact of technology-based psychological empowerment interventions on distress among parents of children and adolescents with cancer. The pooled analysis involving 94 participants in the intervention group and 95 participants in the control group showed a



Studies	D1	D2	D3	D4	D5	Overall
Park et al,2023	+	!	+	+	+	!
Oztürk and Katikol,2024	+	!	+	+	+	!
Luo et al, 2021	+	!	+	+	+	!
Rosenberg et al, 2019	+	!	+	+	+	!
Duan et al., 2024	+	!	+	+	+	!
Cernval et al,2017	+	!	+	+	+	!
Jin et al, 2022	+	!	+	+	+	!
Joosten et al.,2024	+	!	+	+	+	!
Wang et al.,2024	+	!	+	+	+	!

FIGURE 2 | Risk of bias assessment for the included studies.

statistically significant decrease in distress post-intervention with medium effect size (SMD: −0.42, 95% CI [−0.70, −0.13], $p = 0.005$) (Figure 3).

3.5.2 | Depression

Five studies evaluated the effect of technology-based psychological empowerment interventions on depressive symptoms among parents of children with cancer. The pooled analysis included 276 participants in the intervention group and 271 participants in the control group. Results showed a significant decrease in depression immediately after the intervention (SMD: −0.92, 95% CI [−1.56, −0.27], $p = 0.005$). In addition, a follow-up analysis of three studies, each consisting of 163 participants, conducted more than six months after the intervention, showed a performed decrease in depression (SMD: −0.39, 95% CI [−0.61, −0.17], $p = 0.005$) (Figure 4).

3.5.3 | Anxiety

Four studies evaluated the impact of technology-based psychological empowerment interventions on anxiety among parents of children with cancer. The pooled analysis included 228 participants in the intervention group and 225 participants in the control group. Results showed a significant decrease in anxiety immediately after the intervention (SMD: −1.47, 95% CI [−2.50, −0.44], $p = 0.005$). Also, a follow-up analysis of two studies, each consisting of 115 participants, conducted more than six months after the intervention, showed that the decrease in anxiety maintained (SMD: −0.32, 95% CI [−0.58, −0.07], $p = 0.01$) (Figure 5).

3.5.4 | Health-Related Quality of Life

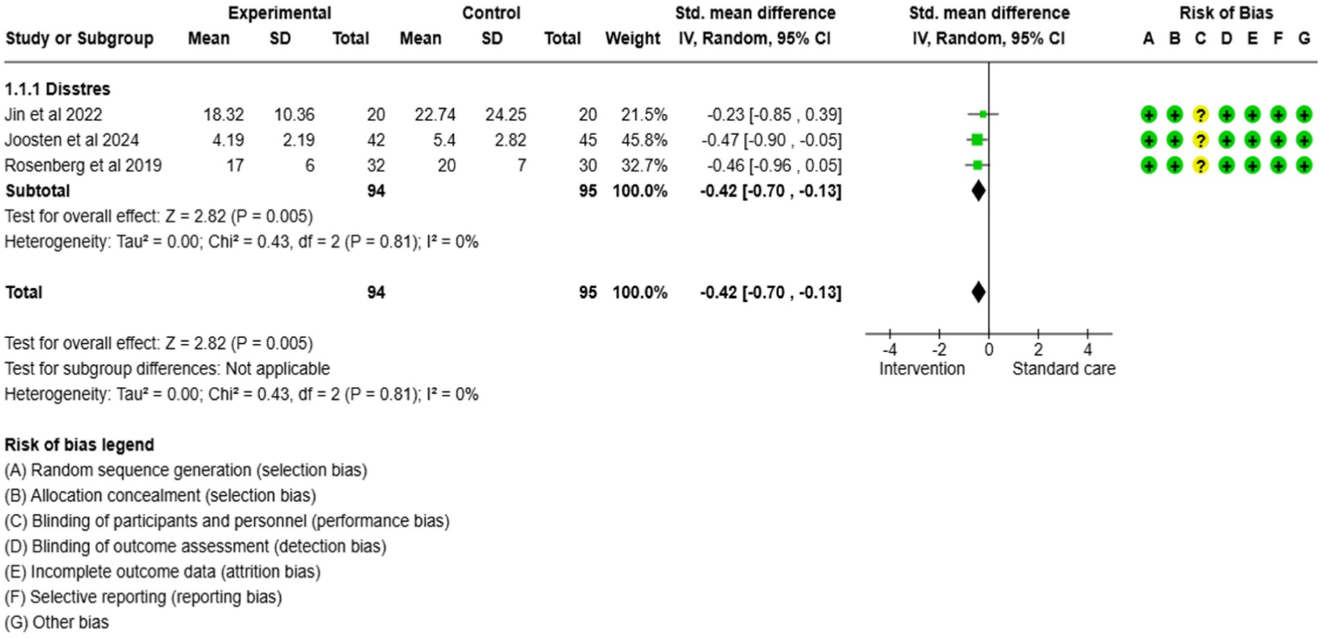
Three studies evaluated the effect of technology-based psychological empowerment interventions on the health-related quality of life among parents of children and adolescents with cancer. The pooled analysis included 104 participants in the intervention group and 103 in the control group. The results showed no significant difference in health-related quality of life post-intervention (SMD: 0.02 (95% CI [−0.25, 0.29], $p = 0.88$)) (Figure 6).

3.5.5 | Coping

Three studies evaluated the impact of technology-based psychological empowerment interventions on coping mechanisms among parents of children with cancer. The pooled analysis included 177 participants, 87 in the intervention group and 90 in the control group. Results showed a significant increase in coping post-intervention (SMD: 4.31, 95% CI [1.19, 7.44], $p = 0.007$) (Figure 7).

3.5.6 | Resilience

Three studies evaluated the impact of technology-based empowerment interventions on resilience among parents of children with cancer. The pooled analysis included 206 participants, 105 in the experimental group and 101 in the control group. Results showed a significant increase in resilience post-intervention (SMD: 4.68, 95% CI [1.23, 8.13], $p = 0.008$) (Figure 8).



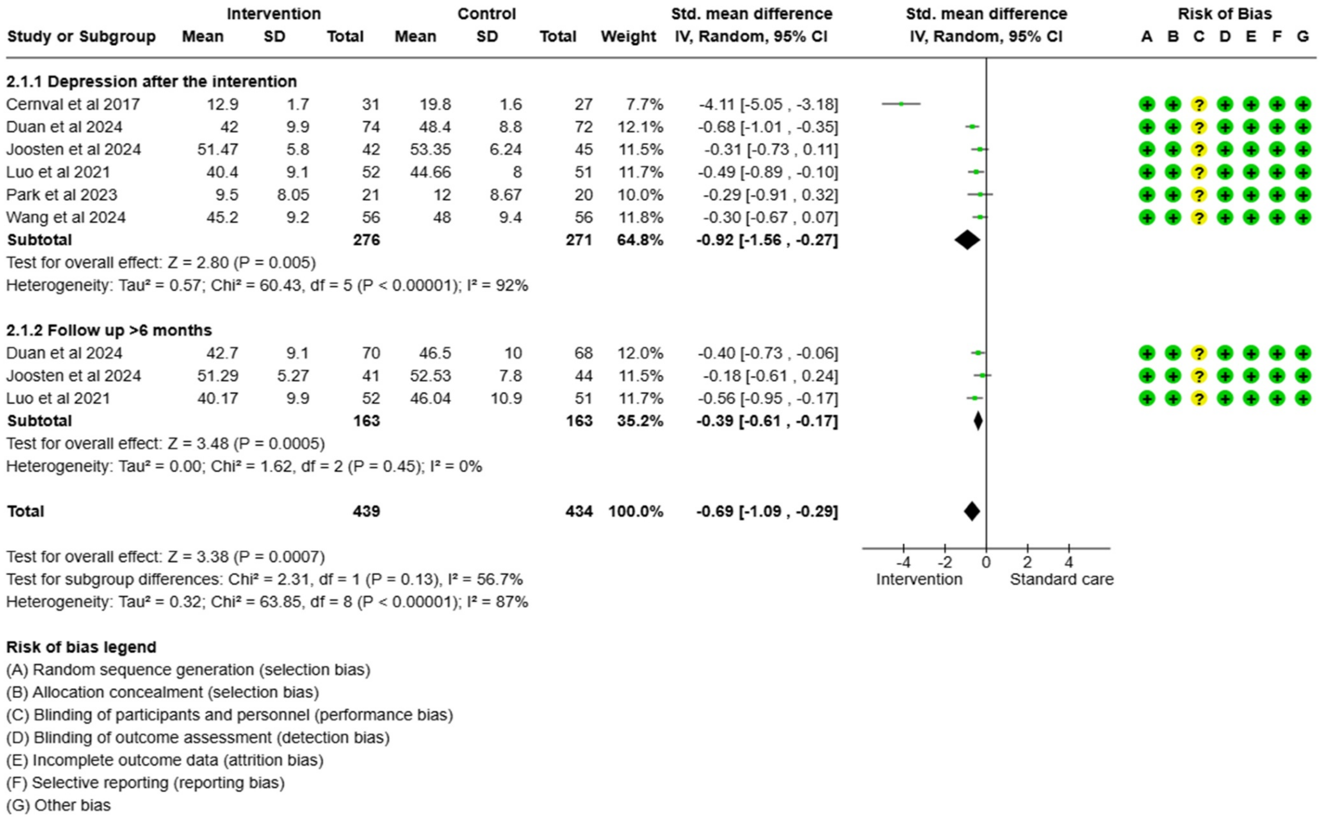
	Experimental			Control				Std. mean difference	Risk of Bias						
Study or Subgroup	Mean	SD	Total	Mean	SD	Total	Weight	IV, Random, 95% CI	A	B	C	D	E	F	G
1.1.1 Disstres															
Jin et al 2022	18.32	10.36	20	22.74	24.25	20	21.5%	-0.23 [-0.85 , 0.39]	+	+	?	+	+	+	+
Joosten et al 2024	4.19	2.19	42	5.4	2.82	45	45.8%	-0.47 [-0.90 , -0.05]	+	+	?	+	+	+	+
Rosenberg et al 2019	17	6	32	20	7	30	32.7%	-0.46 [-0.96 , 0.05]	+	+	?	+	+	+	+
Subtotal			**94**			**95**	**100.0%**	**-0.42 [-0.70 , -0.13]**							
Total			**94**			**95**	**100.0%**	**-0.42 [-0.70 , -0.13]**							

Subtotal: Test for overall effect: Z = 2.82 (P = 0.005)
Heterogeneity: Tau² = 0.00; Chi² = 0.43, df = 2 (P = 0.81); I² = 0%

Test for overall effect: Z = 2.82 (P = 0.005)
Test for subgroup differences: Not applicable
Heterogeneity: Tau² = 0.00; Chi² = 0.43, df = 2 (P = 0.81); I² = 0%

Risk of bias legend
(A) Random sequence generation (selection bias)
(B) Allocation concealment (selection bias)
(C) Blinding of participants and personnel (performance bias)
(D) Blinding of outcome assessment (detection bias)
(E) Incomplete outcome data (attrition bias)
(F) Selective reporting (reporting bias)
(G) Other bias

FIGURE 3 | Effect of technology-based empowerment interventions on distress immediately post-intervention.

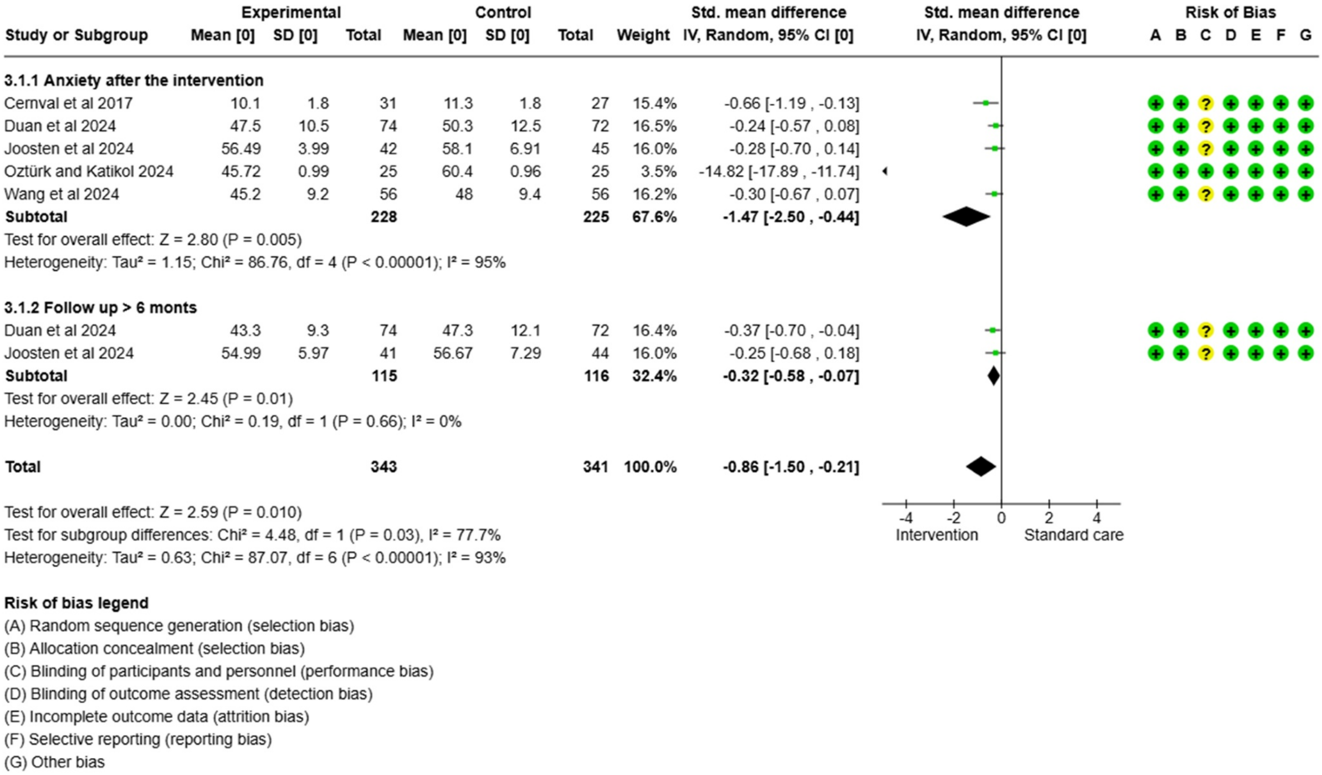


Study or Subgroup	Intervention Mean	Intervention SD	Intervention Total	Control Mean	Control SD	Control Total	Weight	Std. mean difference IV, Random, 95% CI	A	B	C	D	E	F	G
2.1.1 Depression after the interention															
Cernval et al 2017	12.9	1.7	31	19.8	1.6	27	7.7%	-4.11 [-5.05 , -3.18]	+	+	?	+	+	+	+
Duan et al 2024	42	9.9	74	48.4	8.8	72	12.1%	-0.68 [-1.01 , -0.35]	+	+	?	+	+	+	+
Joosten et al 2024	51.47	5.8	42	53.35	6.24	45	11.5%	-0.31 [-0.73 , 0.11]	+	+	?	+	+	+	+
Luo et al 2021	40.4	9.1	52	44.66	8	51	11.7%	-0.49 [-0.89 , -0.10]	+	+	?	+	+	+	+
Park et al 2023	9.5	8.05	21	12	8.67	20	10.0%	-0.29 [-0.91 , 0.32]	+	+	?	+	+	+	+
Wang et al 2024	45.2	9.2	56	48	9.4	56	11.8%	-0.30 [-0.67 , 0.07]	+	+	?	+	+	+	+
Subtotal			**276**			**271**	**64.8%**	**-0.92 [-1.56 , -0.27]**							
Test for overall effect: Z = 2.80 (P = 0.005)															
Heterogeneity: Tau² = 0.57; Chi² = 60.43, df = 5 (P < 0.00001); I² = 92%															
2.1.2 Follow up >6 months															
Duan et al 2024	42.7	9.1	70	46.5	10	68	12.0%	-0.40 [-0.73 , -0.06]	+	+	?	+	+	+	+
Joosten et al 2024	51.29	5.27	41	52.53	7.8	44	11.5%	-0.18 [-0.61 , 0.24]	+	+	?	+	+	+	+
Luo et al 2021	40.17	9.9	52	46.04	10.9	51	11.7%	-0.56 [-0.95 , -0.17]	+	+	?	+	+	+	+
Subtotal			**163**			**163**	**35.2%**	**-0.39 [-0.61 , -0.17]**							
Test for overall effect: Z = 3.48 (P = 0.0005)															
Heterogeneity: Tau² = 0.00; Chi² = 1.62, df = 2 (P = 0.45); I² = 0%															
Total			**439**			**434**	**100.0%**	**-0.69 [-1.09 , -0.29]**							

Test for overall effect: Z = 3.38 (P = 0.0007)
Test for subgroup differences: Chi² = 2.31, df = 1 (P = 0.13), I² = 56.7%
Heterogeneity: Tau² = 0.32; Chi² = 63.85, df = 8 (P < 0.00001); I² = 87%

Risk of bias legend
(A) Random sequence generation (selection bias)
(B) Allocation concealment (selection bias)
(C) Blinding of participants and personnel (performance bias)
(D) Blinding of outcome assessment (detection bias)
(E) Incomplete outcome data (attrition bias)
(F) Selective reporting (reporting bias)
(G) Other bias

FIGURE 4 | Effect of technology-based empowerment interventions on depression immediately post-intervention and at 6-month follow-up.

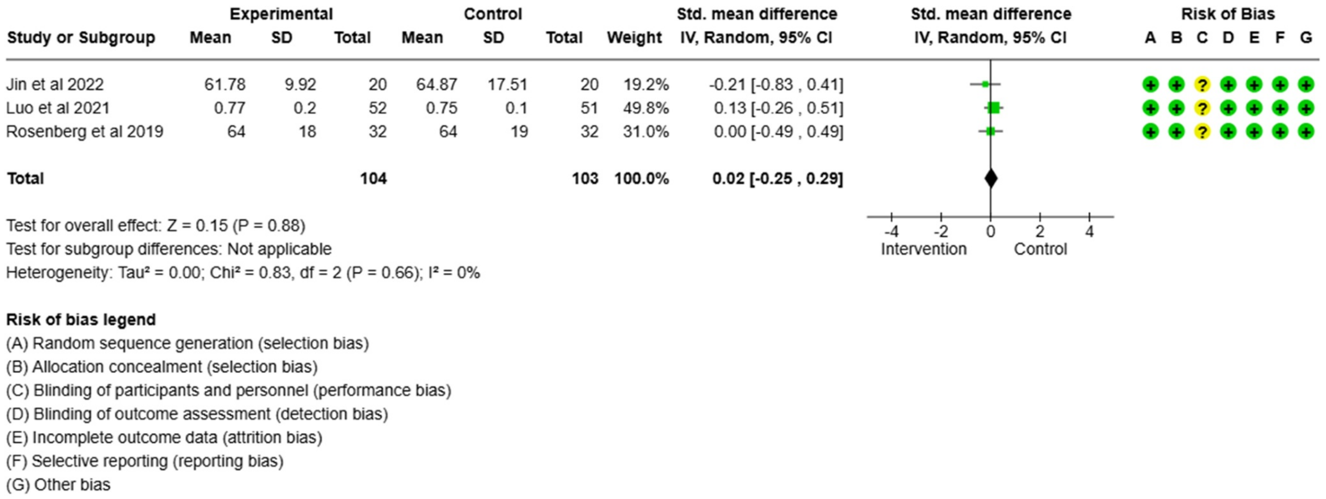


Study or Subgroup	Experimental Mean [0]	Experimental SD [0]	Experimental Total	Control Mean [0]	Control SD [0]	Control Total	Weight	Std. mean difference IV, Random, 95% CI [0]	A	B	C	D	E	F	G
3.1.1 Anxiety after the intervention															
Cernval et al 2017	10.1	1.8	31	11.3	1.8	27	15.4%	-0.66 [-1.19 , -0.13]	+	+	?	+	+	+	+
Duan et al 2024	47.5	10.5	74	50.3	12.5	72	16.5%	-0.24 [-0.57 , 0.08]	+	+	?	+	+	+	+
Joosten et al 2024	56.49	3.99	42	58.1	6.91	45	16.0%	-0.28 [-0.70 , 0.14]	+	+	?	+	+	+	+
Oztürk and Katikol 2024	45.72	0.99	25	60.4	0.96	25	3.5%	-14.82 [-17.89 , -11.74]	+	+	+	+	+	+	+
Wang et al 2024	45.2	9.2	56	48	9.4	56	16.2%	-0.30 [-0.67 , 0.07]	+	+	?	+	+	+	+
Subtotal			**228**			**225**	**67.6%**	**-1.47 [-2.50 , -0.44]**							
Test for overall effect: Z = 2.80 (P = 0.005)															
Heterogeneity: Tau² = 1.15; Chi² = 86.76, df = 4 (P < 0.00001); I² = 95%															
3.1.2 Follow up > 6 monts															
Duan et al 2024	43.3	9.3	74	47.3	12.1	72	16.4%	-0.37 [-0.70 , -0.04]	+	+	?	+	+	+	+
Joosten et al 2024	54.99	5.97	41	56.67	7.29	44	16.0%	-0.25 [-0.68 , 0.18]	+	+	?	+	+	+	+
Subtotal			**115**			**116**	**32.4%**	**-0.32 [-0.58 , -0.07]**							
Test for overall effect: Z = 2.45 (P = 0.01)															
Heterogeneity: Tau² = 0.00; Chi² = 0.19, df = 1 (P = 0.66); I² = 0%															
Total			**343**			**341**	**100.0%**	**-0.86 [-1.50 , -0.21]**							

Test for overall effect: Z = 2.59 (P = 0.010)
Test for subgroup differences: Chi² = 4.48, df = 1 (P = 0.03), I² = 77.7%
Heterogeneity: Tau² = 0.63; Chi² = 87.07, df = 6 (P < 0.00001); I² = 93%

Risk of bias legend
(A) Random sequence generation (selection bias)
(B) Allocation concealment (selection bias)
(C) Blinding of participants and personnel (performance bias)
(D) Blinding of outcome assessment (detection bias)
(E) Incomplete outcome data (attrition bias)
(F) Selective reporting (reporting bias)
(G) Other bias

FIGURE 5 | Effect of technology-based empowerment interventions on anxiety immediately post-intervention and at 6-month follow-up.

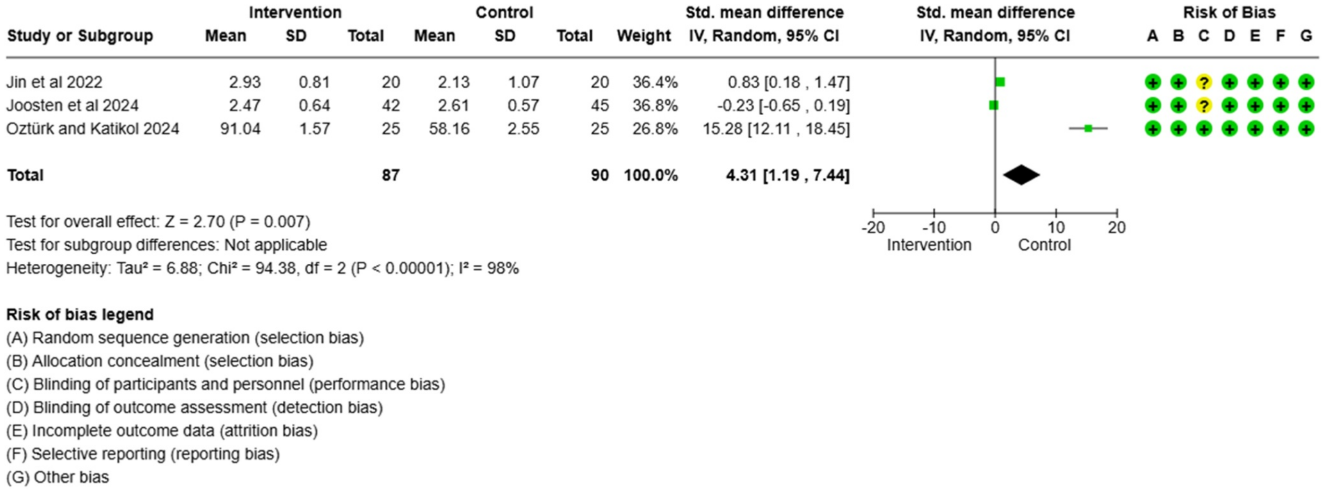


Study or Subgroup	Experimental Mean	Experimental SD	Experimental Total	Control Mean	Control SD	Control Total	Weight	Std. mean difference IV, Random, 95% CI	A	B	C	D	E	F	G
Jin et al 2022	61.78	9.92	20	64.87	17.51	20	19.2%	-0.21 [-0.83 , 0.41]	+	+	?	+	+	+	+
Luo et al 2021	0.77	0.2	52	0.75	0.1	51	49.8%	0.13 [-0.26 , 0.51]	+	+	?	+	+	+	+
Rosenberg et al 2019	64	18	32	64	19	32	31.0%	0.00 [-0.49 , 0.49]	+	+	?	+	+	+	+
Total			**104**			**103**	**100.0%**	**0.02 [-0.25 , 0.29]**							

Test for overall effect: Z = 0.15 (P = 0.88)
Test for subgroup differences: Not applicable
Heterogeneity: Tau² = 0.00; Chi² = 0.83, df = 2 (P = 0.66); I² = 0%

Risk of bias legend
(A) Random sequence generation (selection bias)
(B) Allocation concealment (selection bias)
(C) Blinding of participants and personnel (performance bias)
(D) Blinding of outcome assessment (detection bias)
(E) Incomplete outcome data (attrition bias)
(F) Selective reporting (reporting bias)
(G) Other bias

FIGURE 6 | Effect of technology-based empowerment interventions on health-related quality of life immediately post-intervention.

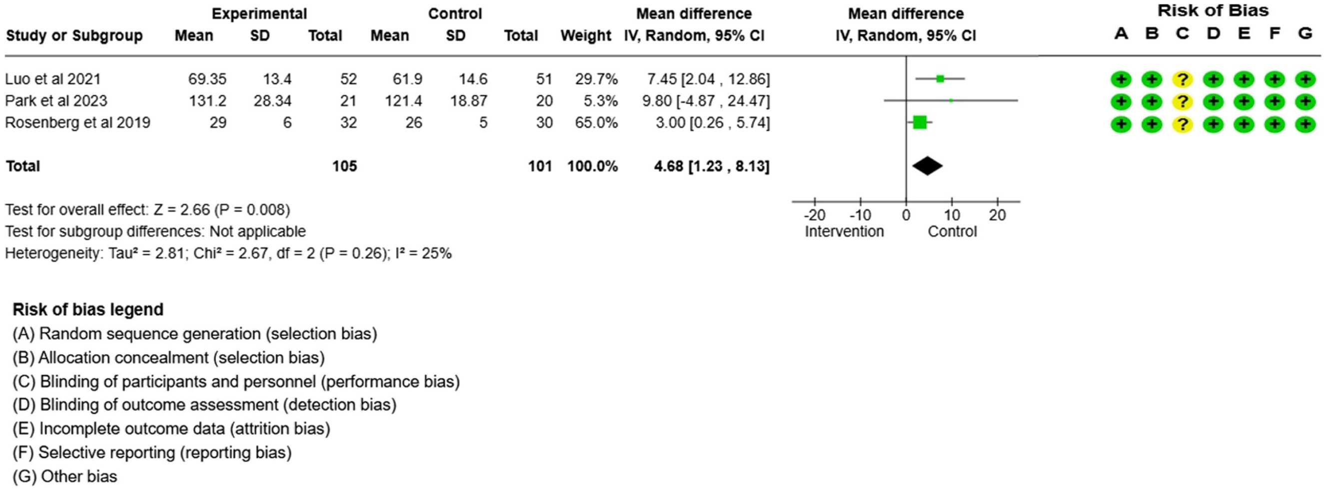


Study or Subgroup	Intervention Mean	Intervention SD	Intervention Total	Control Mean	Control SD	Control Total	Weight	Std. mean difference IV, Random, 95% CI	A	B	C	D	E	F	G
Jin et al 2022	2.93	0.81	20	2.13	1.07	20	36.4%	0.83 [0.18 , 1.47]	+	+	?	+	+	+	+
Joosten et al 2024	2.47	0.64	42	2.61	0.57	45	36.8%	-0.23 [-0.65 , 0.19]	+	+	?	+	+	+	+
Oztürk and Katikol 2024	91.04	1.57	25	58.16	2.55	25	26.8%	15.28 [12.11 , 18.45]	+	+	+	+	+	+	+
Total			**87**			**90**	**100.0%**	**4.31 [1.19 , 7.44]**							

Test for overall effect: Z = 2.70 (P = 0.007)
Test for subgroup differences: Not applicable
Heterogeneity: Tau² = 6.88; Chi² = 94.38, df = 2 (P < 0.00001); I² = 98%

Risk of bias legend
(A) Random sequence generation (selection bias)
(B) Allocation concealment (selection bias)
(C) Blinding of participants and personnel (performance bias)
(D) Blinding of outcome assessment (detection bias)
(E) Incomplete outcome data (attrition bias)
(F) Selective reporting (reporting bias)
(G) Other bias

FIGURE 7 | Effect of technology-based empowerment interventions on coping immediately post-intervention.



Study or Subgroup	Experimental Mean	Experimental SD	Experimental Total	Control Mean	Control SD	Control Total	Weight	Mean difference IV, Random, 95% CI	A	B	C	D	E	F	G
Luo et al 2021	69.35	13.4	52	61.9	14.6	51	29.7%	7.45 [2.04 , 12.86]	+	+	?	+	+	+	+
Park et al 2023	131.2	28.34	21	121.4	18.87	20	5.3%	9.80 [-4.87 , 24.47]	+	+	?	+	+	+	+
Rosenberg et al 2019	29	6	32	26	5	30	65.0%	3.00 [0.26 , 5.74]	+	+	?	+	+	+	+
Total			**105**			**101**	**100.0%**	**4.68 [1.23 , 8.13]**							

Test for overall effect: Z = 2.66 (P = 0.008)
Test for subgroup differences: Not applicable
Heterogeneity: Tau² = 2.81; Chi² = 2.67, df = 2 (P = 0.26); I² = 25%

Risk of bias legend
(A) Random sequence generation (selection bias)
(B) Allocation concealment (selection bias)
(C) Blinding of participants and personnel (performance bias)
(D) Blinding of outcome assessment (detection bias)
(E) Incomplete outcome data (attrition bias)
(F) Selective reporting (reporting bias)
(G) Other bias

FIGURE 8 | Effect of technology-based empowerment interventions on resilience immediately post-intervention.

4 | Discussion

This meta-analysis highlights the transformative potential of technology-based psychological empowerment interventions in significantly enhancing the psychological well-being of parents of children and adolescents with cancer. These interventions show significant efficacy in decreasing psychological distress, depression, and anxiety, while also promoting coping skills and resilience. These findings are particularly critical given the profound emotional and psychological challenges faced by parents in pediatric oncology settings.

The notable decreases in distress, depression, and anxiety highlight the critical role these interventions play in providing essential emotional support. Interventions that address these psychological challenges not only improve parents' immediate psychological well-being, but also empower them internally to manage the complex and demanding responsibilities of caregiving. This improvement can lead to better caregiving outcomes and potentially improve family dynamics during the child's cancer trajectory [14]. Enhancements in coping skills and resilience suggest that these interventions effectively equip parents with the skills and strategies necessary to overcome the multifaceted challenges associated with their child's illness [41]. Furthermore, by promoting a sense of empowerment, these interventions facilitate parents to regain control and authority, which are often compromised during their child's cancer diagnosis [22, 42].

Shao et al.'s meta-analysis showed that psychological interventions positively impacted resilience in family members of pediatric cancer patients and led to sustained improvements in the short to medium term [14]. Similarly, Phiri et al.'s meta-analysis on psychoeducational interventions (PEIs) showed significant reductions in anxiety and depressive symptoms and that these effects sustained over the long term, as well as improvements in health-related quality of life (HRQoL) and coping skills [20]. These findings are in line with our results highlighting the importance of psychological support in enhancing parental well-being.

However, our meta-analysis revealed that the interventions had no significant effect on HRQoL, in notable contrast to the findings of Zhou et al. who reported that problem-solving skills interventions significantly affected HRQoL, depression and distress in parents of children with chronic health conditions [10]. This compelling finding suggests that HRQoL is influenced by a complex interaction of factors beyond psychological well-being, such as physical health status, financial toxicity, and social support networks. Therefore, while technology-based interventions may be effective in addressing psychological aspects, comprehensive support strategies targeting these broader determinants are necessary to fully improve HRQoL. Future research should explore the integration of technology-based interventions with other supportive measures such as financial counseling and increased social support to comprehensively address the multifaceted needs of these families. Longitudinal studies are also needed to assess the long-term sustainability of the effects of these interventions and to determine their impact on quality of life over time. By continuing to innovate and improve these approaches, we can better support families as they navigate the challenges of pediatric cancer and ultimately improve outcomes for both parents and their children.

Technology-based psychological empowerment interventions offer promising and reliable landing sites for supporting parents of children with cancer [23]. By effectively decreasing psychological distress and increasing coping and resilience, these interventions can play an important role in psychosocial support programs. However, to realize their full potential, these interventions should be integrated into a holistic strategy that addresses both psychological well-being and broader quality of life factors. This comprehensive approach should also include additional supportive measures, such as enhanced social support, to meet the multiple needs of these families. By maintaining and advancing evidence-based innovation, we can enhance psychosocial care in pediatric oncology and ultimately improve outcomes for both parents and their children.

4.1 | Limitations

Despite these promising results, some limitations should be recognized. A limitation of this meta-analysis is the limited number of effect sizes available for specific outcomes such as distress, coping and resilience; only two or three studies contributed to the pooled estimates. While this reduces the precision and generalizability of the findings, it is important to note that meta-analyses with a small number of studies are not uncommon, especially in areas with limited research in rare or specific populations. Despite the small number of studies, these analyses provide valuable information about the potential effects of technology-based empowerment interventions and highlight the need for further research in this field. For outcomes with a sufficient number of effect sizes, such as depression and anxiety (five or six studies), pooled estimates are more robust and reliable. Future studies emphasize the need for research on outcomes of distress, coping and resilience to strengthen the evidence in this field. Another important limitation of this meta-analysis is the substantial variability in intervention designs across included studies. Differences in intervention duration, session frequency, delivery platforms (e.g., mobile apps, online support groups, hybrid models), and content may have influenced pooled estimates and limited the generalizability of findings. Although a random effects model was used to account for methodological and clinical heterogeneity, variability in intervention designs remains a potential source of bias. But this variation is not uncommon in meta-analyses involving complex interventions and heterogeneous populations, and reflects real-world variability in how such interventions are implemented. In this context, moderation analyses should have been conducted to explore the differential effects of these different characteristics on outcomes. However, the limited number of included studies precluded such analyses, as reliable moderation analyses typically require a larger number of effect sizes. Despite this limitation, the use of a random effects model provides a robust synthesis of the available evidence, enabling pooled estimates to account for between-study variability. Future research should aim to systematically examine the impact of intervention design features on psychological outcomes to provide more nuanced insights into the effectiveness of technology-based empowerment interventions. While acknowledging its limitations, this meta-analysis provides valuable preliminary evidence and highlights the need for further research to improve and optimize these interventions for parents of pediatric cancer patients. Due to the limited number of studies, it was not possible to conduct sub-group analyses based on variables that could potentially influence the intervention, such as intervention method, parent characteristics (e.g., age, gender), and child characteristics (e.g., age, diagnosis, duration of diagnosis, disease stage). Finally, this study included only English-language articles, which may introduce language bias and limit the generalizability of the findings. Additionally, no meta-analysis in this study included more than 10 studies, which precluded the assessment of publication bias.

4.2 | Implications of Practice

Future research should aim to standardize intervention protocols to enable more consistent comparisons across studies. Increasing the demographic diversity of study samples and conducting longitudinal studies with longer follow-up periods will increase the feasibility and comprehensibility of these interventions. Exploring the integration of technology-based interventions with other forms of support, such as peer support groups or professional counseling, may provide a more comprehensive approach to addressing the multifaceted needs of parents of pediatric cancer patients. Also, investigating the cost-effectiveness of these interventions will be important to inform policy and practice and ensure that effective support is accessible to all parents in need.

5 | Conclusion

In conclusion, this meta-analysis provides robust evidence that technology-based psychological empowerment interventions play a critical role in enhancing the psychological well-being of parents of children with cancer. These interventions significantly decrease distress, depression, and anxiety while enhance coping skills and resilience, highlighting their potential to improve the quality of psychosocial care in pediatric oncology settings. By addressing the unique challenges faced by parents throughout the trajectory of childhood cancer, this study contributes to the evidence-based literature and underscores the importance of standardizing these interventions in clinical practice. Future research should focus on refining these approaches, exploring their long-term effects, and integrating them into comprehensive care strategies that address both psychological outcomes and broader quality of life factors.

Author Contributions

Hazal Ozdemir Koyu: conceptualization, methodology, data analysis, writing–original draft preparation, writing–reviewing and editing. **Ebru Kilicarslan:** methodology, data analysis, supervision, writing–reviewing and editing.

Ethics Statement

As the data were obtained from previously published studies, the study did not require ethical approval or informed consent.

Conflicts of Interest

The authors declare no conflicts of interest.

Data Availability Statement

Data sharing is not applicable to this article as no new data were created or analyzed in this study.

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