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Effects of a Phase-Based PRISM Intervention on Psychological Resilience and Treatment Adherence in Children Undergoing Radiotherapy for Cancer: A Randomized Controlled Trial

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Abstract

Objective: To investigate the effects of a phase-based psychological intervention based on the Promoting Resilience in Stress Management (PRISM) model on psychological resilience and treatment adherence among children undergoing radiotherapy for cancer.

Methods: A total of 40 pediatric oncology patients receiving radiotherapy at the Department of Radiation Oncology, Sun Yat-sen University Cancer Center, between November 2025 and April 2026 were enrolled and randomly assigned to either an intervention group (n = 20) or a control group (n = 20) using a random number table method. The control group received routine radiotherapy education and standard

preparation, whereas the intervention group additionally received a phase-based PRISM intervention consisting of four modules: stress management, goal setting, cognitive reframing, and meaning-making. Psychological resilience, emotional status, behavioral problems, and treatment adherence were assessed at baseline and weekly during radiotherapy using the Connor–Davidson Resilience Scale (CD-RISC), Depression Anxiety Stress Scale-21 (DASS-21), Conners Children's Behavior Scale, and Frankl Compliance Scale, respectively. Positioning time was also recorded throughout treatment.

Results: No significant differences were observed between the two groups in baseline demographic characteristics or outcome measures (all $P > 0.05$). Repeated-measures analyses demonstrated that psychological resilience scores increased significantly over time in the intervention group, with a more favorable trajectory than that observed in the control group ($P < 0.05$). At the completion of radiotherapy, depression scores were significantly lower in the intervention group than in the control group ($P < 0.05$), while anxiety and stress scores showed downward trends. Children in the intervention group demonstrated significantly better Frankl compliance ratings and a higher proportion of good or excellent treatment adherence than those in the control group ($P < 0.05$). Positioning time decreased progressively in both groups during radiotherapy. Although a larger numerical reduction was observed in the intervention group, the between-group difference did not reach statistical significance. Behavioral problem scores showed improvement within the intervention group; however, between-group differences were not statistically significant.

Conclusions: A phase-based psychological intervention based on the PRISM model can enhance psychological resilience among children undergoing radiotherapy for cancer and may improve treatment adherence. Psychological resilience may represent an important factor underlying treatment adaptation. These findings suggest

that the PRISM intervention has promising clinical value and may serve as an effective supportive care strategy in pediatric radiation oncology.

Keywords: pediatric cancer; radiotherapy; PRISM; psychological resilience; treatment adherence

1 Introduction

In recent years, approximately 30,000–40,000 new cases of childhood cancer have been diagnosed annually in China [1–2], making pediatric cancer a major contributor to the disease burden among children [3]. Radiotherapy constitutes an essential component of multimodal treatment for pediatric malignancies and plays a critical role in the management of central nervous system tumors, lymphomas, and various solid tumors [4–6]. However, in addition to potential long-term adverse effects on neurocognitive and social functioning, radiotherapy is frequently associated with substantial psychological distress, which may negatively affect treatment experiences and quality of life among pediatric patients [7–8].

To improve treatment cooperation during radiotherapy, a variety of interventions have been developed worldwide, including the “kindergarten effect,” medical play therapy, and child-friendly educational programs. Previous studies have shown that these approaches can alleviate fear and anxiety related to the treatment environment, improve treatment experiences, and enhance quality of life to some extent [9–10]. Nevertheless, poor treatment adherence and inadequate cooperation remain significant challenges in pediatric radiotherapy. During treatment, children are often required to remain alone in a confined treatment room while facing multiple stressors, including the discomfort associated with immobilization masks, machine noise, laser positioning procedures, and temporary separation from family members [11–12]. These stressors may trigger anxiety, fear, and avoidance behaviors, thereby compromising positioning accuracy and treatment delivery. In severe cases, they may even result in treatment delays or interruptions [13].

Currently, sedation and physical restraint are commonly used to improve treatment cooperation during pediatric radiotherapy. However, sedation may introduce additional medical risks, while physical restraint raises ethical concerns and is often poorly accepted by families [14–16]. Therefore, there is a pressing need to develop safe, sustainable, and non-pharmacological interventions that focus on strengthening children's psychological adaptation and coping abilities during treatment.

Previous studies have demonstrated that psychological interventions can reduce anxiety and improve positioning cooperation among children undergoing radiotherapy for cancer [17–18]. However, most existing interventions primarily focus on behavioral management and environmental adaptation, and their benefits are often limited to short-term behavioral improvements. Comparatively less attention has been paid to enhancing the internal psychological resources that help children cope with disease- and treatment-related stress.

In recent years, psychological resilience has been increasingly recognized as a key protective factor that enables children with cancer to adapt to illness-related challenges, maintain psychological well-being, and improve treatment adherence. Promoting Resilience in Stress Management (PRISM) is a structured psychosocial intervention designed to strengthen resilience through four core components: stress management, goal setting, cognitive reframing, and meaning-making [19]. Previous studies have demonstrated that PRISM interventions can effectively enhance resilience, reduce psychological distress, and promote psychosocial adaptation among patients with cancer [20–21]. However, existing evidence has mainly focused on adult and adolescent oncology populations, and research examining the application of PRISM in preschool- and school-aged children undergoing radiotherapy remains limited.

Moreover, pediatric patients undergoing radiotherapy often face multiple concurrent challenges, including emotional distress, behavioral problems, and reduced

treatment adherence [22–23]. Therefore, the present study introduced the PRISM model throughout the radiotherapy process and conducted a prospective randomized controlled trial to evaluate its effects on psychological resilience, emotional well-being, and treatment adherence among children with cancer. In addition, the study explored the potential role of psychological resilience in treatment adaptation, with the aim of providing evidence-based support for supportive care strategies in pediatric radiation oncology.

2 Materials and Methods

2.1 Participants

This prospective randomized controlled trial enrolled 40 pediatric patients with cancer who underwent radiotherapy at the Department of Radiation Oncology, Sun Yat-sen University Cancer Center, between November 2025 and April 2026. Participants were randomly assigned to either the intervention group ($n = 20$) or the control group ($n = 20$) using a random number table method.

The inclusion criteria were as follows: (1) histologically confirmed malignant tumor; (2) age between 4 and 17 years; (3) first-time receipt of radiotherapy; (4) an anticipated radiotherapy course of at least 4 weeks; and (5) provision of written informed consent by both the patient and his/her legal guardian.

The exclusion criteria were as follows: (1) severe psychiatric disorders or cognitive impairment that would preclude completion of study assessments; (2) severe comorbid medical conditions or serious treatment-related complications occurring during the study period that prevented completion of radiotherapy or study interventions; and (3) previous exposure to radiotherapy.

The study protocol was approved by the Ethics Committee of Sun Yat-sen University Cancer Center (Approval No. SL-B2023-608-01). The study was conducted in accordance with the principles of the Declaration of Helsinki. Written

informed consent was obtained from all participants and their legal guardians prior to enrollment.

2.2.1 Control Group Intervention

Participants in the control group received routine nursing care and standard radiotherapy education provided by the attending radiation oncologist, specialized oncology nurse, and radiation therapist. The intervention consisted of the following components:

(1) **Environmental orientation:** Prior to the initiation of radiotherapy, children and their legal guardians were guided through the radiotherapy department and introduced to the treatment environment, equipment, and treatment procedures to reduce anxiety associated with unfamiliar surroundings.

(2) **Information support:** Children and their families were provided with information regarding the purpose of radiotherapy, treatment procedures, precautions, and potential adverse effects. Questions and concerns raised by patients and caregivers were addressed in a timely manner.

(3) **Emotional support:** During treatment, children were encouraged to express their emotions and concerns, and appropriate psychological comfort and emotional support were provided by healthcare professionals.

All interventions were delivered according to routine departmental practice. No additional structured psychological intervention was provided to the control group.

2.2.2 Intervention Group

In addition to routine radiotherapy education and standard care, participants in the intervention group received a phase-based resilience intervention grounded in the Promoting Resilience in Stress Management (PRISM) model. Prior to study initiation, the research team systematically reviewed the existing literature on PRISM

interventions and developed a standardized intervention protocol tailored to the specific needs of children undergoing radiotherapy for cancer. All intervention providers received standardized training and delivered the intervention according to a detailed intervention manual to ensure consistency and fidelity.

The intervention was delivered individually by trained radiation therapists once weekly throughout the radiotherapy course. Each session lasted approximately 30–60 minutes. The content and delivery methods were adapted according to the child's age, cognitive level, and treatment stage. The intervention consisted of four sequential phases:

(1) Stress Management Phase (Before Radiotherapy Initiation)

Children were introduced to the radiotherapy process through age-appropriate storybooks, animated videos, and simulated treatment demonstrations to reduce fear of unfamiliar treatment environments and procedures. In addition, children were taught diaphragmatic breathing, progressive muscle relaxation, and simple mindfulness exercises to enhance emotional regulation and coping skills.

(2) Goal-Setting Phase (Week 1 of Radiotherapy)

Children collaborated with the intervention provider to establish achievable short-term treatment goals, such as independently completing positioning procedures or successfully wearing the immobilization mask. Positive reinforcement was provided through visual reward systems, such as a “goal achievement star chart,” to enhance children's sense of control, self-efficacy, and active participation in treatment.

(3) Cognitive Reframing Phase (Week 2 of Radiotherapy)

Children were encouraged to identify and express negative thoughts and concerns related to radiotherapy. Through role-playing activities, storytelling, and

guided discussions, they were assisted in developing more adaptive and positive interpretations of treatment experiences. For example, radiotherapy was reframed from a “frightening procedure” into a “superhero mission” that helps the body fight disease, thereby reducing catastrophic thinking and avoidance behaviors.

(4) Meaning-Making Phase (Late Stage of Radiotherapy)

During the later stages of treatment, children were encouraged to reflect on positive experiences throughout the radiotherapy journey through drawing, journaling, and family-sharing activities. With active parental involvement and support, children were guided to recognize personal growth, strengths, and positive changes resulting from their treatment experience. This process aimed to strengthen resilience, foster a sense of meaning, and promote positive psychological adaptation.

The conceptual framework of the phase-based PRISM intervention is presented in Fig. 1.

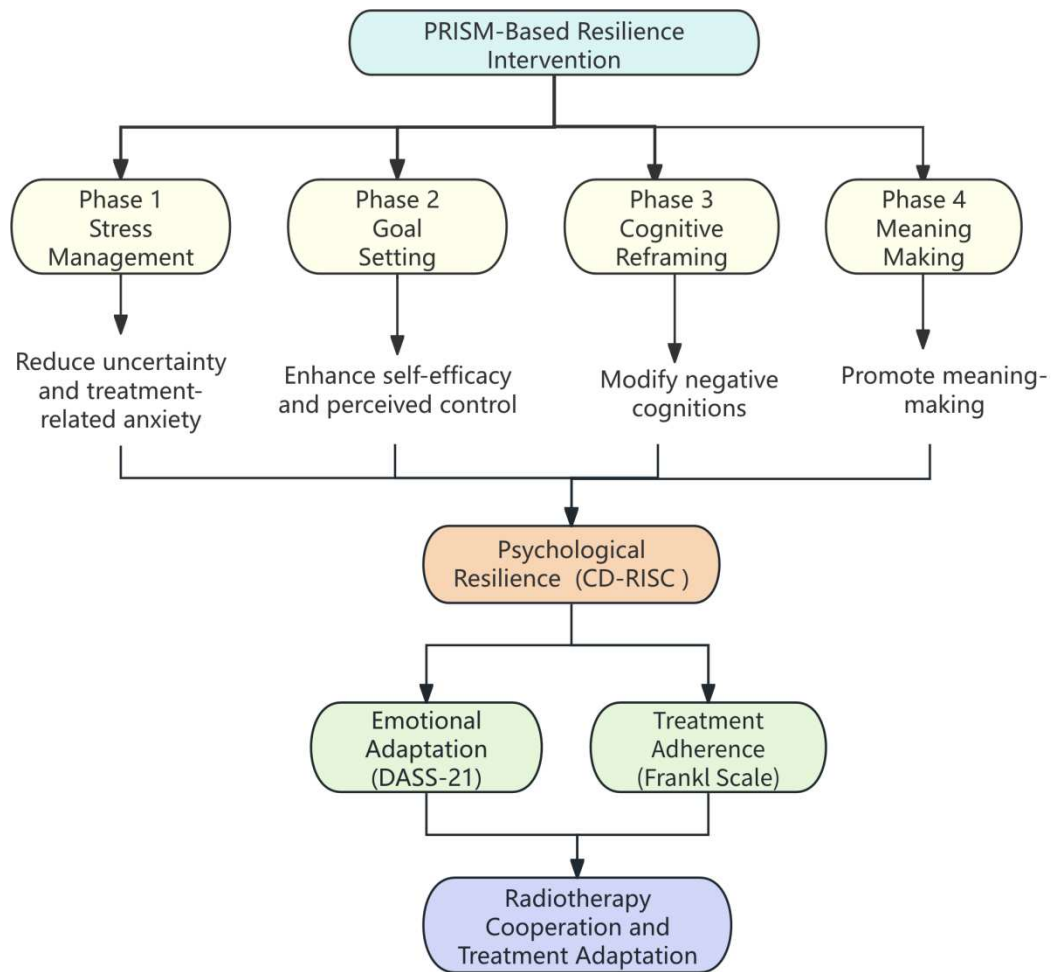


Figure 1. Conceptual Framework of the Phase-Based PRISM Resilience Intervention for Children Undergoing Radiotherapy

The PRISM intervention consists of four sequential modules: stress management, goal setting, cognitive reframing, and meaning making. These modules are designed to strengthen psychological resilience, which may subsequently promote emotional adaptation and treatment adherence, ultimately improving radiotherapy cooperation and treatment adaptation among pediatric patients.

2.3 Outcome Measures

2.3.1 Demographic and clinical characteristics

A structured questionnaire was developed to collect participants' demographic and clinical information, including age, sex, diagnosis, disease classification,

treatment regimen, place of residence, primary caregiver, health insurance type, parental educational level, family monthly income, religious affiliation, and Karnofsky Performance Status (KPS).

2.3.2 Psychological resilience

Psychological resilience was assessed using the 10-item Connor–Davidson Resilience Scale (CD-RISC-10) [24]. The scale consists of 10 items rated on a 5-point Likert scale ranging from 0 (“not true at all”) to 4 (“true nearly all the time”), yielding a total score ranging from 0 to 40. Higher scores indicate greater resilience.

2.3.3 Psychological distress

Psychological distress was evaluated using the Depression Anxiety Stress Scale-21 (DASS-21) [25]. The instrument comprises three subscales assessing depression, anxiety, and stress. Each item is rated on a 4-point Likert scale (0–3), with higher scores indicating greater psychological distress.

2.3.4 Behavioral problems

Behavioral problems were assessed using the Conners Parent Rating Scale (CPRS). Higher scores indicate greater behavioral problems. Considering that completion of the CPRS required active parental participation and that frequent assessments might increase respondent burden, behavioral evaluations were performed at baseline, week 2, and the completion of radiotherapy only.

2.3.5 Treatment adherence

Radiotherapy adherence was assessed using the Frankl Compliance Scale. An independent radiation therapist blinded to group allocation evaluated participants weekly throughout treatment. The scale ranges from 1 to 4, with higher scores indicating better treatment adherence and cooperation.

2.3.6 Positioning time

Positioning time was recorded using a stopwatch during each radiotherapy session. Timing commenced when the child entered the treatment room and positioning procedures began, and ended when treatment positioning met clinical requirements. Shorter positioning time was considered indicative of better treatment cooperation and adherence.

2.4 Data collection and quality control

Prior to study initiation, all intervention providers received standardized training on the PRISM protocol to ensure intervention fidelity and consistency. Participants were enrolled after written informed consent had been obtained from their legal guardians.

Baseline assessments were conducted before the initiation of radiotherapy. Follow-up assessments were performed weekly throughout treatment, including at baseline, weeks 1–3 of radiotherapy, and at treatment completion, resulting in five assessment time points.

All outcome measures were administered using standardized instructions. Data collection was conducted by trained research personnel, and treatment adherence assessments were performed by radiation therapists who were not involved in intervention delivery. Completed questionnaires were reviewed immediately for completeness and consistency. Any missing or unclear responses were verified with participants or caregivers whenever possible.

A total of 200 assessments were scheduled across all study time points. After data verification, 192 valid assessments were included in the final analysis.

2.5 Statistical analysis

Statistical analyses were performed using SPSS version 26.0 (IBM Corp., Armonk, NY, USA). Continuous variables were tested for normality and are presented as mean $\pm$ standard deviation (SD), while categorical variables are presented as frequencies and percentages [n (%)]. Baseline continuous variables were compared using the independent-samples t-test or Mann–Whitney U test, as appropriate. Categorical variables were compared using the chi-square test or Fisher’s exact test.

For repeated measures outcomes, including CD-RISC, DASS-21, Conners Rating Scale scores, and positioning time, repeated-measures analysis of variance (RM-ANOVA) was performed to evaluate group effects, time effects, and group-by-time interaction effects. Mauchly’s test of sphericity was conducted before analysis. When the assumption of sphericity was violated, Greenhouse–Geisser correction was applied. Bonferroni-adjusted post hoc comparisons were performed when appropriate.

Treatment adherence assessed by the Frankl Compliance Scale was treated as an ordinal variable. Differences in adherence levels between groups at each assessment point were compared using the Mann–Whitney U test, while within-group changes over time were evaluated using the Wilcoxon signed-rank test.

Correlations between psychological resilience, treatment adherence, and psychological distress were explored using Pearson’s or Spearman’s correlation analyses, depending on data distribution. Correlation analyses were considered exploratory because of the limited sample size. All statistical tests were two-tailed, and a P value < 0.05 was considered statistically significant.

3 Results

3.1 Baseline characteristics of the participants

Baseline demographic, clinical, and family-related characteristics were compared between the intervention and control groups prior to radiotherapy. Variables included age, sex, place of residence, primary caregiver, personality traits, disease type, treatment modality, health insurance status, parenting style, family monthly income, parental educational level, religious affiliation, and Karnofsky Performance Status (KPS).

No statistically significant differences were observed between the two groups with respect to any baseline characteristic (all $P > 0.05$), indicating good comparability following randomization. KPS scores were available for 17 participants in the intervention group and 19 participants in the control group, and no significant between-group difference was identified (85.88 ± 8.45 vs. 87.63 ± 7.96 , $P = 0.097$). Detailed baseline characteristics of the study participants are presented in Table 1.

Table 1. Baseline demographic, clinical, and family characteristics of participants

Variable	Category	Intervention Group (n = 20)	Control Group (n = 20)	Statistic	P value
Age (years)		10.05±3.50	10.70±3.78	t=0.562	0.577
Sex	Male	8(40.0)	8(40.0)	$\chi^2=0.000$	1.000
	Female	12(60.0)	12(60.0)		
Residence	Urban	11(55.0)	10(50.0)	$\chi^2=0.433$	0.805
	Town	4(20.0)	5(25.0)		
	Rural	5(25.0)	5(25.0)		
Primary caregiver	Parent(s)	19(95.0)	20(100.0)	0	1.000
	Other	1(5.0)	0(0.0)		
Child	Extrovert	8(40.0)	9(45.0)	$\chi^2=0.102$	0.749

personality	ed				
	Introverte	12(60.0)	11(55.0)		
Disease type	d				
	Solid tumor	19(95.0)	19(95.0)	0	1.000
	Hematologic malignancy	1(5.0)	1(5.0)		
Treatment modality	Chemotherapy + Radiotherapy	2(10.0)	2(10.0)	$\chi^2=0.000$	1.000
	Surgery + Chemotherapy + Radiotherapy	18(90.0)	18(90.0)		
Parenting style	Authoritative	11(55.0)	10(50.0)	$\chi^2=1.638$	0.651
	Authoritarian	1(5.0)	2(10.0)		
	Permissive	6(30.0)	5(25.0)		
	Neglectful	2(10.0)	3(15.0)		
Monthly family income	≤3,000	2(10.0)	2(10.0)	Z=1.417	0.156

	(RMB)				
	3,001–6,000	18(90.0)	16(80.0)		
	10,000–20,000	0(0.0)	1(5.0)		
	≥20,001	0(0.0)	1(5.0)		
Father's education	Primary school or below	1(5.0)	1(5.0)	Z=0.812	0.417
	Junior high school	10(50.0)	9(45.0)		
	Senior high school	7(35.0)	8(40.0)		
	Bachelor's degree	2(10.0)	2(10.0)		
Mother's education	Primary school or below	5(25.0)	5(25.0)	Z=0.319	0.750
	Junior high school	12(60.0)	11(55.0)		
	Senior high school	2(10.0)	2(10.0)		
	Bachelor's degree	1(5.0)	2(10.0)		
Religious	None	19(95.0)	19(95.0)	0	1.000

affiliation					
	Buddhism	1(5.0)	1(5.0)		
KPS score*	-	85.88±8.45	87.63±7.96	t=1.706	0.097

Note: KPS scores were available for 17 participants in the intervention group and 19 participants in the control group because KPS assessments were not completed for all enrolled participants.

3.2 Comparison of psychological resilience (CD-RISC) scores between the two groups over time

Repeated-measures analysis of variance was conducted to examine changes in CD-RISC scores between the intervention and control groups across five assessment time points, including baseline, weeks 1–3 of radiotherapy, and treatment completion. A significant main effect of time was observed ($F = 8.442$, $P < 0.001$), indicating that psychological resilience changed over the course of treatment. In addition, a significant group-by-time interaction effect was identified ($F = 2.743$, $P = 0.032$), suggesting different trajectories of resilience between the two groups. No significant main effect of group was found ($F = 1.894$, $P = 0.177$).

Bonferroni-adjusted post hoc comparisons revealed no significant differences in CD-RISC scores across time points within the control group (all $P > 0.05$). In contrast, participants in the intervention group demonstrated significantly higher CD-RISC scores at week 2 ($P = 0.018$) and at treatment completion ($P < 0.001$) compared with baseline. No significant difference was observed between week 2 and treatment completion ($P = 0.106$). Detailed Bonferroni-adjusted pairwise comparisons are shown in Table 4.

Regarding longitudinal trends, CD-RISC scores in the intervention group increased progressively following the initiation of radiotherapy, with significant improvements becoming evident by week 2 and remaining stable through treatment

completion (Figure 2A). Although resilience scores in the control group also showed a slight upward trend over time, the magnitude of change was comparatively smaller. These findings indicate that children receiving the phase-based PRISM intervention exhibited greater improvements in psychological resilience than those receiving routine education alone. The beneficial effects emerged as early as the second week of radiotherapy and were maintained until the completion of treatment. The longitudinal changes in CD-RISC scores are presented in Figure 2A.

Table 2. Changes in Psychological Resilience (CD-RISC) Scores Over Time in the Intervention and Control Groups

Group	n	Baseline	Week 1	Week 2	Week 3	End of RT
Intervention	20	21.35±6.7	22.20±7.14	24.45±5.77	25.65±5.37	26.65±5.23
Control	20	22.35±5.08	22.20±5.09	23.20±4.60	23.65±4.73	23.85±4.72

Abbreviation: RT, radiotherapy.

Note: Data are presented as mean ± standard deviation (SD).

Detailed results of the repeated-measures ANOVA for psychological resilience are presented in Table 3.

Table 3. Repeated-measures ANOVA of CD-RISC scores

Source of variation	SS	df	MS	F	P value
Group	104.04	1	104.04	1.894	0.177
Time	368.04	4	92.01	8.442	<0.001
Group × Time	119.56	4	29.89	2.743	0.032
Error	-	152	-	-	-

Abbreviations: SS, sum of squares; MS, mean square.

Table 4. Bonferroni-adjusted post hoc comparisons of CD-RISC scores within the intervention group

Comparison	Mean difference	P value
Baseline vs. Week 2	-3.10	0.018
Baseline vs. End of RT	-5.30	<0.001
Week 2 vs. End of RT	-2.20	0.106

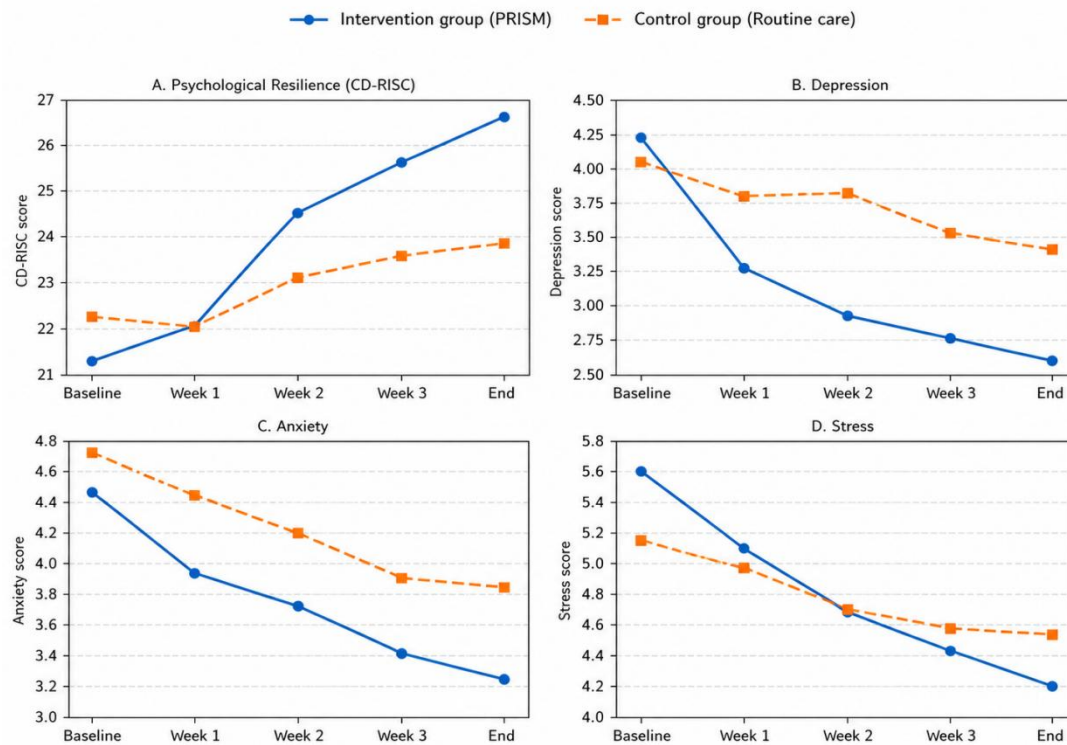


Figure 2. Longitudinal Changes in Psychological Outcomes During Pediatric Radiotherapy

3.3 Changes in psychosocial adaptation during radiotherapy

Repeated-measures ANOVA was performed to evaluate changes in depression, anxiety, and stress scores during radiotherapy. Significant time effects were observed for depression, anxiety, and stress (all $P < 0.001$), indicating that psychological distress changed over the course of treatment. No significant group effects were identified (all $P > 0.05$). However, significant group-by-time interaction effects were observed for depression ($F = 2.876$, $P = 0.025$), anxiety ($F = 2.693$, $P = 0.034$), and

stress ($F = 3.124$, $P = 0.018$), suggesting different trajectories of psychological distress between the intervention and control groups (Table 5).

Visual inspection of the longitudinal trends demonstrated only modest reductions in depression, anxiety, and stress scores in the control group. In contrast, all three indicators showed progressive decreases from Week 2 onward in the intervention group and remained lower throughout the remainder of treatment. By the end of radiotherapy, depression, anxiety, and stress scores were consistently lower in the intervention group than in the control group, with the greatest reduction observed in depressive symptoms (Figures 2 B-D).

These findings suggest that the phase-based PRISM intervention may improve psychosocial adaptation in children undergoing radiotherapy by reducing depression, anxiety, and stress during treatment, with benefits emerging early and persisting throughout the radiotherapy course.

Table 5. Changes in psychosocial adaptation during radiotherapy

Outcome	Group	Baseline	Week 1	Week 2	Week 3	End of radiotherapy	Ftime	Ptime	Fgroup	Pgroup	Fintera	Pintera
Depression	Control (n=20)	4.05±2.86	3.85±2.76	3.85±2.62	3.55±2.39	3.45±2.35	8.365	<0.001	0.956	0.335	2.876	0.025
	Intervention (n=20)	4.25±3.24	3.20±2.73	2.85±2.41	2.70±2.34	2.55±2.39						
Anxiety	Control	4.70±3.24	4.40±3.24	4.20±2.41	3.90±2.34	3.85±2.35	7.482	<0.001	1.248	0.271	2.693	0.034

Stress	Intervention	4.50±3.	3.90±2.	3.65±2.	3.35±2.	3.20±2.3						
	(n=20)	66	94	70	58	6						
Stress	Control	5.20±2.	5.00±2.	4.70±1.	4.55±1.	4.50±1.7	9.147	<0.00	1.562	0.219	3.124	0.018
	(n=20)	12	00	92	82	9						
	Intervention	5.65±2.	5.10±2.	4.65±1.	4.40±1.	4.20±1.6						
	(n=20)	43	00	73	70	7						

3.4 Comparison of behavioral problems (Conners Rating Scale) between the two groups over time

Comparisons of Conners Rating Scale scores across all dimensions and total difficulties scores between the two groups are presented in Table 6. At baseline, no significant differences were observed between the intervention and control groups in emotional symptoms, conduct problems, hyperactivity, peer relationship problems, prosocial behavior, or total difficulties scores (all $P > 0.05$), indicating good baseline comparability with respect to behavioral functioning.

At week 2 and at the completion of radiotherapy, no significant between-group differences were observed in any Conners Rating Scale dimension or in total difficulties scores (all $P > 0.05$). However, longitudinal trends suggested relatively stable behavioral scores in the control group throughout the treatment period. In contrast, the intervention group demonstrated a gradual reduction in total difficulties scores, decreasing from (23.60 ± 4.81) at baseline to (20.90 ± 3.98) at the completion of radiotherapy.

Within-group analyses showed no significant changes in total difficulties scores across assessment time points in the control group (all $P > 0.05$). In the intervention group, total difficulties scores at treatment completion were significantly lower than those at baseline and at week 2 (both $P < 0.05$), suggesting that the phase-based PRISM intervention may contribute to improvements in overall behavioral functioning among children undergoing radiotherapy.

Although no statistically significant between-group differences were identified in individual Conners Rating Scale dimensions or total difficulties scores, the consistent downward trend observed in the intervention group suggests a potential beneficial effect of the PRISM intervention on behavioral adaptation during radiotherapy.

Table 6. Changes in Conners Rating Scale Scores During Radiotherapy

Outcome	Group	Baseline	Week 2	End of RT	t	P value
					value	(End of
					(End	RT)
					of	
					RT)	
Emotional symptoms	Intervention (n=20)	4.15 ± 1.81	3.55±1.50	3.00±1.17	0.132	0.896
	Control (n=20)	3.65±1.76	3.35±1.50	2.95±1.23		
Conduct problems	Intervention (n=20)	3.35 ± 1.14	2.60±1.10	2.35±0.93	1.861	0.071
	Control (n=20)	3.15 ± 0.93	2.85±0.81	2.85±0.75		
Hyperactivi	Intervention	4.60 ± 1.85	4.35±1.9	4.20±1.88	1.226	0.228

ty	(n=20)		5			
	Control (n=20)	3.85 ± 1.50	3.65±1.5	3.55±1.43		
			3			
Peer	Intervention	4.35 ± 1.04	3.90±1.1	3.10±0.85	1.842	0.074
relationship	(n=20)		2			
problems						
	Control (n=20)	4.20 ± 0.95	3.90±0.9	3.60±0.88		
			1			
Prosocial	Intervention	7.15 ± 1.76	7.95±1.7	8.35±1.60	0.810	0.423
behavior	(n=20)		6			
	Control (n=20)	7.55 ± 1.82	7.90±1.5	7.95±1.54		
			9			
Total	Intervention	23.60 ± 4.81	22.35±4.	20.90±3.98	0.108	0.915
difficulties	(n=20)		35			
	Control (n=20)	22.40 ± 4.09	21.90±4.	21.05±4.87		
			65			

3.5 Comparison of treatment adherence (Frankl Compliance Scale) between the two groups

The longitudinal distribution of Frankl Compliance Scale ratings is presented in Table 7 and illustrated in Fig. 3. At baseline, no significant difference in treatment adherence was observed between the intervention and control groups ($Z = -0.258$, $P = 0.796$). Similarly, adherence levels remained comparable during the first week ($Z = -0.775$, $P = 0.439$) and second week of radiotherapy ($Z = -1.800$, $P = 0.072$).

From the third week onward, treatment adherence in the intervention group was significantly better than that in the control group. Significant between-group

differences were observed at week 3 ($Z = -2.138$, $P = 0.033$) and at the completion of radiotherapy ($Z = -2.074$, $P = 0.038$).

At treatment completion, 95.0% of children in the intervention group achieved good or excellent adherence (Frankl grades 3–4), compared with 80.0% in the control group. Furthermore, 50.0% of participants in the intervention group achieved the highest adherence level (grade 4), compared with 45.0% in the control group.

These findings indicate that the phase-based PRISM intervention was associated with improved treatment adherence among children undergoing radiotherapy. The beneficial effect became evident during the later phase of treatment and was maintained through treatment completion.

Table 7. Distribution of Frankl Compliance Scale ratings during radiotherapy [n (%)]

Time point	Frankl grade	Control (n = 20)	Intervention (n=20)	Z value	P value
Baseline	Grade 1 (Poor)	1(5.0)	1(5.0)	-0.258	0.796
	Grade 2 (Fair)	6(30.0)	5(25.0)		
	Grade 3 (Good)	10(50.0)	10(50.0)		
	Grade 4 (Excellent)	3(15.0)	4(20.0)		
Week 1	Grade 1 (Poor)	1(5.0)	0(0.0)	-0.775	0.439
	Grade 2	6(30.0)	5(25.0)		

	(Fair)				
	Grade 3	9(45.0)	10(50.0)		
	(Good)				
	Grade 4	4(20.0)	5(25.0)		
	(Excellent)				
Week 2	Grade 1	1(5.0)	0(0.0)	-1.800	0.072
	(Poor)				
	Grade 2	5(25.0)	3(15.0)		
	(Fair)				
	Grade 3	8(40.0)	10(50.0)		
	(Good)				
	Grade 4	6(30.0)	7(35.0)		
	(Excellent)				
Week 3	Grade 1	0(0.0)	0(0.0)	-2.138	0.033
	(Poor)				
	Grade 2	5(25.0)	2(10.0)		
	(Fair)				
	Grade 3	7(35.0)	9(45.0)		
	(Good)				
	Grade 4	8(40.0)	9(45.0)		
	(Excellent)				
End of RT	Grade 1	0(0.0)	0(0.0)	-2.074	0.038
	(Poor)				
	Grade 2	4(20.0)	1(5.0)		
	(Fair)				
	Grade 3	7(35.0)	9(45.0)		
	(Good)				
	Grade 4	9(45.0)	10(50.0)		
	(Excellent)				

Note: Treatment adherence was assessed using the Frankl Compliance Scale. Higher grades indicate better treatment adherence and cooperation during radiotherapy.

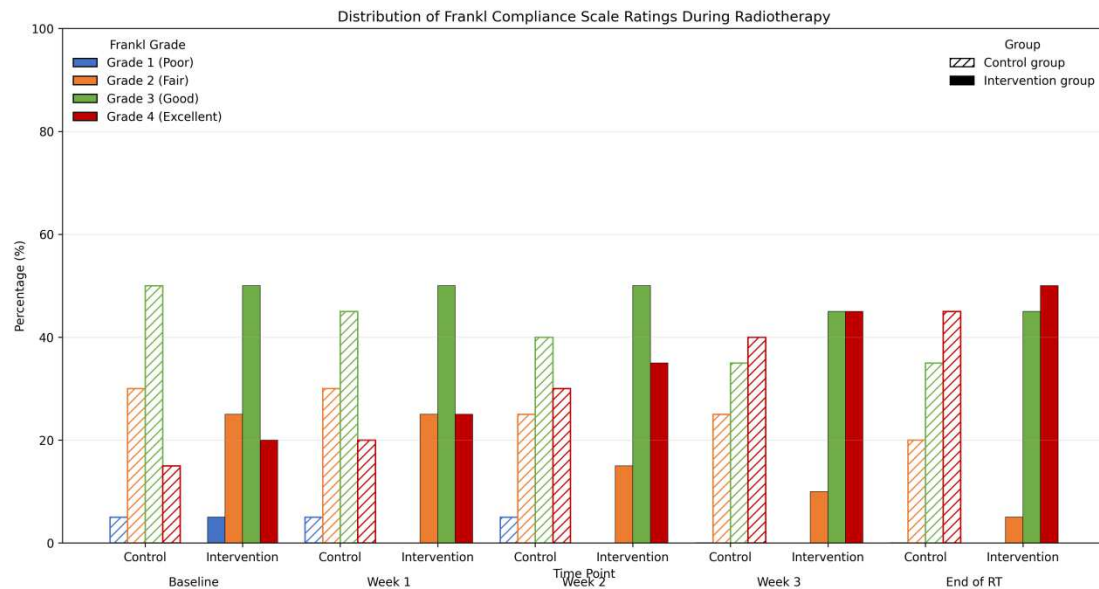


Figure 3. Longitudinal Changes in Frankl Compliance Ratings During Radiotherapy

3.6 Comparison of positioning time between the two groups

The longitudinal changes in positioning time are presented in Table 8 and illustrated in Fig. 4. At baseline, no significant difference in positioning time was observed between the intervention and control groups ($P = 0.623$), indicating good baseline comparability.

Positioning time decreased progressively throughout radiotherapy in both groups. Within-group repeated-measures analyses demonstrated significant reductions over time in both the control group ($F = 3.247$, $P = 0.014$) and the intervention group ($F = 6.892$, $P < 0.001$). In the intervention group, mean positioning time decreased from (136.45 ± 32.18 s) at baseline to (107.85 ± 25.43 s) at treatment completion, representing a reduction of 28.60 s (20.96%). In comparison, positioning time in the

control group decreased from (141.85 ± 36.72 s) to (120.15 ± 28.96 s), corresponding to a reduction of 21.70 s (15.30%).

Although positioning time at treatment completion was shorter in the intervention group than in the control group (107.85 ± 25.43 s vs. 120.15 ± 28.96 s), the between-group difference did not reach statistical significance ($P = 0.162$). Overall, children receiving the PRISM intervention exhibited a greater reduction in positioning time, suggesting a potential improvement in treatment cooperation; however, the effect on positioning efficiency requires confirmation in studies with larger sample sizes.

Table 8. Longitudinal changes in positioning time during radiotherapy (s, mean $\pm$ SD)

Time point	Control (n=20)	Intervention (n=20)	t value	P value
Baseline	141.85 $\pm$ 36.72	136.45 $\pm$ 32.18	0.495	0.623
Week 1	129.45 $\pm$ 31.26	131.85 $\pm$ 34.57	0.233	0.817
Week 2	126.95 $\pm$ 31.18	122.55 $\pm$ 30.96	0.448	0.657
Week 3	122.35 $\pm$ 29.83	115.20 $\pm$ 27.94	0.784	0.438
End of RT	120.15 $\pm$ 28.96	107.85 $\pm$ 25.43	1.427	0.162

Table 9. Within-group repeated-measures analysis of positioning time

Group	Ftime	Ptime	Trend
Control group	3.247	0.014	Gradual decrease
Intervention group	6.892	< 0.001	Marked decrease

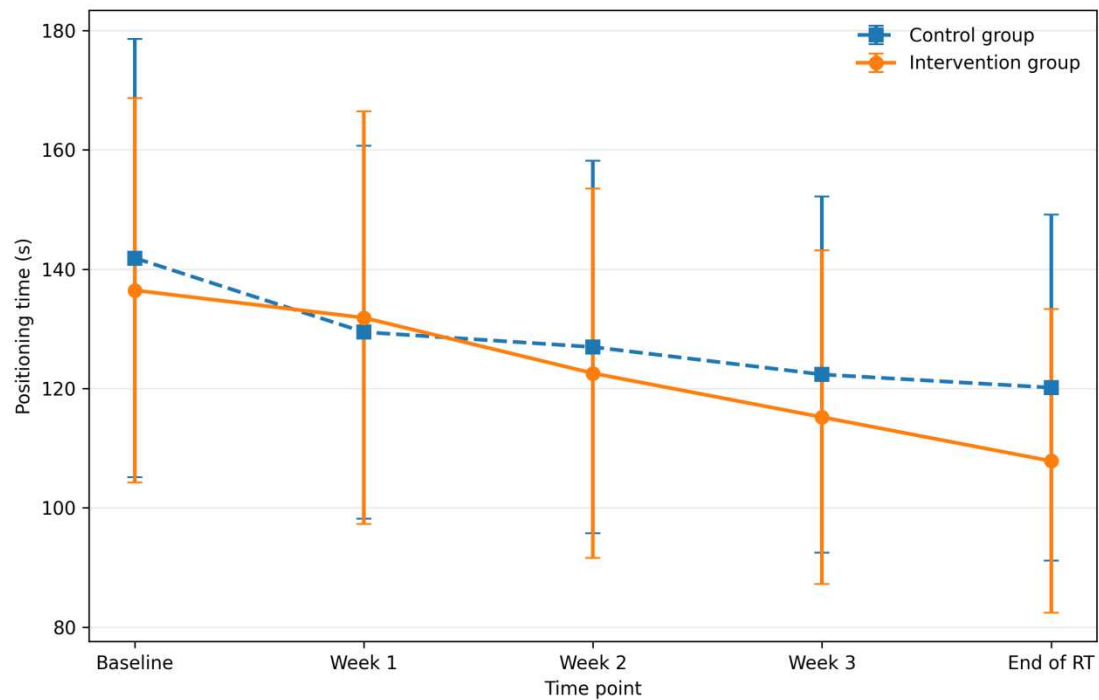


Figure 4. Longitudinal Changes in Positioning Time During Radiotherapy

Note: Mean positioning time ($\pm$ SD) in the intervention and control groups measured at baseline, weeks 1–3 of radiotherapy, and treatment completion. Positioning time decreased progressively in both groups, with a greater reduction observed in the intervention group.

3.7 Correlations Between Psychological Resilience, Treatment Adherence, and Negative Emotional Symptoms

Detailed correlation analyses between psychological resilience, treatment adherence, and negative emotional symptoms at the completion of radiotherapy are presented in Table 10. Overall, CD-RISC scores were positively correlated with Frankl compliance ratings ($r = 0.712$, $P < 0.001$), indicating that higher levels of psychological resilience were associated with better treatment adherence. In contrast, CD-RISC scores were negatively correlated with DASS-21 depression ($r = -0.658$, $P < 0.001$), anxiety ($r = -0.592$, $P < 0.001$), stress ($r = -0.634$, $P < 0.001$), and total

DASS-21 scores ($r = -0.681$, $P < 0.001$), suggesting that greater psychological resilience was associated with lower levels of psychological distress.

Further subgroup analyses demonstrated stronger correlations in the intervention group than in the control group. Specifically, the positive correlation between psychological resilience and treatment adherence was stronger in the intervention group ($r = 0.743$, $P < 0.001$) than in the control group ($r = 0.586$, $P = 0.007$). Likewise, the negative correlations between CD-RISC scores and depression ($r = -0.702$ vs. -0.512), anxiety ($r = -0.668$ vs. -0.448), stress ($r = -0.691$ vs. -0.475), and total DASS-21 scores ($r = -0.715$ vs. -0.513) were consistently stronger in the intervention group than in the control group.

These findings indicate that higher psychological resilience was associated with better treatment adherence and lower levels of negative emotional symptoms among children undergoing radiotherapy. Moreover, the stronger correlations observed in the intervention group suggest a closer relationship between resilience, emotional well-being, and treatment cooperation following the PRISM-based intervention.

Table 10. Correlations Between Psychological Resilience, Treatment Adherence, and Negative Emotional Symptoms at the Completion of Radiotherapy

Variable	Control group (n=20)	Intervention group (n=20)	Overall (n=40)
CD-RISC vs Frankl compliance	$r = 0.586$, $P = 0.007$	$r = 0.743$, $P < 0.001$	$r = 0.712$, $P < 0.001$
CD-RISC vs Depression	$r = -0.512$, $P = 0.021$	$r = -0.702$, $P < 0.001$	$r = -0.658$, $P < 0.001$
CD-RISC vs Anxiety	$r = -0.448$, $P = 0.048$	$r = -0.668$, $P < 0.001$	$r = -0.592$, $P < 0.001$
CD-RISC vs Stress	$r = -0.475$, $P = 0.034$	$r = -0.691$, $P < 0.001$	$r = -0.634$, $P < 0.001$

CD-RISC vs DASS-21	$r = -0.513, P = 0.020$	$r = -0.715, P < 0.001$	$r = -0.681, P < 0.001$
total score			

4 Discussion

Children undergoing radiotherapy for cancer are particularly vulnerable to fear, anxiety, and emotional distress due to unfamiliar treatment environments, immobilization devices, and machine-related noise. These psychological challenges may negatively affect treatment adherence and positioning cooperation during radiotherapy. To address these issues, the present study implemented a phase-based resilience intervention grounded in the Promoting Resilience in Stress Management (PRISM) model. The findings demonstrated that the intervention effectively improved psychological outcomes and treatment cooperation among pediatric oncology patients, suggesting its potential clinical value in radiotherapy settings.

The present study showed that children who received the PRISM intervention exhibited a progressive increase in psychological resilience throughout radiotherapy, with significantly higher CD-RISC scores than those in the control group at treatment completion. These findings are consistent with previous studies demonstrating that targeted resilience interventions can enhance psychological adaptation and coping abilities among children with cancer [26–27]. Several mechanisms may explain these effects. The stress management component of PRISM helps children acquire relaxation and emotional regulation skills, thereby reducing immediate anxiety. Goal-setting strategies enhance children's sense of control over the treatment process, while cognitive reframing encourages them to reinterpret radiotherapy from a threatening experience into a meaningful step toward recovery, thereby reducing catastrophic thinking. Furthermore, the meaning-making component helps children identify positive meaning within their treatment experiences. Previous studies have shown that children and their parents adopt a variety of coping strategies during cancer treatment, and different coping approaches may significantly influence emotional well-being and treatment cooperation [28]. Fuji et al. reported that stepwise

video-based exposure to radiotherapy equipment, positioning procedures, and treatment environments substantially reduced children's fear of the unknown [29]. Similarly, interactive educational interventions have been shown to alleviate distress among both pediatric patients and their caregivers during radiotherapy. Collectively, these multidimensional intervention components may facilitate the gradual accumulation of psychological resources and contribute to enhanced resilience [30].

Regarding negative emotional symptoms, depression, anxiety, and stress scores in the intervention group all demonstrated downward trends following the intervention. Among these outcomes, depression scores were significantly lower in the intervention group than in the control group at the completion of radiotherapy, whereas improvements in anxiety and stress did not reach statistical significance. These findings suggest that the PRISM intervention may have beneficial effects on negative emotional symptoms, although the magnitude of improvement differs across emotional domains. This observation is consistent with findings reported by Ros et al. [31]. Depression in pediatric cancer patients is often associated with deeper psychological concerns, including uncertainty regarding prognosis, social isolation, and diminished self-worth [32–33]. The meaning-making component of PRISM may directly target these underlying psychological processes by fostering positive cognitive appraisal and adaptive coping. In contrast, anxiety and stress are more closely related to immediate treatment-related stimuli, such as immobilization procedures and treatment environments, and may partially improve naturally as children become familiar with radiotherapy over time [34–36]. Therefore, between-group differences in these dimensions were relatively modest. Future interventions may benefit from incorporating additional strategies specifically targeting anxiety and stress management [37].

With respect to behavioral outcomes, the total difficulties score on the Conners scale decreased significantly from baseline to treatment completion in the intervention group, whereas no significant changes were observed in the control group. Although

between-group differences did not reach statistical significance, likely due to the relatively small sample size and substantial inter-individual variability in behavioral symptoms, the observed within-group improvement may indicate a potential beneficial effect of resilience enhancement on behavioral adaptation during treatment. Previous studies have suggested that higher levels of psychological resilience are associated with better emotional regulation, self-control, and social adjustment, which may contribute to reductions in impulsivity, hyperactivity, and peer relationship difficulties among children with cancer [38]. Therefore, the continuous improvement observed in the intervention group remains clinically meaningful and warrants further investigation in larger studies [39].

Treatment adherence is an important objective indicator for evaluating the effectiveness of psychological interventions during pediatric radiotherapy. In the present study, children in the intervention group demonstrated significantly better Frankl compliance ratings than those in the control group beginning in the third week of radiotherapy. At treatment completion, 95% of children in the intervention group achieved good or excellent adherence, compared with 80% in the control group. Positioning time decreased progressively in both groups throughout radiotherapy. Although the intervention group demonstrated a larger numerical reduction in positioning time from baseline to treatment completion (28.60 seconds, 20.96%) than the control group (21.70 seconds, 15.30%), the between-group difference did not reach statistical significance. Nevertheless, the observed trend, together with the improvement in treatment adherence, suggests that the PRISM intervention may facilitate treatment cooperation and adaptation during radiotherapy.

Previous studies have demonstrated that systematic psychological preparation, behavioral training, and cognitive interventions can effectively reduce radiotherapy-related fear and anxiety in children, improve treatment accuracy and cooperation, and decrease the need for sedation during radiotherapy [40–41]. Notably, several children in the intervention group gradually transitioned from requiring

repeated encouragement to actively cooperating with treatment during the later stages of radiotherapy. This change may be attributable to the goal-setting component of the PRISM intervention. By helping children achieve incremental treatment-related goals and providing positive reinforcement, the intervention may enhance self-efficacy and perceived control over treatment. Higher levels of self-efficacy have been consistently associated with improved healthcare behaviors and treatment adherence [37].

To further explore the potential mechanisms underlying the effects of the PRISM intervention, correlation analyses were conducted between psychological resilience, treatment adherence, and negative emotional symptoms. The results demonstrated that CD-RISC scores were positively correlated with Frankl compliance ratings and negatively correlated with all dimensions of the DASS-21. Moreover, the strength of these correlations was consistently greater in the intervention group than in the control group. These findings suggest that psychological resilience may serve as an important link between emotional adaptation and treatment-related behaviors. Therefore, the beneficial effects of the PRISM intervention on treatment adherence may be partially mediated through improvements in psychological resilience, which in turn contribute to better emotional adjustment and behavioral functioning [42].

In addition, parental involvement constituted an important component of the intervention process. Through goal-oriented reward systems and positive feedback, parents were encouraged to reinforce children's confidence and motivation throughout treatment, highlighting the critical role of family support in pediatric oncology care. Previous research examining the everyday experiences of Swedish families during childhood cancer treatment identified family support as a key resource for coping with treatment-related stress, demonstrating that parental presence and emotional support can substantially alleviate psychological distress among pediatric patients [43]. This finding is particularly relevant in pediatric oncology, where parents often function as co-regulators of children's emotional responses during treatment.

Consistent with these findings, parents in the present study were encouraged to participate in the intervention by assisting with “Little Warrior” goal-setting activities and reward programs, such as creating achievement charts and providing praise following successful treatment sessions. These family-centered strategies may have further strengthened the effectiveness of the intervention and enhanced children's engagement with treatment.

Several limitations of this study should be acknowledged. First, the relatively small sample size may have limited statistical power and reduced the generalizability of the findings. Larger multicenter studies are needed to validate these results. Second, follow-up was limited to the radiotherapy period, and therefore the long-term effects of the intervention on psychological adaptation, quality of life, and social functioning remain unclear. Third, complete blinding was not feasible due to the nature of the intervention, which may have introduced potential bias. In addition, several outcomes were assessed using questionnaire-based measures, which may be subject to reporting bias. Furthermore, factors such as parenting style, parental educational level, and socioeconomic status may influence intervention outcomes and should be considered in future multivariate analyses.

In conclusion, the phase-based PRISM intervention effectively enhanced psychological resilience among children undergoing radiotherapy for cancer and was associated with improvements in emotional well-being, behavioral adaptation, and treatment adherence. Psychological resilience may represent an important factor underlying treatment adaptation. Given its feasibility, simplicity, and high acceptability, the PRISM intervention may serve as a promising supportive care strategy in pediatric radiation oncology.

5 Conclusion

A phase-based resilience intervention based on the Promoting Resilience in Stress Management (PRISM) model effectively enhanced psychological resilience

among children undergoing radiotherapy for cancer and contributed to improvements in emotional well-being, behavioral adaptation, and treatment adherence.

Psychological resilience was positively associated with treatment adherence and negatively associated with depression, anxiety, and stress, suggesting that resilience enhancement may be an important factor in treatment adaptation.

As a structured, feasible, and highly acceptable intervention, the PRISM model demonstrates promising clinical applicability and may represent a valuable supportive care strategy in pediatric radiation oncology. Further multicenter studies with larger sample sizes and longer follow-up periods are warranted to confirm its long-term effectiveness.

Declarations

1. Clinical Trial Registration

Clinical trial number: not applicable.

This investigator-initiated behavioral and psychosocial intervention study was not prospectively registered in a public clinical trial registry.

2. Ethics Approval

The study protocol was reviewed and approved by the Ethics Committee of Sun Yat-sen University Cancer Center (Approval No. SL-B2023-608-01). The study was conducted in accordance with the principles of the Declaration of Helsinki.

3. Funding

The authors received no specific funding for this work.

4. Conflict of Interest

The authors declare that they have no conflict of interest.

5. Data Availability

The datasets generated and/or analyzed during the current study are available from the corresponding author upon reasonable request.

6. Author Contributions

Zhiyue Lin, Jiaxiu Luo, and Zongtai Li contributed to the study conception and design, intervention implementation, data interpretation, and manuscript drafting. Xiaolan Zhong, Hailong Wang, and Jindi Liu were responsible for participant recruitment, data collection, and database management. Wenlong Zhu prepared the figures and graphical presentations. Wenyan Yao participated in data verification and manuscript preparation. Senkui Xu, Feng Chi, and Huilang He critically reviewed and revised the manuscript. Huilang He supervised the study, provided methodological guidance, and served as the corresponding author. All authors read and approved the final manuscript.

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