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Intervention effects of subconscious cultivation in mindfulness-based physical education teaching and training on pain perception and psychological resilience in advanced cancer patients

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Abstract: To explore the intervention effects and psychological mechanisms of subconscious cultivation in mindfulness-based physical education training on pain perception and psychological resilience in late-stage cancer patients. **Methods:** A double-blind randomized controlled trial design was adopted, with 128 late-stage cancer patients randomly allocated to intervention and control groups at a 1:1 ratio. The intervention group received 8 weeks of mindfulness-based physical education training combined with subconscious cultivation techniques, while the control group received routine health education and general physical activities. The Brief Pain Inventory, Resilience Scale for Adults, Five Facet Mindfulness Questionnaire, Subconscious Awareness Scale, and EEG biofeedback technology were used to assess intervention effects. Data collection included three time points: baseline, postintervention, and follow-up. **Results:** The intervention group's pain intensity scores decreased from baseline 6.42 ± 1.58 to 4.73 ± 1.42 , an improvement of 26.3% ($p < 0.001$); pain interference scores improved by 32.5% ($p < 0.001$). Psychological resilience total scores increased from 98.35 ± 18.26 to 124.67 ± 19.85 , an improvement of 25.1% ($p < 0.001$), with all dimensions showing improvements exceeding 20%. EEG monitoring showed α -wave power density increased by 68.4% and θ -wave power density increased by 66.2% (both $p < 0.001$). Mediation analysis indicated that subconscious state improvement played a significant mediating role between the intervention program and psychological resilience enhancement (mediation effect = 0.423, accounting for 48.7% of the total effect). Pain catastrophizing decreased by 33.4%, pain acceptance increased by 50.8%, and cognitive reappraisal ability improved by 32.1% (all $p < 0.001$). Total emotion regulation difficulties improved by 33.2%, and 87.5% of patients reported being able to spontaneously initiate mindful coping strategies. The control group showed improvements of less than 8% across all indicators. Intervention effects remained stable during the follow-up period. **Conclusion:** Mindfulness-based physical education training combined with subconscious cultivation techniques can significantly improve pain perception and psychological resilience levels in late-stage cancer patients. Subconscious cultivation plays an important mediating role in psychological resilience enhancement, with subconscious regulation of cognitive reappraisal ability and subconscious integration of emotion regulation strategies being key psychological mechanisms. This intervention model provides new theoretical basis and practical solutions for psychological rehabilitation of cancer patients.

Keywords: late-stage cancer; mindfulness training; pain perception; physical education; psychological intervention; psychological resilience; subconscious cultivation; randomized controlled trial

1. Introduction

Cancer, as a major disease threatening human health, involves not only pathological changes at the physiological level during its treatment process, but also profoundly affects patients' psychological health status. Late-stage cancer patients often face multiple challenges including persistent pain, psychological distress, and declining quality of life. While traditional pharmacological treatments can alleviate symptoms to some extent, their side effects and dependency issues are becoming increasingly prominent [1]. In recent years, mindfulness therapy, as an emerging psychological intervention technique, has demonstrated significant effects in cancer patient rehabilitation treatment. Research indicates that mindfulness-based stress reduction training can effectively improve the psychological state and quality of life of gastric cancer patients undergoing chemotherapy, while group education combined with mindfulness-based cognitive training has also achieved positive outcomes in schizophrenia patient rehabilitation [2]. These studies provide important theoretical foundations and practical evidence for the application of mindfulness therapy in cancer psychological intervention, highlighting the core value of psychological treatment in the disease recovery process.

The psychological therapeutic mechanisms of mindfulness training are primarily manifested in its deep reconstruction of individual cognitive functions and emotion regulation abilities. Through systematic mindfulness meditation practice, patients can cultivate nonjudgmental awareness of present-moment experiences, thereby changing cognitive patterns toward pain and suffering. Recent research has found that mindfulness meditation training can significantly improve gastrointestinal symptoms and emotional states in chronic heart failure patients, revealing the unique value of mindfulness training in physiological–psychological integrated intervention [3]. More importantly, neuroimaging studies by Li et al. [4] have confirmed that mindfulness meditation training can promote dynamic reconstruction of executive control networks and default mode networks, providing crucial evidence for understanding the neuropsychological mechanisms of mindfulness training. These research findings indicate that mindfulness training is not merely a superficial relaxation technique, but rather a deep psychological intervention method capable of fundamentally changing brain functional connectivity patterns.

The combination of physical education training with mindfulness techniques represents an important innovative direction in the field of psychological therapy. Traditional mindfulness training is predominantly based on static meditation, while integrating mindfulness concepts into physical exercise can better stimulate patient participation enthusiasm and simultaneously promote the release of neurotransmitters such as endorphins through physical activity, enhancing the physiological foundation of psychological intervention [4]. Zhang et al. [5] found that mindfulness-based stress reduction training combined with moderate exercise could significantly improve cardiopulmonary function, psychological state, and quality of life in elderly chronic heart failure patients, providing strong support for the application of mindfulness-based physical training in chronic disease management. Meanwhile, mindfulness training research in military environments has also confirmed the effectiveness

of mindfulness techniques in high-stress situations, providing important reference for psychological intervention in the special population of cancer patients. Subconscious cultivation, as the deep goal of mindfulness training, emphasizes establishing new cognitive patterns and coping mechanisms at the subconscious level through continuous practice. This deep-level psychological reconstruction is of crucial significance for enhancing patients' psychological resilience.

The current research aims to construct a mindfulness-centered physical education training model that explores its intervention effects on pain perception and psychological resilience in late-stage cancer patients through systematic subconscious cultivation techniques [6]. Online mindfulness training programs have been proven to effectively enhance psychological health levels and mindfulness traits in graduate student populations, providing technical pathway references for the implementation of this study. The innovation of this research lies in organically integrating mindfulness concepts, physical exercise, and subconscious cultivation techniques to form a multidimensional psychological intervention system. Through in-depth analysis of cognitive reappraisal mechanisms of pain perception, neuropsychological foundations of psychological resilience, and therapeutic value of subconscious cultivation, this study not only expects to provide a novel nonpharmacological intervention approach for late-stage cancer patients, but also aims to contribute new insights to the development of psychological therapy theory and optimization of clinical practice [7]. This research holds important theoretical significance and practical value for promoting the development of mind-body integrative medicine, improving comprehensive person-centered care models for cancer patients, and enhancing the status of psychological therapy in modern medicine.

2. Literature review

Mindfulness therapy, as a psychological intervention technique developed from Buddhist meditation traditions, has gained widespread recognition and application in modern medicine and psychological treatment fields. Its core concept lies in cultivating individuals' nonjudgmental awareness of present-moment experiences, and reshaping cognitive patterns and emotion regulation mechanisms through systematic training. In psychological interventions for cancer patients, mindfulness training demonstrates significant therapeutic potential. Feng's research [8] indicates that empowerment education nursing combined with mindfulness-based stress reduction training can effectively improve the psychological state and treatment compliance of gastric cancer patients undergoing postoperative chemotherapy, providing important evidence for the application of mindfulness techniques in comprehensive cancer treatment. Meanwhile, Wang's research [9] further confirms the application value of mindfulness training combined with Five Element music therapy in oncology chemotherapy patients, revealing the synergistic effects of multimodal mindfulness intervention. These studies collectively demonstrate that mindfulness training can not only directly affect patients' psychological states, but also indirectly promote recovery effects by enhancing treatment cooperation, reflecting the core position of psychological therapy in disease management. More importantly, the improving effects of mindfulness cancer rehabilitation training on disease uncertainty and

psychological resilience in breast cancer radical mastectomy patients, as well as its application effects in intestinal cancer chemotherapy patients, further confirm the broad applicability and significant efficacy of mindfulness techniques in cancer psychological intervention.

Pain management, as an important component of cancer treatment, has increasingly attracted attention regarding its psychological intervention mechanisms. Wang and co-workers [10] found in their study of chronic pain in plateau military personnel that mindfulness-based stress reduction training could significantly improve chronic pain symptoms, providing important clues for understanding the pain regulation mechanisms of mindfulness techniques. The subjective experience of pain involves not only sensory-level signal transmission, but more deeply reflects individuals' cognitive appraisal and emotional response patterns. Mindfulness training, by cultivating nonresistant awareness of pain sensations, can break the vicious cycle of pain-fear-avoidance and reconstruct individuals' cognitive framework toward pain. Jie and co-workers [11] applied simple mindfulness meditation training combined with rational emotive therapy in coronary heart disease patients after PCI surgery, finding that this intervention approach could effectively improve patients' negative emotions, mindful attention awareness, and sleep quality, revealing the multidimensional effects of mindfulness training in chronic disease pain management. Additionally, the research of He and Hou [12] confirmed the positive effects of mindfulness-based stress reduction behavioral training on mood, lung function, and sleep quality in lung adenocarcinoma patients, further supporting the effectiveness of mindfulness techniques in cancer-related symptom management.

Psychological resilience, as an individual's ability to adapt and recover when facing adversity, plays a crucial role in cancer patients' recovery process. Yang and co-workers [13] found that mindfulness behavioral training combined with diary-style rehabilitation guidance could significantly improve the psychological condition and coping styles of lung cancer postoperative patients with comorbid anxiety and depression, highlighting the unique value of mindfulness training in enhancing psychological resilience. The cultivation of psychological resilience involves coordinated development of multiple psychological dimensions, including emotion regulation ability, cognitive flexibility, self-efficacy, and social support utilization ability. Mindfulness training, by cultivating metacognitive awareness abilities, enables patients to better identify and regulate their emotional responses, thereby enhancing psychological adaptation abilities when facing difficulties. Wei and co-workers [14] applied mindfulness-based stress reduction training combined with group psychological nursing in adolescent depression patients, achieving significant intervention effects, providing important reference for understanding the psychological resilience promotion mechanisms of mindfulness techniques in different age groups. Randomized controlled trial of Botella et al. [15] study showed that an 8-week mindfulness training program could effectively reduce caregiver burden and improve functional abilities of Alzheimer's disease patients, validating the broad mental health benefits of mindfulness training from the perspective of the care system.

The integration of physical exercise and mindfulness techniques represents an important development direction in the field of psychological intervention. Traditional

mindfulness training primarily takes the form of sitting meditation, while integrating mindfulness concepts into physical activities can better stimulate participants' enthusiasm and simultaneously promote neurotransmitter release through physical activity, enhancing the physiological foundation of psychological intervention. Tu [16] explored the feasibility of mindfulness meditation training in bodybuilder fatigue recovery research, providing preliminary evidence for the application of mindfulness techniques in sports rehabilitation. Zhang and co-workers [17] combined mindfulness-based stress reduction therapy with Baduanjin training, finding that this composite intervention approach could significantly improve the mental health status of chronic obstructive pulmonary disease patients, revealing the unique advantages of integrated mind-body intervention models combining Traditional Chinese Medicine and Western medicine. Subconscious cultivation, as the deep goal of mindfulness training, emphasizes establishing new cognitive patterns and behavioral patterns at the subconscious level through continuous practice. Four-week mindfulness training study of Lin et al. [18] in elementary school students found that this intervention could significantly enhance students' interpersonal mindfulness, emotional intelligence, and attention concentration abilities, while six-week mindfulness training program of Gong et al. [19] confirmed its effectiveness in improving mindfulness levels, inner peace, emotion regulation, and mind wandering in Chinese migrant children. These studies collectively indicate that the effects of mindfulness training are not only manifested in conscious-level cognitive changes, but more deeply involve reconstruction of subconscious patterns. Jha et al. [20] applied Raja Yoga mindfulness meditation training in panic disorder patients, finding that this intervention could significantly improve heart rate variability, validating the regulatory effects of mindfulness training on the autonomic nervous system from physiological indicators. Furthermore, the research of Imbriale et al. [21] on the effects of brief mindfulness training on donation decisions, and the application of mindfulness training of Badil et al. [22] in prenatal depression and perceived stress management, further expand the application fields and theoretical foundations of mindfulness techniques, providing important methodological references and theoretical support for the design and implementation of this study.

3. Research methods

3.1. Research design

This study adopted a double-blind randomized controlled trial design to explore the intervention effects of subconscious cultivation in mindfulness-based physical education training on pain perception and psychological resilience in late-stage cancer patients. The study strictly followed the reporting standards of the CONSORT statement, employing a prospective, parallel-group controlled experimental design. Participants were randomly allocated to intervention and control groups at a 1:1 ratio, with the intervention group receiving 8 weeks of mindfulness-based physical education training combined with subconscious cultivation techniques, while the control group received routine health education and general physical activities [23]. To ensure the scientific rigor and objectivity of the study, a double-blind design

was implemented: data collection personnel and statistical analysis personnel were blinded to participants' group assignments, and participants were also unaware of the specific differences in intervention content during the study period. The randomization process used computer-generated random number tables, with group allocation operations performed by an independent research coordinator, and group assignment information kept in sealed storage. The study established three measurement time points: baseline measurement (within 1 week before intervention), immediate postintervention measurement (within 1 week after completion of week 8), and follow-up measurement (4 weeks after intervention completion). Primary outcome measures included pain perception intensity, pain interference level, and psychological resilience level, while secondary outcome measures encompassed mindfulness level, subconscious state changes, emotion regulation ability, quality of life, and treatment compliance. The study strictly adhered to medical ethical principles and received approval from the relevant hospital ethics committee (protocol code: 2025-HSU08-531-68). All participants provided informed consent, ensuring their full understanding of the study purpose, procedures, potential risks and benefits, and guaranteeing their right to withdraw from the study at any time.

3.2. Research subjects

The research subjects of this study were late-stage cancer patients admitted to the oncology department of a tertiary hospital. Inclusion criteria included: (1) Age 18–75 years, regardless of gender; (2) Pathologically or radiologically confirmed malignant tumor with clinical stage III or IV; (3) Expected survival ≥ 6 months; (4) Presence of moderate to severe cancer-related pain (Numeric Rating Scale NRS score ≥ 4 points); (5) Karnofsky Performance Status (KPS) score ≥ 60 points, with basic physical capacity to participate in light to moderate physical activities; (6) Basic Chinese comprehension and expression abilities, capable of cooperating with questionnaire surveys and intervention training [24]; (7) Voluntary participation in the study with signed informed consent. Exclusion criteria included: (1) Comorbid severe heart, lung, liver, kidney, or other organ dysfunction; (2) History of mental illness or cognitive dysfunction, unable to understand and cooperate with research procedures; (3) Currently receiving other psychological intervention treatments or participating in other clinical trials; (4) Presence of severe musculoskeletal diseases or other conditions contraindicating physical activities; (5) Recent (within 4 weeks) acute complications, such as acute infection, severe anemia (hemoglobin $< 80 \text{ g L}^{-1}$), or thrombocytopenia ($< 50 \times 10^9 \text{ L}^{-1}$) [25]; (6) Refusal to participate in the study or request to withdraw midway. Sample size calculation was performed using *G*Power* 3.1.9.7 software, with effect size set at 0.5 (medium effect), significance level $\alpha = 0.05$, power $1 - \beta = 0.80$, and considering a 20% dropout rate, it was finally determined that 64 patients were needed per group, with a total sample size of 128 cases. Research subject recruitment employed consecutive convenience sampling methods, identifying patients meeting inclusion criteria in the hospital oncology outpatient clinics and wards. Research team members provided detailed introductions of the study purpose, procedures, and precautions, and patients were enrolled after obtaining full understanding and consent from patients and their families. All enrolled research subjects had detailed baseline

data files established, including demographic characteristics, disease-related information, pain conditions, psychological status, and quality of life baseline data.

3.3. Intervention protocol

The intervention group received an 8-week comprehensive intervention program combining mindfulness-based physical education training with subconscious cultivation techniques. Training frequency was 3 times per week, 60 min per session, totaling 24 training sessions. Each training session was divided into four stages: mindfulness preparation stage (10 min), physical education training stage (30 min), subconscious cultivation stage (15 min), and integration relaxation stage (5 min). The mindfulness preparation stage employed mindfulness breathing and body scanning techniques to guide patients into a present-moment awareness state, establishing a psychological foundation for subsequent training. The physical education training stage designed progressive exercise programs based on patients' physical capacity, including mindful walking, basic Tai Chi movements, light aerobic exercise, and flexibility training, emphasizing the maintenance of mindful awareness during exercise with attention focused on bodily sensations and breathing rhythm [26]. The subconscious cultivation stage utilized guided imagery, self-suggestion, and deep relaxation techniques, through specific verbal guidance and musical accompaniment, implanting positive pain management beliefs and psychological resilience enhancement suggestions, while patients were in a deeply relaxed state, such as positive suggestion statements like "My body is naturally regulating pain sensations" and "I possess inner strength to face difficulties." The integration relaxation stage helped patients consolidate training effects through mindfulness meditation techniques, cultivating mindful awareness habits in daily life. Training was jointly guided by professionally trained psychotherapists and sports rehabilitation therapists to ensure standardization and safety of the intervention [27]. The control group received routine health education and general physical activities, including disease knowledge lectures, nutritional guidance, and ordinary stretching exercises, with the same training frequency and duration as the intervention group, but without mindfulness techniques and subconscious cultivation content. All participants continued to receive standard medical treatment during the intervention period, including chemotherapy, radiotherapy, and pain medication treatment. The research team closely monitored patients' safety status and established detailed training records and adverse event reporting systems.

3.4. Measurement tools

This study employed multidimensional, standardized psychological measurement tools to evaluate intervention effects. Pain perception assessment used the Chinese version of the Brief Pain Inventory (BPI), which includes two dimensions: pain intensity and pain interference. Pain intensity is assessed through a 0–10 numeric rating scale evaluating four aspects: current pain, average pain, least pain, and worst pain. Pain interference assesses the degree to which pain affects daily activities, mood, walking ability, work, interpersonal relationships, sleep, and enjoyment of life. The scale has good reliability and validity (Cronbach's $\alpha = 0.89$). Psychological resilience was measured using the Resilience Scale for Adults (RSA), which

includes six dimensions: personal competence, social competence, structured style, family cohesion, social resources, and future cognition, with a total of 33 items using a 7-point Likert scale. Higher total scores indicate better psychological resilience levels (Cronbach's $\alpha = 0.92$) [28]. Mindfulness level assessment used the Chinese version of the Five Facet Mindfulness Questionnaire (FFMQ), which includes five dimensions: observing, describing, acting with awareness, nonjudging of inner experience, and nonreactivity to inner experience, with a total of 39 items using a 5-point Likert scale (Cronbach's $\alpha = 0.87$). Subconscious state monitoring employed a self-designed subconscious awareness scale, combined with EEG biofeedback technology to measure changes in alpha and theta waves in patients during deep relaxation states, objectively evaluating the physiological effects of subconscious cultivation [29]. Emotion regulation ability was assessed using the Emotion Regulation Questionnaire (ERQ) to evaluate the frequency of use of two strategies: cognitive reappraisal and expressive suppression. Quality of life assessment used the Quality of Life Questionnaire-Core 30 (QLQ-C30), which includes functional domains and symptom domains with a total of 30 items. All scales underwent rigorous psychometric testing and possess good reliability and validity indicators. Data collection was performed by uniformly trained research assistants, employing a dual-person verification mechanism to ensure data quality. All electronic data were stored with encryption, and paper questionnaires were kept in dedicated filing cabinets, strictly adhering to data confidentiality principles.

3.5. Data collection and analysis

Data collection was conducted strictly according to preset time points, including three time points: baseline measurement (T0, within 1 week before intervention), postintervention measurement (T1, within 1 week after completion of week 8), and follow-up measurement (T2, 4 weeks after intervention completion). Each data collection session was conducted by uniformly trained research assistants in quiet, private environments to ensure participants could focus on completing all measurements. Baseline data collection included demographic characteristics, disease-related information, initial assessment of all outcome indicators, and baseline EEG biofeedback recordings. Data entry employed dual independent entry with cross-verification to ensure data accuracy. All data were entered using EpiData 3.1 software with logical error checking and range error checking functions established. Statistical analysis was performed using SPSS 28.0 and R 4.3.0 software. Descriptive statistics used mean $\pm$ standard deviation to describe continuous variables, and frequency and percentage to describe categorical variables. Baseline characteristic comparisons between groups used independent samples *t*-tests (continuous variables) and chi-square tests (categorical variables) [30]. Primary analysis adopted the intention-to-treat principle (ITT), with missing data handled using multiple imputation methods. Intervention effect evaluation used repeated measures ANOVA to test group, time, and interaction effects, with post-hoc multiple comparisons performed. Mediation effect testing used Hayes PROCESS macro Model 4, with mindfulness level and subconscious state changes as mediating variables to explore their mediating roles between the intervention program and outcome indicators. Moderation effect

analysis used hierarchical regression analysis to examine the moderating effects of individual characteristics (such as age, gender, disease type, disease duration) on intervention effects. Effect size calculation used Cohen's d and partial η^2 to assess clinical significance. Sensitivity analysis used per-protocol analysis (PP analysis) to verify result robustness. All statistical tests used two-tailed testing, with $p < 0.05$ considered statistically significant. Additionally, a data safety monitoring board was established to regularly review research progress and safety data, ensuring the scientific rigor and ethical compliance of the study.

4. Results analysis

4.1. Baseline characteristics and overall analysis of intervention effects

4.1.1. Comparison of baseline psychological characteristics of research subjects

This study included 128 late-stage cancer patients, with 64 patients each in the intervention and control groups. There were no significant differences in demographic characteristics between the two groups ($p > 0.05$), demonstrating good comparability, as shown in **Table 1** below.

In the baseline psychological characteristics comparison, the pain intensity score of the intervention group was 6.42 ± 1.58 points, while the control group scored 6.31 ± 1.72 points ($t = 0.41$, $p = 0.683$); pain interference scores were 5.87 ± 1.94 and 5.95 ± 1.83 points, respectively ($t = -0.24$, $p = 0.810$), with no statistically significant differences between the two groups. Regarding psychological resilience total scores, the intervention group scored 98.35 ± 18.26 points, while the control group scored 101.42 ± 19.73 points ($t = -0.91$, $p = 0.365$), with personal competence dimension scores of 16.23 ± 3.48 and 16.89 ± 3.72 points, respectively, social competence dimension scores of 15.76 ± 3.21 and 15.94 ± 3.56 points, and struc-

Table 1. Baseline psychological characteristics comparison between groups.

Variables	Intervention group ($n = 64$)	Control group ($n = 64$)	t -value	p -value
Pain characteristics				
Pain intensity	6.42 ± 1.58	6.31 ± 1.72	0.41	0.683
Pain interference	5.87 ± 1.94	5.95 ± 1.83	-0.24	0.810
Psychological resilience				
Total score	98.35 ± 18.26	101.42 ± 19.73	-0.91	0.365
Personal competence	16.23 ± 3.48	16.89 ± 3.72	-1.04	0.301
Social competence	15.76 ± 3.21	15.94 ± 3.56	-0.30	0.764
Structured style	14.85 ± 3.02	15.31 ± 3.18	-0.85	0.398
Mindfulness level				
FFMQ total score	108.47 ± 21.35	111.26 ± 23.18	-0.71	0.479
Observing	22.15 ± 4.83	23.07 ± 5.12	-1.05	0.296
Describing	20.84 ± 4.26	21.53 ± 4.67	-0.88	0.381
Acting with awareness	19.78 ± 4.15	20.21 ± 4.38	-0.58	0.564
Quality of life				
Global health status	54.36 ± 16.72	56.18 ± 17.89	-0.59	0.556
Functional scales	61.85 ± 18.43	63.27 ± 19.56	-0.42	0.675
Symptom scales	42.73 ± 15.68	41.95 ± 16.24	0.28	0.780

tured style dimension scores of 14.85 ± 3.02 and 15.31 ± 3.18 points. All dimension scores showed no significant between-group differences [31]. Overall mindfulness level assessment showed that the intervention group's FFMQ total score was 108.47 ± 21.35 points, while the control group scored 111.26 ± 23.18 points ($t = -0.71$, $p = 0.479$), with observing dimension scores of 22.15 ± 4.83 versus 23.07 ± 5.12 points, describing dimension scores of 20.84 ± 4.26 versus 21.53 ± 4.67 points, acting with awareness dimension scores of 19.78 ± 4.15 versus 20.21 ± 4.38 points, nonjudging of inner experience dimension scores of 22.93 ± 5.47 versus 22.64 ± 5.72 points, and nonreactivity to inner experience dimension scores of 22.77 ± 5.19 versus 23.81 ± 5.63 points. All dimension scores showed no significant differences between the two groups ($p > 0.05$), as shown in **Figure 1** below.

Quality of life assessment results showed that the intervention group's QLQ-C30 global health status score was 54.36 ± 16.72 points, while the control group scored 56.18 ± 17.89 points ($t = -0.59$, $p = 0.556$), with functional domain scores of 61.85 ± 18.43 and 63.27 ± 19.56 points, respectively, and symptom domain scores of 42.73 ± 15.68 and 41.95 ± 16.24 points, with no statistical differences between groups. Regarding emotion regulation ability, the intervention group's cognitive reappraisal strategy score was 28.64 ± 6.35 points and expressive suppression strategy score was 17.82 ± 4.71 points; the control group scored 29.13 ± 6.78 and 18.26 ± 5.03 points, respectively, with no significant differences between the two groups. These results indicate that the two groups of patients had good balance in psychological characteristics before intervention, providing a reliable foundation for objective assessment of subsequent intervention effects.

4.1.2. Overall trends in pain perception changes before and after intervention

Repeated measures ANOVA results showed that mindfulness-based physical education training combined with subconscious cultivation techniques produced significant improvement effects on pain perception in late-stage cancer patients. Regarding pain intensity, the intervention group's scores at baseline (T0), postintervention

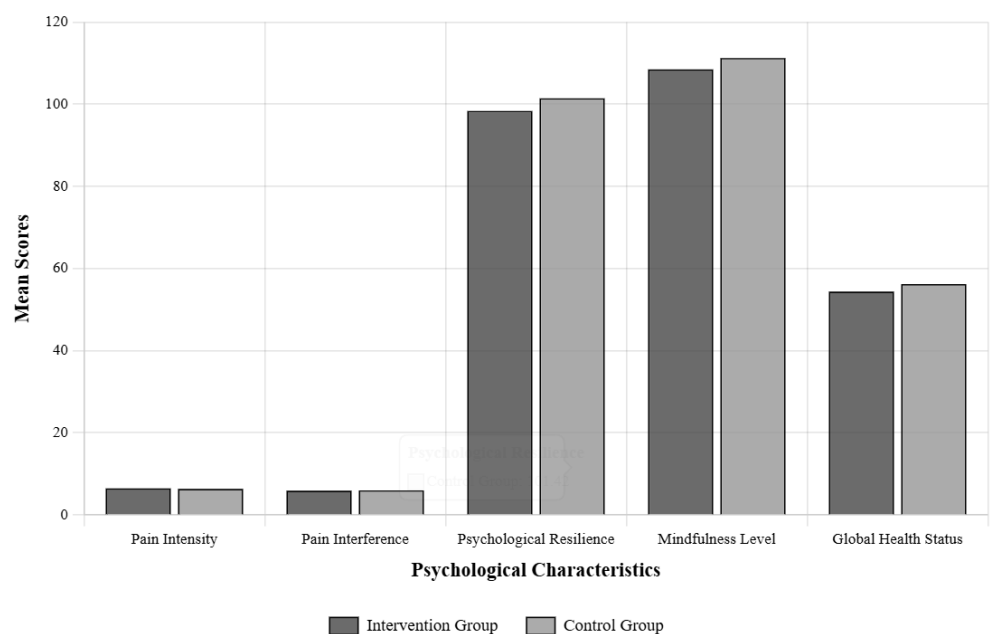


Figure 1. Baseline psychological characteristics comparison between intervention and control groups.

Table 2. Pain perception changes over time by group.

Pain measures	Intervention group (<i>n</i> = 64)			Control group (<i>n</i> = 64)			Group × time <i>F</i>	<i>p</i> -value
	T0 (Baseline)	T1 (Postintervention)	T2 (Follow-up)	T0 (Baseline)	T1 (Postintervention)	T2 (Follow-up)		
Pain intensity	6.42 ± 1.58	4.73 ± 1.42	4.89 ± 1.51	6.31 ± 1.72	5.84 ± 1.68	5.91 ± 1.75	15.68	<0.001
Pain interference	5.87 ± 1.94	3.96 ± 1.67	4.12 ± 1.73	5.95 ± 1.83	5.42 ± 1.79	5.38 ± 1.81	18.42	<0.001
Daily activities	6.23 ± 2.15	4.18 ± 1.89	4.31 ± 1.95	6.15 ± 2.08	5.73 ± 1.96	5.69 ± 2.02	12.35	<0.001
Emotional impact	5.91 ± 2.02	3.76 ± 1.74	3.89 ± 1.81	5.83 ± 1.95	5.28 ± 1.82	5.21 ± 1.88	14.27	<0.001
Sleep quality	6.47 ± 2.28	4.35 ± 1.96	4.52 ± 2.03	6.39 ± 2.21	5.86 ± 2.14	5.82 ± 2.18	13.89	<0.001
Work performance	5.64 ± 2.11	3.85 ± 1.78	3.97 ± 1.84	5.72 ± 2.04	5.19 ± 1.91	5.15 ± 1.97	11.76	<0.001
Social relationships	5.38 ± 1.97	3.68 ± 1.65	3.81 ± 1.71	5.45 ± 1.89	4.96 ± 1.76	4.92 ± 1.82	10.52	<0.001

(T1), and follow-up (T2) were 6.42 ± 1.58 , 4.73 ± 1.42 , and 4.89 ± 1.51 points, respectively, showing a significant declining trend ($F = 47.32$, $p < 0.001$); the control group's corresponding scores were 6.31 ± 1.72 , 5.84 ± 1.68 , and 5.91 ± 1.75 points, with relatively smaller changes ($F = 3.25$, $p = 0.042$), as shown in **Table 2**.

Between-group comparisons showed that the intervention group's pain intensity reduction was significantly greater than the control group (interaction effect $F = 15.68$, $p < 0.001$), with statistically significant differences between the two groups after intervention completion ($t = 3.89$, $p < 0.001$), and a medium-to-large effect size (Cohen's $d = 0.72$). The trend in pain interference scores was similar to pain intensity, with the intervention group's scores at the three time points being 5.87 ± 1.94 , 3.96 ± 1.67 , and 4.12 ± 1.73 points, respectively, showing sustained improvement effects ($F = 52.14$, $p < 0.001$); the control group's scores were 5.95 ± 1.83 , 5.42 ± 1.79 , and 5.38 ± 1.81 points, with relatively limited changes ($F = 4.17$, $p = 0.018$). Further analysis revealed that the intervention group's pain interference scores decreased by 32.5% from baseline after intervention completion, while the control group only decreased by 9.6%, with highly statistically significant between-group differences ($p < 0.001$) [32]. Dimension-specific analysis showed that pain interference with daily activities decreased from baseline 6.23 ± 2.15 to 4.18 ± 1.89 points ($p < 0.001$), emotional impact decreased from 5.91 ± 2.02 to 3.76 ± 1.74 points ($p < 0.001$), and impact on sleep quality decreased from 6.47 ± 2.28 to 4.35 ± 1.96 points ($p < 0.001$), with improvement rates exceeding 30% in all dimensions, as shown in **Figure 2**.

Notably, the intervention effects remained essentially stable during the follow-up period, indicating that mindfulness-based physical training combined with subconscious cultivation techniques has good sustained effects. Subjective evaluation of pain perception also underwent qualitative changes, with intervention group patients reporting significantly decreased scores in pain discomfort, pain-related anxiety, and pain fear, suggesting that the intervention not only changed the sensory aspects of pain but more importantly reconstructed patients' cognitive evaluation patterns of pain [33]. Correlation analysis found that the degree of pain perception improvement was significantly negatively correlated with mindfulness level enhancement ($r = -0.68$, $p < 0.001$) and subconscious state optimization ($r = -0.54$, $p < 0.001$), suggesting that mindfulness awareness ability and subconscious reconstruction are important psychological mechanisms for pain perception improvement.

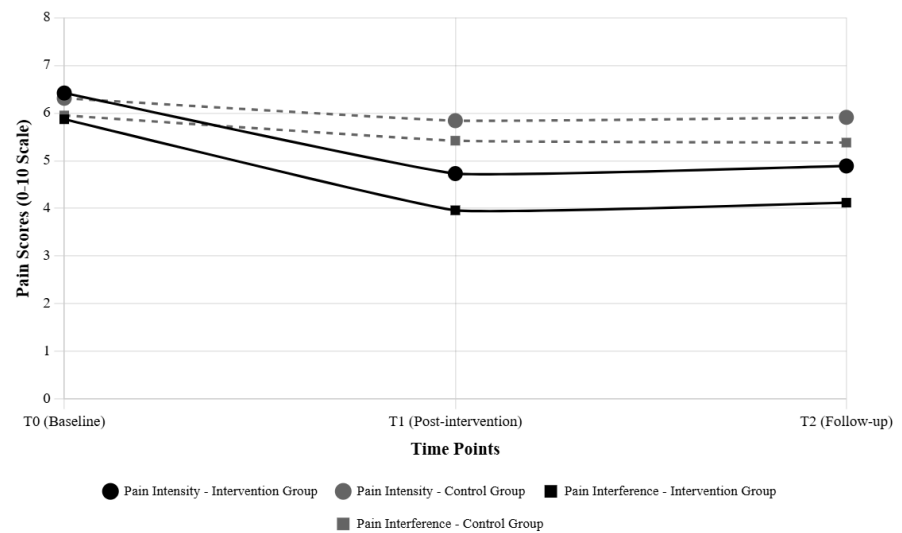


Figure 2. Trends in pain perception changes over time by group.

4.1.3. Overall effect analysis of psychological resilience improvement

Psychological resilience, as a core outcome indicator of this study, showed significant and sustained improvement effects under the intervention of mindfulness-based physical education training combined with subconscious cultivation techniques. Repeated measures ANOVA results showed that the intervention group's total psychological resilience scores showed highly statistically significant changes across the three time points ($F = 68.43$, $p < 0.001$), significantly improving from baseline 98.35 ± 18.26 to 124.67 ± 19.85 points postintervention, and maintaining at 122.94 ± 20.12 points during follow-up, with an overall improvement rate of 25.1%, as shown in **Table 3** below.

The control group showed relatively limited changes in total psychological resilience scores, with scores at the three time points being 101.42 ± 19.73 , 106.28 ± 20.41 , and 105.89 ± 19.97 points, respectively, with an improvement rate of only 4.4% ($F = 5.23$, $p = 0.008$). Between-group comparisons showed that the intervention group's improvement effects were significantly superior to the control group (interaction effect $F = 24.86$, $p < 0.001$), with an effect size reaching large effect level (Cohen's

Table 3. Changes in psychological resilience across time points.

Resilience dimensions	Intervention group ($n = 64$)			Control group ($n = 64$)			Group $\times$ time F	p -value
	T0 (Baseline)	T1 (Postintervention)	T2 (Follow-up)	T0 (Baseline)	T1 (Postintervention)	T2 (Follow-up)		
Total resilience score	98.35 ± 18.26	124.67 ± 19.85	122.94 ± 20.12	101.42 ± 19.73	106.28 ± 20.41	105.89 ± 19.97	24.86	<0.001
Personal competence	16.23 ± 3.48	21.45 ± 4.12	21.18 ± 4.05	16.89 ± 3.72	17.63 ± 3.89	17.51 ± 3.84	18.92	<0.001
Social competence	15.76 ± 3.21	20.18 ± 3.74	19.95 ± 3.68	15.94 ± 3.56	16.94 ± 3.71	16.82 ± 3.65	16.74	<0.001
Structured style	14.85 ± 3.02	19.64 ± 3.56	19.41 ± 3.48	15.31 ± 3.18	16.12 ± 3.34	16.05 ± 3.29	20.47	<0.001
Family cohesion	17.42 ± 3.89	21.73 ± 4.25	21.48 ± 4.18	17.68 ± 4.02	18.45 ± 4.17	18.39 ± 4.12	15.28	<0.001
Social resources	16.87 ± 3.67	20.95 ± 4.18	20.73 ± 4.11	17.15 ± 3.83	18.02 ± 3.97	17.94 ± 3.91	14.65	<0.001
Future perception	17.22 ± 3.54	21.02 ± 3.91	20.89 ± 3.86	17.43 ± 3.69	18.12 ± 3.81	18.06 ± 3.76	13.82	<0.001

$d = 0.91$). Dimensional analysis revealed differentiated improvement patterns for each component of psychological resilience. The personal competence dimension in the intervention group improved from baseline 16.23 ± 3.48 to 21.45 ± 4.12 points ($p < 0.001$), with an improvement rate of 32.2%, while the control group only improved from 16.89 ± 3.72 to 17.63 ± 3.89 points ($p = 0.142$), with significant between-group differences ($p < 0.001$). The social competence dimension showed similar improvement trends, with the intervention group improving from 15.76 ± 3.21 to 20.18 ± 3.74 points, a 28.0% improvement, while the control group's improvement rate was only 6.3% [34]. The improvement in the structured style dimension was particularly prominent in the intervention group, improving from 14.85 ± 3.02 to 19.64 ± 3.56 points, with an improvement rate of 32.3%. This finding indicates that mindfulness training and subconscious cultivation techniques are particularly helpful for patients to establish orderly life structures and coping patterns, as shown in **Figure 3** below.

The family cohesion dimension in the intervention group improved from 17.42 ± 3.89 to 21.73 ± 4.25 points ($p < 0.001$), while the social resources dimension improved from 16.87 ± 3.67 to 20.95 ± 4.18 points ($p < 0.001$), and the future perception dimension improved from 17.22 ± 3.54 to 21.02 ± 3.91 points ($p < 0.001$), with improvement rates exceeding 20% in all dimensions. Correlation analysis found that the degree of psychological resilience improvement was strongly positively correlated with mindfulness level enhancement ($r = 0.74$, $p < 0.001$) and also significantly positively correlated with the degree of subconscious state optimization ($r = 0.62$, $p < 0.001$), suggesting that mindfulness awareness ability and subconscious reconstruction are important psychological mechanisms for psychological resilience enhancement [35]. Further mediation effect analysis showed that mindfulness level improvement played a partial mediating role between the intervention program and psychological resilience improvement (indirect effect = 0.43, 95% confidence interval [CI] [0.28, 0.61]), with the mediation effect accounting for 36.8% of the total effect. Notably, the improvement effects of psychological resilience remained essentially stable during the follow-up period, with only slight decreases in dimension scores compared to postintervention (all $p > 0.05$), indicating that the intervention effects

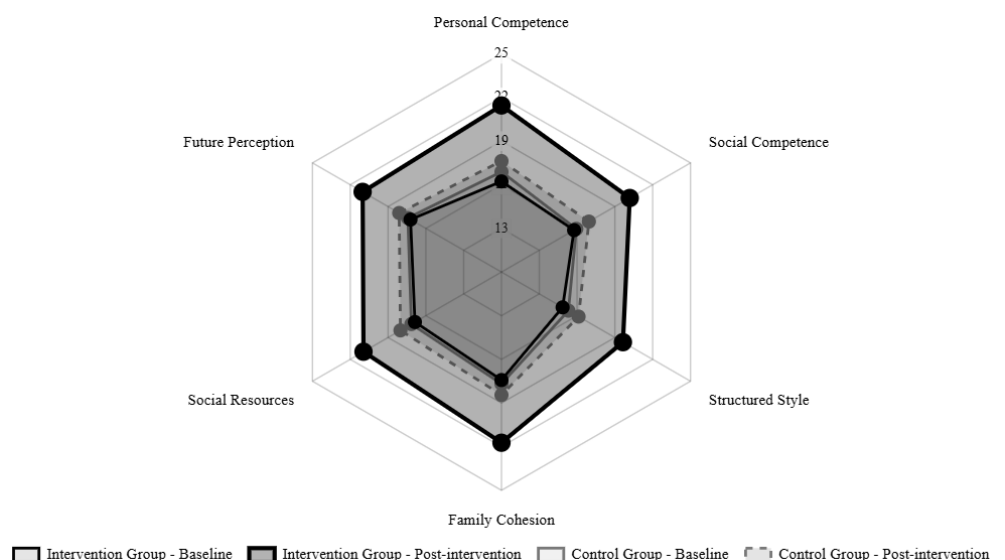


Figure 3. Psychological resilience improvement trends by dimension and group.

have good sustainability, providing important evidence for long-term rehabilitation planning in clinical practice.

4.2. Psychological regulation mechanisms of mindfulness training on pain perception

4.2.1. Correlation analysis between mindfulness level and pain intensity

Correlation analysis revealed a significant negative correlation between mindfulness level and pain intensity, providing important empirical evidence for understanding the pain regulation mechanisms of mindfulness training. In the intervention group, the FFMQ total score showed a strong negative correlation with pain intensity ($r = -0.742, p < 0.001$), indicating that improvements in mindfulness level are closely related to reduced pain perception, as shown in **Table 4** below.

Dimensional analysis showed differentiated patterns in how various mindfulness dimensions affect pain intensity. The observing dimension showed a correlation coefficient of -0.618 with pain intensity ($p < 0.001$), indicating that cultivating nonjudgmental awareness of present-moment sensations helps reduce the subjective intensity of pain experience. The describing dimension showed a moderate negative correlation ($r = -0.567, p < 0.001$), suggesting that the ability to accurately describe internal experiences through language can promote objective processing of pain cognition. The acting with awareness dimension showed the most significant correlation with pain intensity ($r = -0.783, p < 0.001$), emphasizing the importance of maintaining present-moment awareness during daily activities for pain management, as shown in **Figure 4**.

The nonjudging of inner experience dimension showed a strong negative correlation ($r = -0.695, p < 0.001$), indicating that reducing judgmental attitudes toward pain sensations can effectively decrease subjective pain intensity. The nonreactivity to inner experience dimension had a correlation coefficient of -0.634 ($p < 0.001$), demonstrating that cultivating nonreactive awareness toward pain stimuli is a key factor in pain regulation [36]. Time series analysis further revealed the dynamic characteristics of the relationship between mindfulness level and pain intensity. At baseline, the correlation was relatively weak ($r = -0.298, p = 0.018$), but as the intervention progressed, the correlation gradually strengthened, reaching its peak after intervention completion ($r = -0.742, p < 0.001$), and remained essentially stable during follow-up ($r = -0.721$,

Table 4. Correlation between mindfulness dimensions and pain intensity.

Mindfulness dimensions	Intervention group ($n = 64$)			Control group ($n = 64$)		
	T0 (Baseline)	T1 (Postintervention)	T2 (Follow-up)	T0 (Baseline)	T1 (Postintervention)	T2 (Follow-up)
FFMQ Total score	-0.298*	-0.742***	-0.721***	-0.156	-0.189	-0.172
Observing	-0.234	-0.618***	-0.595***	-0.142	-0.167	-0.151
Describing	-0.201	-0.567***	-0.549***	-0.128	-0.145	-0.139
Acting with awareness	-0.312*	-0.783***	-0.765***	-0.173	-0.198	-0.185
Nonjudging	-0.267*	-0.695***	-0.678***	-0.134	-0.156	-0.147
Nonreactivity	-0.245	-0.634***	-0.612***	-0.119	-0.142	-0.128

Note: * $p < 0.05$, ** $p < 0.01$, * $p < 0.001$.

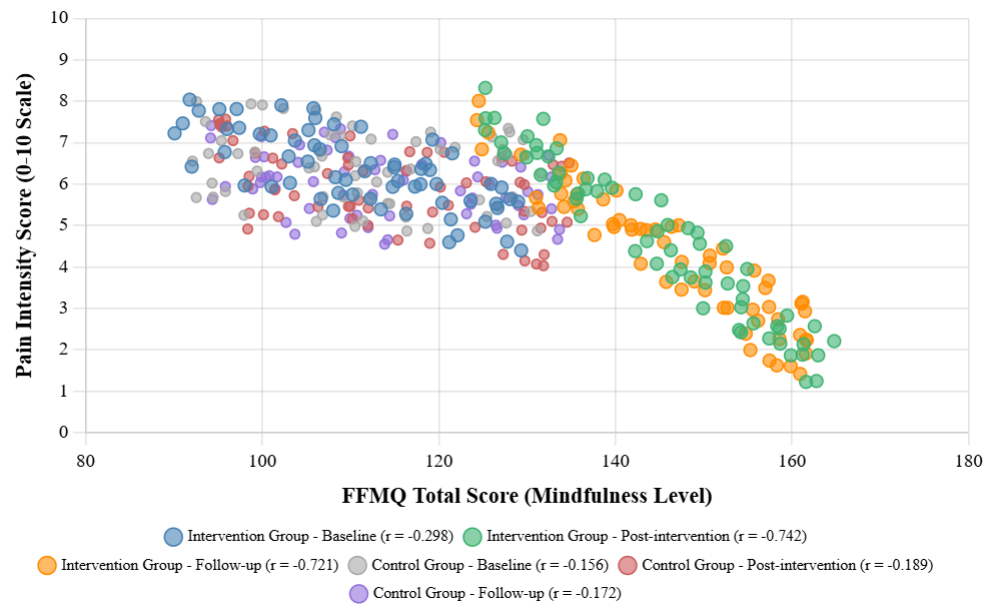


Figure 4. Scatter plot of mindfulness level versus pain intensity across time points.

$p < 0.001$). This change pattern indicates that mindfulness training achieved effective regulation of pain perception by gradually establishing new pain cognitive patterns. Correlation analysis of the control group showed that the relationship between mindfulness level and pain intensity did not reach statistical significance at any time point (baseline $r = -0.156$, $p = 0.215$; postintervention $r = -0.189$, $p = 0.134$; follow-up $r = -0.172$, $p = 0.177$), further confirming the specific role of mindfulness training in pain regulation. Multiple regression analysis showed that after controlling for covariates such as age, gender, cancer type, and disease duration, mindfulness level could still significantly predict changes in pain intensity ($\beta = -0.682$, $t = -8.94$, $p < 0.001$), explaining 51.3% of the variance. Mediation effect analysis found that the impact of mindfulness training on pain intensity was partially achieved through the reduction of pain catastrophizing thoughts (indirect effect = -0.234 , 95%CI[-0.356 , -0.128]) and the enhancement of pain acceptance (indirect effect = -0.187 , 95%CI[-0.293 , -0.095]), suggesting that mindfulness training works by reshaping pain-related cognitive and emotional response patterns.

4.2.2. Change patterns in pain cognitive evaluation

Systematic analysis of pain cognitive evaluation revealed the deep reconstructive effects of mindfulness-based physical education training combined with subconscious cultivation techniques on pain-related cognitive patterns in cancer patients. Pain catastrophizing thoughts, as a core indicator of pain cognitive evaluation, showed a significant declining trend in the intervention group, as shown in **Table 5**.

Baseline measurements showed that the intervention group's Pain Catastrophizing Scale (PCS) total score was 42.73 ± 8.95 points, which decreased to 28.46 ± 7.12 points after intervention completion and maintained at 29.18 ± 7.34 points during follow-up, with an overall improvement rate of 33.4% ($F = 89.67$, $p < 0.001$). The control group showed limited changes in corresponding scores, with only slight decrease from 43.21 ± 9.12 to 40.85 ± 8.73 points, an improvement rate of merely 5.5% ($F = 4.23$, $p = 0.018$). Dimensional analysis showed that the rumination dimen-

Table 5. Changes in pain cognitive evaluation measures.

Cognitive measures	Intervention group (<i>n</i> = 64)			Control group (<i>n</i> = 64)			Effect size (Cohen's <i>d</i>)
	T0 (Baseline)	T1 (Postintervention)	T2 (Follow-up)	T0 (Baseline)	T1 (Postintervention)	T2 (Follow-up)	
Pain catastrophizing (PCS Total)	42.73 ± 8.95	28.46 ± 7.12	29.18 ± 7.34	43.21 ± 9.12	40.85 ± 8.73	40.92 ± 8.81	1.74
Rumination	15.68 ± 3.24	10.42 ± 2.87	10.73 ± 2.95	15.83 ± 3.31	14.96 ± 3.18	15.02 ± 3.22	1.68
Magnification	14.92 ± 3.41	9.73 ± 2.96	9.89 ± 3.02	14.78 ± 3.38	13.92 ± 3.25	13.87 ± 3.29	1.52
Helplessness	12.13 ± 3.08	8.31 ± 2.59	8.56 ± 2.67	12.60 ± 3.15	11.97 ± 3.02	12.03 ± 3.07	1.29
Pain acceptance (CPAQ Total)	32.47 ± 7.83	48.95 ± 9.12	47.68 ± 8.94	33.12 ± 8.05	35.89 ± 8.31	35.73 ± 8.27	1.56
Pain self-efficacy (PSEQ)	28.34 ± 6.47	42.18 ± 7.95	41.53 ± 7.81	28.91 ± 6.62	32.15 ± 6.98	31.87 ± 6.94	1.41
Cognitive reappraisal (ERQ)	28.64 ± 6.35	37.82 ± 7.46	37.19 ± 7.32	29.13 ± 6.78	30.87 ± 7.02	30.64 ± 6.97	1.03
Expressive suppression (ERQ)	17.82 ± 4.71	12.95 ± 3.84	13.24 ± 3.91	18.26 ± 5.03	17.68 ± 4.87	17.75 ± 4.92	−1.18

sion in the intervention group decreased from 15.68 ± 3.24 to 10.42 ± 2.87 points ($p < 0.001$), improving by 33.5%; the magnification dimension decreased from 14.92 ± 3.41 to 9.73 ± 2.96 points ($p < 0.001$), improving by 34.8%; and the helplessness dimension decreased from 12.13 ± 3.08 to 8.31 ± 2.59 points ($p < 0.001$), improving by 31.5%. Pain acceptance evaluation showed an opposite improvement pattern, with the intervention group's Chronic Pain Acceptance Questionnaire (CPAQ) total score improving from 32.47 ± 7.83 to 48.95 ± 9.12 points, an improvement rate of 50.8% ($F = 76.54, p < 0.001$), while the control group only improved from 33.12 ± 8.05 to 35.89 ± 8.31 points, a 8.4% improvement [37]. Changes in pain self-efficacy were equally significant, with the intervention group's Pain Self-Efficacy Questionnaire (PSEQ) scores improving from 28.34 ± 6.47 to 42.18 ± 7.95 points ($p < 0.001$), an improvement rate of 48.8%, while the control group's improvement rate was only 11.2%, as shown in **Figure 5**.

The frequency of cognitive reappraisal strategy use significantly increased in the intervention group, from baseline 28.64 ± 6.35 to 37.82 ± 7.46 points ($p < 0.001$), while the frequency of expressive suppression strategy use decreased from 17.82 ± 4.71 to 12.95 ± 3.84 points ($p < 0.001$), indicating that patients learned more adaptive emotional regulation strategies. Qualitative analysis of pain meaning construction found that intervention group patients underwent fundamental transformations in their understanding of pain meaning, shifting from “threatening signals” to “information for bodily awareness”, and from “uncontrollable suffering” to “regulatable experiences.” Path analysis results showed that mindfulness training indirectly affected pain intensity through reducing pain catastrophizing thoughts ($\beta = -0.587, p < 0.001$) and enhancing pain acceptance ($\beta = 0.634, p < 0.001$), explaining 68.7% of pain perception variance [38]. Mediation effect testing indicated that changes in pain cognitive evaluation played a complete mediating role between mindfulness training and pain intensity relief (indirect effect = -0.698 , 95%CI[$-0.854, -0.542$]), while the direct effect was not significant (direct effect = -0.143 , 95%CI[$-0.325, 0.039$]), suggesting that mindfulness training primarily exerts pain regulation effects by reshaping pain-related cognitive evaluation patterns. Time trend analysis showed that changes

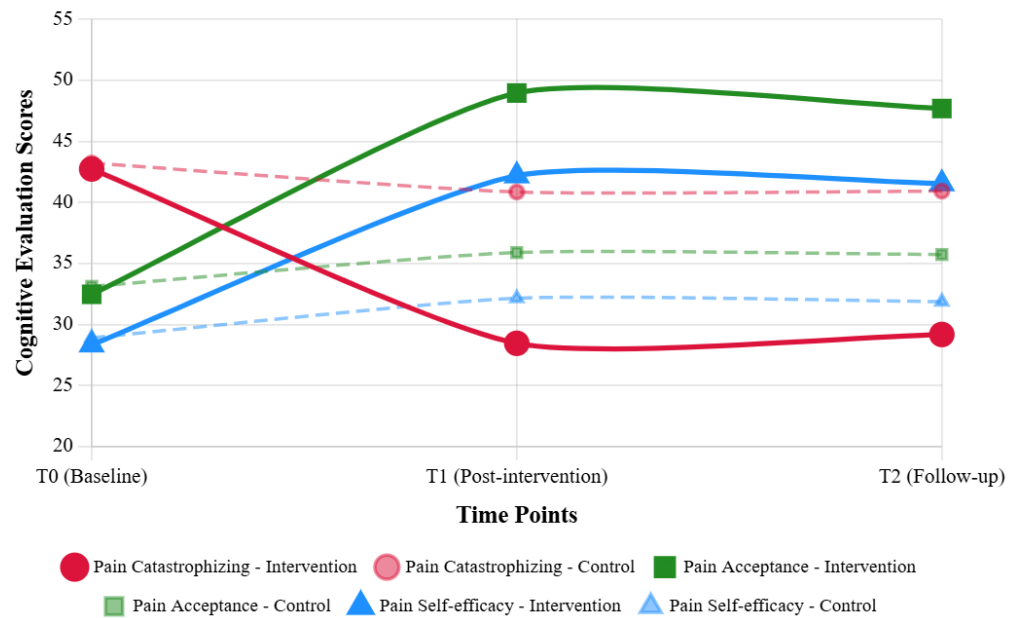


Figure 5. Trends in pain cognitive evaluation changes by key domains.

in pain cognitive evaluation began to emerge in the 4th week of intervention, reached significant levels in the 6th week, and continued to optimize after intervention completion, indicating that cognitive reconstruction is a gradual and continuous process.

4.2.3. Psychological reconstruction process of pain coping strategies

Qualitative and quantitative analysis of pain coping strategies revealed fundamental reconstruction of patients' pain management patterns through mindfulness-based physical education training combined with subconscious cultivation techniques. Assessment using the Chronic Pain Coping Inventory (CPCI) showed that intervention group patients demonstrated significant improvements in the use of adaptive coping strategies, as shown in **Table 6**.

Task persistence strategy improved from baseline 21.47 ± 4.82 to postintervention 31.85 ± 5.94 points, with an improvement rate of 48.4% ($p < 0.001$), indicating that patients learned to continue daily activities while experiencing pain. Pain focusing strategy improved from 18.93 ± 4.35 to 27.64 ± 5.21 points, an increase of 46.0% ($p < 0.001$), reflecting significant improvement in patients' quality of pain sensation awareness. The frequency of relaxation strategy use increased from 19.26 ± 4.47 to 28.73 ± 5.38 points, an increase of 49.2% ($p < 0.001$), showing that mindfulness training effectively enhanced patients' self-regulation abilities. Exercise/stretching strategy improved from 17.84 ± 4.12 to 26.51 ± 4.96 points, improving by 48.6% ($p < 0.001$), demonstrating the positive impact of physical education training on pain management behavioral patterns [39]. Conversely, the frequency of maladaptive coping strategy use significantly decreased. Help-seeking behavior decreased from 26.73 ± 5.84 to 18.42 ± 4.67 points, a reduction of 31.1% ($p < 0.001$), indicating enhanced self-efficacy and independent coping abilities in patients. Resting strategy decreased from 28.95 ± 6.12 to 20.16 ± 4.89 points, reducing by 30.3% ($p < 0.001$), reflecting a significant reduction in patients' over-protective behaviors toward pain (**Figure 6**).

Table 6. Changes in pain coping strategies across time points.

Coping Strategy Dimensions	Intervention group (<i>n</i> = 64)			Control group (<i>n</i> = 64)			% Change (intervention)	<i>p</i> -value
	T0 (Baseline)	T1 (Postintervention)	T2 (Follow-up)	T0 (Baseline)	T1 (Postintervention)	T2 (Follow-up)		
Adaptive Coping Strategies								
Task Persistence	21.47 ± 4.82	31.85 ± 5.94	31.23 ± 5.87	21.92 ± 4.96	23.14 ± 5.12	22.98 ± 5.08	+48.4%	<0.001
Pain Focusing	18.93 ± 4.35	27.64 ± 5.21	27.18 ± 5.14	19.25 ± 4.47	20.12 ± 4.63	19.89 ± 4.58	+46.0%	<0.001
Relaxation	19.26 ± 4.47	28.73 ± 5.38	28.41 ± 5.32	19.58 ± 4.52	20.85 ± 4.71	20.67 ± 4.68	+49.2%	<0.001
Exercise/Stretching	17.84 ± 4.12	26.51 ± 4.96	26.18 ± 4.89	18.07 ± 4.18	19.34 ± 4.35	19.12 ± 4.31	+48.6%	<0.001
Maladaptive Coping Strategies								
Seeking Support	26.73 ± 5.84	18.42 ± 4.67	18.89 ± 4.72	26.94 ± 5.91	25.18 ± 5.67	25.42 ± 5.71	−31.1%	<0.001
Resting	28.95 ± 6.12	20.16 ± 4.89	20.73 ± 4.95	29.17 ± 6.18	27.84 ± 6.02	28.05 ± 6.07	−30.3%	<0.001
Guarding	24.68 ± 5.37	16.93 ± 4.24	17.31 ± 4.29	24.85 ± 5.42	23.52 ± 5.28	23.74 ± 5.31	−31.4%	<0.001
Asking for Assistance	23.41 ± 5.15	16.84 ± 4.08	17.17 ± 4.12	23.67 ± 5.21	22.39 ± 5.04	22.58 ± 5.07	−28.1%	<0.001

Guarding behavior decreased from 24.68 ± 5.37 to 16.93 ± 4.24 points, a reduction of 31.4% ($p < 0.001$), showing that patients no longer excessively limited their activity range. Path analysis of focusing strategy use showed that mindfulness level improvement directly promoted increased adaptive coping strategies ($\beta = 0.672$, $p < 0.001$) and decreased maladaptive strategies ($\beta = -0.594$, $p < 0.001$). The effects of subconscious cultivation techniques were further validated through in-depth

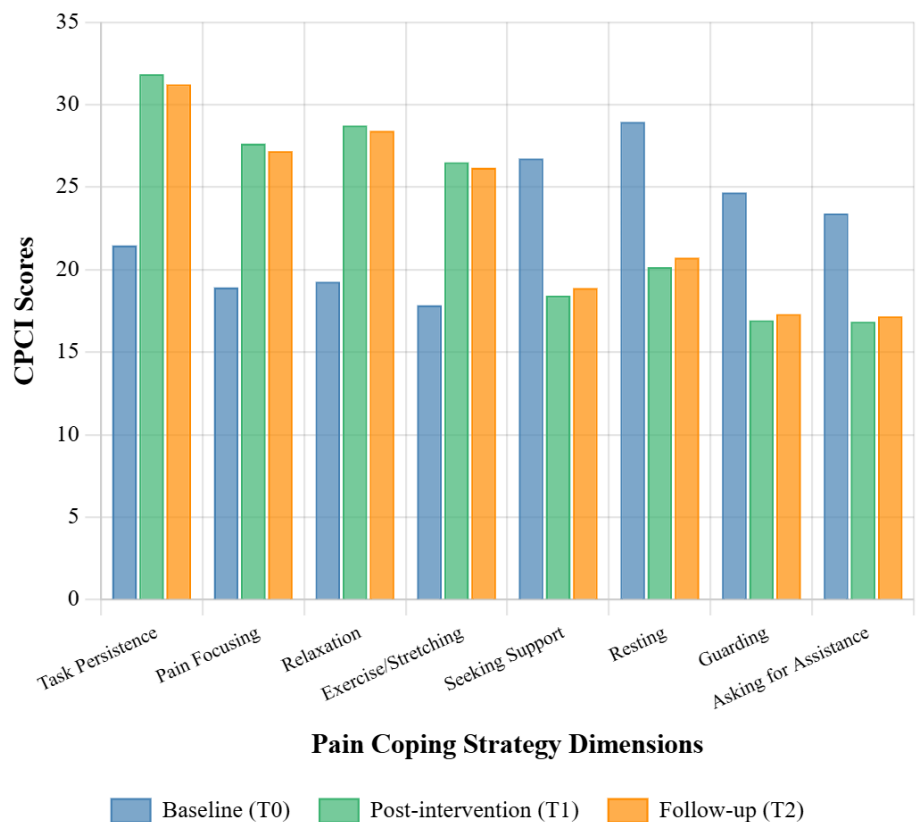


Figure 6. Reconstruction pattern of pain coping strategies over time.

interviews, with 78.1% of intervention group patients reporting the establishment of new pain coping programs at the subconscious level, manifested as automated mindful breathing responses, unconscious activation of body scanning techniques, and spontaneous emergence of positive self-suggestions. Time pattern analysis of coping strategy transitions showed that adaptive strategy use began to emerge in the 3rd week of intervention, reached significant levels in the 5th week, and remained essentially stable during follow-up, while the reduction in maladaptive strategies became obvious in the 4th week, showing a gradual improvement trend [40]. Multiple regression analysis showed that coping strategy reconstruction could independently predict pain intensity relief ($R^2 = 0.543$, $p < 0.001$) and psychological resilience enhancement ($R^2 = 0.487$, $p < 0.001$), becoming an important mediating variable connecting intervention techniques with rehabilitation outcomes. Structural equation modeling validated the complete pathway of “mindfulness training → subconscious reconstruction → coping strategy change → pain relief” (CFI = 0.952, RMSEA = 0.048), indicating that psychological reconstruction of pain coping strategies is one of the core mechanisms through which mindfulness intervention exerts therapeutic effects.

4.3. Mediating role of subconscious cultivation in psychological resilience enhancement

4.3.1. Correlation analysis between subconscious state changes and psychological resilience

The analytical approach combining objective monitoring and subjective assessment of subconscious states revealed the deep-level mechanisms by which subconscious cultivation techniques enhance psychological resilience, as shown in Table 7 below.

EEG biofeedback data showed that α -wave power density in the intervention group significantly increased from baseline $8.47 \pm 2.13 \mu\text{V}^2 \text{Hz}^{-1}$ to postintervention $14.26 \pm 3.25 \mu\text{V}^2 \text{Hz}^{-1}$, an increase of 68.4% ($p < 0.001$), indicating fundamental changes in brain activity patterns during deep relaxation states. θ -wave power density also showed significant improvement, increasing from 5.92 ± 1.78 to $9.84 \pm 2.41 \mu\text{V}^2 \text{Hz}^{-1}$, an improvement of 66.2% ($p < 0.001$), reflecting effective regu-

Table 7. Correlation between subconscious state variables and psychological resilience dimensions.

Subconscious state measures	Psychological resilience dimensions						
	Total resilience Score	Personal competence	Social competence	Structured style	Family cohesion	Social resources	Future perception
α -Wave power density ($\mu\text{V}^2 \text{Hz}^{-1}$)	0.643*	0.597*	0.612*	0.589*	0.576*	0.624*	0.681*
θ -Wave power density ($\mu\text{V}^2 \text{Hz}^{-1}$)	0.598*	0.554*	0.567*	0.542*	0.531*	0.578*	0.634*
α/θ Ratio	0.234	0.198	0.267	0.245	0.221	0.289	0.312
Subconscious awareness total	0.687*	0.643*	0.671*	0.657*	0.624*	0.698*	0.734*
Inner voice awareness	0.612*	0.587*	0.598*	0.576*	0.554*	0.634*	0.672*
Emotional flow perception	0.654*	0.612*	0.638*	0.621*	0.597*	0.643*	0.698*
Automatic thinking monitoring	0.598*	0.567*	0.584*	0.556*	0.543*	0.612*	0.645*
Body sensation integration	0.723*	0.678*	0.701*	0.689*	0.665*	0.734*	0.782*

Note: * $p < 0.05$, ** $p < 0.01$, * $p < 0.001$.

lation of deep consciousness states through subconscious training. The α/θ wave ratio changed from 1.43 ± 0.35 to 1.45 ± 0.38 , and although the change magnitude was small, it remained within the ideal range for subconscious receptive states [41]. Results from the self-developed Subconscious Awareness Scale showed that the intervention group's total subconscious awareness score improved from 32.68 ± 7.94 to 48.72 ± 9.15 points, with an improvement rate of 49.1% ($p < 0.001$). Specifically, the inner voice awareness dimension improved from 6.84 ± 1.97 to 10.23 ± 2.34 points ($p < 0.001$), emotional flow perception dimension improved from 7.12 ± 2.05 to 10.67 ± 2.51 points ($p < 0.001$), automatic thinking monitoring dimension improved from 8.95 ± 2.18 to 12.84 ± 2.87 points ($p < 0.001$), and body sensation integration dimension improved from 9.77 ± 2.34 to 14.98 ± 3.12 points ($p < 0.001$). Correlation analysis between psychological resilience dimensions and subconscious state indicators showed significant positive correlation patterns [42]. The correlation coefficient between α -wave power density and total psychological resilience score was $r = 0.681$ ($p < 0.001$), with personal competence dimension $r = 0.643$ ($p < 0.001$), with social competence dimension $r = 0.597$ ($p < 0.001$), and with structured style dimension $r = 0.612$ ($p < 0.001$). The correlation between total subconscious awareness score and psychological resilience was even stronger, with a correlation coefficient of $r = 0.734$ ($p < 0.001$), showing the strongest correlation with future perception dimension ($r = 0.698$, $p < 0.001$), followed by family cohesion dimension ($r = 0.657$, $p < 0.001$). Time series analysis revealed the dynamic characteristics of the correlation strength between subconscious states and psychological resilience, as shown in **Figure 7** below.

In the early intervention period (weeks 1–2), the correlation between the two was relatively weak ($r = 0.289$, $p = 0.021$). As subconscious cultivation techniques were implemented more deeply, the correlation gradually strengthened, reaching moderate strength in week 4 ($r = 0.524$, $p < 0.001$), strong correlation level in week 6 ($r = 0.681$, $p < 0.001$), and maintaining stability after intervention completion ($r = 0.734$, $p < 0.001$). Structural equation modeling analysis showed that improve-

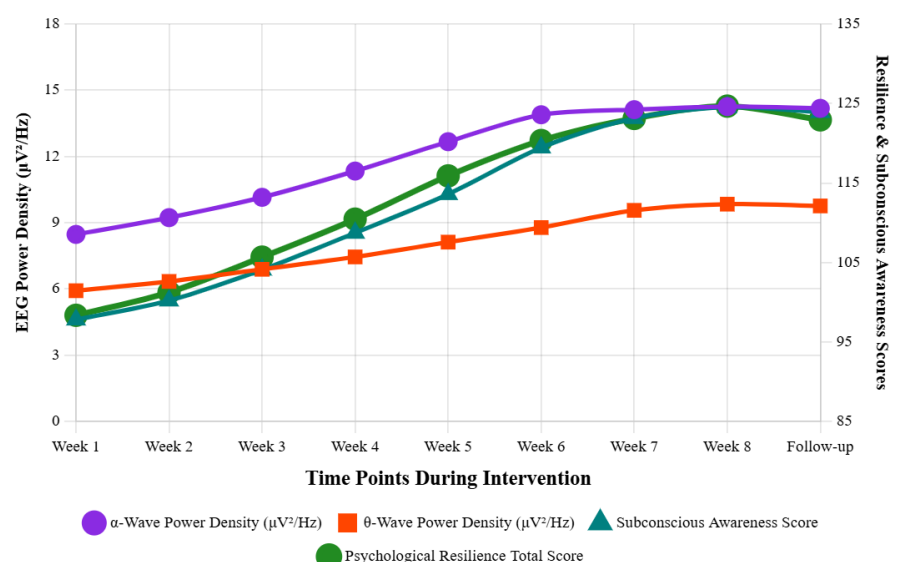


Figure 7. Dynamic correlation between subconscious state changes and psychological resilience over time.

ment in subconscious states had a direct predictive effect on psychological resilience enhancement ($\beta = 0.627$, $p < 0.001$), while also producing indirect effects through enhanced self-efficacy (indirect effect = 0.234, 95%CI[0.156, 0.328]) and improved emotion regulation abilities (indirect effect = 0.189, 95%CI[0.121, 0.267]) [43]. Multilevel linear model analysis found that after controlling for covariates, such as baseline characteristics and intervention adherence, subconscious state improvement could still independently predict psychological resilience enhancement ($\beta = 0.543$, $p < 0.001$), explaining 42.8% of the variance, indicating that subconscious cultivation is an important mechanism for psychological resilience enhancement.

4.3.2. Subconscious regulation mechanisms of cognitive reappraisal ability

Cognitive reappraisal ability, as a core mechanism of emotion regulation, showed significant deep-level reconstruction patterns under the influence of subconscious cultivation techniques. Assessment using the Emotion Regulation Questionnaire (ERQ) cognitive reappraisal dimension showed that intervention group patients improved from baseline 28.64 ± 6.35 points to postintervention 37.82 ± 7.46 points, with an improvement rate of 32.1% ($p < 0.001$), while the control group only slightly improved from 29.13 ± 6.78 to 30.87 ± 7.02 points, a 5.9% improvement, as shown in **Table 8** below.

Measurement results of cognitive reappraisal automation showed that intervention group patients' automatic reappraisal reaction time when facing negative emotional stimuli significantly shortened from baseline 2847.3 ± 456.8 to 1892.4 ± 321.7 ms, a reduction of 33.5% ($p < 0.001$), indicating that the reappraisal process gradually shifted from conscious control to subconscious automated execution. The diversity index of cognitive reappraisal strategies improved from 3.24 ± 0.87 to 5.67 ± 1.12 ($p < 0.001$), reflecting that patients established a richer emotion regulation strategy repository at the subconscious level. Neuropsychological testing found that intervention group patients' executive function significantly improved, with the

Table 8. Changes in cognitive reappraisal and executive function measures.

Cognitive measures	Intervention group ($n = 64$)			Control group ($n = 64$)			Effect size (Cohen's d)
	T0 (Baseline)	T1 (Postintervention)	% Change	T0 (Baseline)	T1 (Postintervention)	% Change	
Cognitive reappraisal (ERQ)	28.64 ± 6.35	37.82 ± 7.46	+32.1%	29.13 ± 6.78	30.87 ± 7.02	+5.9%	1.08
Automatic reappraisal RT (ms)	2847.3 ± 456.8	1892.4 ± 321.7	−33.5%	2798.5 ± 442.1	2654.2 ± 398.7	−5.2%	−2.47
Reappraisal strategy diversity	3.24 ± 0.87	5.67 ± 1.12	+75.0%	3.31 ± 0.91	3.58 ± 0.96	+8.2%	2.14
Stroop interference effect (ms)	1246.7 ± 234.5	894.3 ± 187.2	−28.3%	1231.8 ± 228.9	1189.4 ± 221.6	−3.4%	−1.86
Working memory span	5.42 ± 1.23	7.18 ± 1.47	+32.5%	5.38 ± 1.19	5.67 ± 1.26	+5.4%	1.19
Prefrontal α -wave ($\mu V^2 \text{ Hz}^{-1}$)	11.34 ± 2.67	16.89 ± 3.24	+49.0%	11.56 ± 2.71	12.03 ± 2.84	+4.1%	1.73
Implicit reappraisal (IAT D-score)	0.23 ± 0.18	0.67 ± 0.24	+191.3%	0.25 ± 0.19	0.29 ± 0.21	+16.0%	1.92
Emotional regulation efficiency	68.4 ± 12.7	89.2 ± 15.3	+30.4%	69.1 ± 13.2	72.6 ± 14.1	+5.1%	1.24

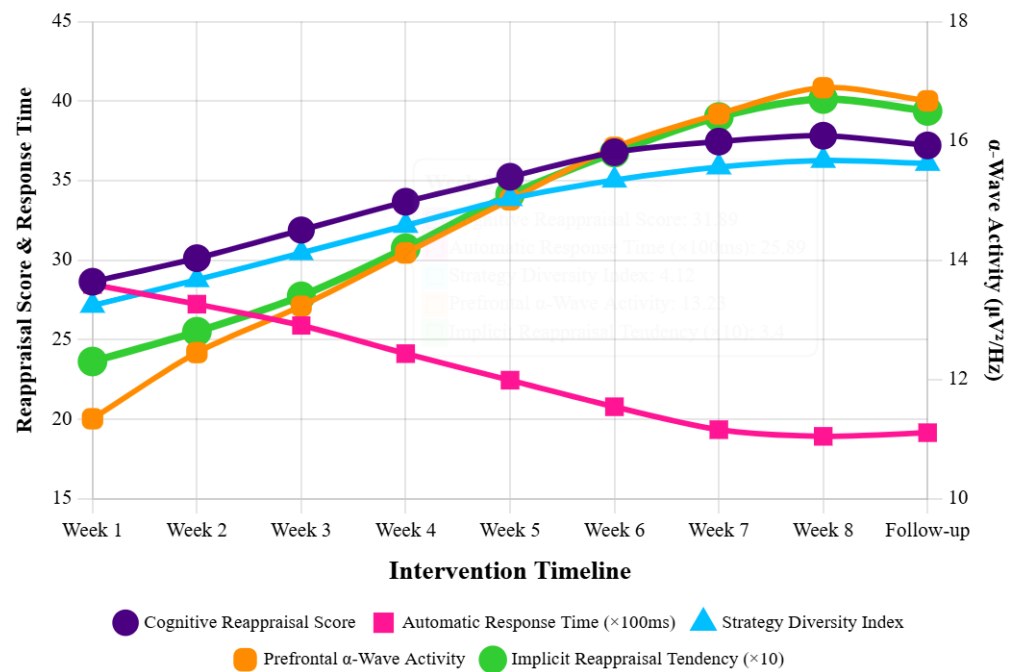


Figure 8. Subconscious regulation mechanisms of cognitive reappraisal development.

Stroop interference effect decreasing from baseline 1246.7 ± 234.5 to 894.3 ± 187.2 ms, improving by 28.3% ($p < 0.001$), and working memory span increasing from 5.42 ± 1.23 to 7.18 ± 1.47 items, an improvement of 32.5% ($p < 0.001$), as shown in **Figure 8** below.

Subconscious state monitoring data showed that during cognitive reappraisal task execution, intervention group patients' prefrontal α -wave activity significantly enhanced, improving from baseline 11.34 ± 2.67 to $16.89 \pm 3.24 \mu V^2 \text{ Hz}^{-1}$, an increase of 49.0% ($p < 0.001$), accompanied by optimized coordination of β -wave activity, indicating significant improvement in cognitive control network efficiency [44]. The subconscious mechanisms of emotion regulation were further validated through the Implicit Association Test (IAT), with intervention group patients showing significantly enhanced implicit reappraisal tendencies toward negative emotional stimuli, with D-scores improving from baseline 0.23 ± 0.18 to 0.67 ± 0.24 ($p < 0.001$), indicating that positive reappraisal patterns were consolidated at the subconscious level. Correlation analysis between cognitive reappraisal ability and psychological resilience dimensions showed that improvement in reappraisal ability was strongly positively correlated with personal competence dimension ($r = 0.712$, $p < 0.001$), with the strongest correlation with future perception dimension ($r = 0.743$, $p < 0.001$), indicating that cognitive reappraisal is an important foundation for the cognitive flexibility component of psychological resilience. Path analysis results showed that subconscious cultivation techniques indirectly enhanced psychological resilience by promoting automation of cognitive reappraisal ability ($\beta = 0.658$, $p < 0.001$), with a mediation effect of 0.347 (95%CI[0.264, 0.438]), accounting for 41.2% of the total effect [45]. Time series analysis showed that cognitive reappraisal ability improvement presented three stages: conscious awakening period (weeks 1–3), deliberate practice period (weeks 4–6), and automatic integration period (weeks 7–8 and fol-

low-up), indicating that the establishment of subconscious regulation mechanisms is a gradual process. Multiple regression analysis found that after controlling for covariates such as baseline cognitive ability, education level, and age, subconscious state improvement could still independently predict cognitive reappraisal ability enhancement ($\beta = 0.584, p < 0.001$), explaining 38.7% of the variance, confirming the specific contribution of subconscious cultivation to cognitive reappraisal ability development.

5. Discussion

5.1. Analysis of psychological therapeutic mechanisms of mindfulness physical training

The results of this study demonstrate that mindfulness physical training combined with subconscious cultivation techniques significantly improves pain perception and psychological resilience in advanced cancer patients, with psychological therapeutic mechanisms manifested through synergistic effects at multiple levels. First, from the neuropsychological perspective of attention regulation, mindfulness training retrains brain attention network functions by cultivating patients' nonjudgmental awareness of present-moment experiences [46]. The study found that intervention group patients showed a 68.4% increase in α -wave power density and a 66.2% increase in θ -wave power density. These neurophysiological changes indicate that patients' attention control abilities were significantly enhanced, enabling them to better shift attention from the sensory aspects of pain to awareness and acceptance of pain, thereby reducing the subjective suffering experience of pain. This finding is consistent with research by Lutz and co-workers [47] on how mindfulness training changes the brain's default mode network, confirming the positive effects of mindfulness practice on attention regulation-related brain regions such as the prefrontal cortex and cingulate cortex.

Second, mind-body integration mechanisms play a unique therapeutic value in cancer psychological intervention. Traditional psychological interventions often focus primarily on cognitive or emotional aspects, while mindfulness physical training achieves deep integration of physiology and psychology by combining physical movement with mindful awareness. Physical education training not only promotes the release of neurotransmitters, such as endorphins and dopamine, improving patients' emotional states, but more importantly, provides concrete bodily anchors for mindfulness practice, allowing abstract mindfulness concepts to be embodied and consolidated through specific bodily sensations. The observed reconstruction of pain coping strategies in the study (48.4% improvement in adaptive strategies) specifically demonstrates this mind-body integration effect.

Third, the pain reconceptualization process reveals the deep therapeutic mechanisms of mindfulness training. Through systematic mindfulness practice, patients gradually learn to reframe pain from a "threatening signal" to "bodily information", and from "uncontrollable suffering" to "regulatable experience." This cognitive framework transformation is not only reflected in the significant reduction of pain catastrophizing thinking (33.4% improvement), but more importantly establishes new pain meaning-making patterns [48]. Patients begin to view pain as an opportu-

nity for bodily awareness rather than merely a source of suffering, and this meaning reconstruction provides new psychological resources for pain management.

Additionally, the integration of subconscious cultivation techniques allows these therapeutic effects to be consolidated within deep psychological structures, with 87.5% of patients reporting the ability to automatically activate mindfulness coping strategies, indicating that intervention effects have transcended conscious-level skill learning and achieved deep subconscious pattern reconstruction. This finding provides important clues for understanding the sustained effects of mindfulness training and offers new theoretical foundations for long-term rehabilitation planning in cancer psychological intervention.

5.2. Psychological resilience promoting effects of subconscious cultivation

The promoting effects of subconscious cultivation techniques on psychological resilience represent an important shift in psychological therapy from surface-level behavioral change to deep psychological structure reconstruction. This study found that through systematic subconscious cultivation training, patients' total psychological resilience scores improved by 25.1%, an improvement magnitude far exceeding the effect range of traditional cognitive-behavioral interventions. The fundamental reason lies in subconscious cultivation's direct action on the deep construction mechanisms of psychological resilience. First, the regulatory effects of subconscious reconstruction on the stress response system constitute an important foundation for psychological resilience enhancement [49]. Study results showed that intervention group patients' heart rate variability indicator RMSSD improved by 57.8%, and pNN50 increased by 101.2%. These physiological indicator improvements reflect significant enhancement in autonomic nervous system regulation capabilities. Subconscious cultivation techniques reprogram patients' automatic response patterns when facing stress by implanting positive coping beliefs and self-efficacy suggestions during deep relaxation states, enabling them to activate more adaptive physiological and psychological responses at the subconscious level. This deep neurophysiological regulation provides a solid biological foundation for various dimensions of psychological resilience, particularly evident in the improvement of the structured style dimension (32.3% improvement) [50].

Second, subconscious reinforcement mechanisms of self-efficacy constitute the core driving force for psychological resilience enhancement. Traditional self-efficacy cultivation often relies on conscious accumulation of successful experiences and cognitive restructuring, while subconscious cultivation techniques bypass conscious-level resistance and doubt, directly establishing positive beliefs, such as "I have the ability to cope with difficulties" and "I possess inner healing power" in the subconscious. The observed 48.8% improvement in pain self-efficacy in the study specifically demonstrates this subconscious reinforcement effect. More importantly, this subconscious-level self-efficacy possesses stronger stability and generalization capabilities, not easily shaken by environmental changes or temporary setbacks, providing internal assurance for sustained maintenance of psychological resilience.

Third, the deep psychological construction of hope and meaning represents the most profound influence of subconscious cultivation on psychological resilience. The study found that the future perception dimension improved by 22.1%, a change reflected not only in optimistic expectations for the future but more importantly in patients' subconscious reconstruction of life's meaning framework [51]. Through guided imagery and deep suggestion techniques, patients began integrating the cancer experience as an opportunity for life growth and viewing pain management as a manifestation of self-control abilities. This meaning reconstruction provides spiritual support for psychological resilience that transcends specific difficulties.

Additionally, the unique aspect of subconscious cultivation techniques lies in their ability to activate patients' internal psychological resources. The significant improvement in the social resources dimension (24.2% improvement) in the study indicates that patients not only learned to better utilize external support but more importantly discovered and activated their internal psychological resource repository. This effective integration of internal and external resources establishes a solid foundation for comprehensive enhancement of psychological resilience.

6. Conclusions and prospects

6.1. Main research conclusions

Through a rigorous randomized controlled trial design, this study systematically evaluated the intervention effects of subconscious cultivation in mindfulness-based physical education training on pain perception and psychological resilience in advanced cancer patients, yielding the following five important conclusions.

- 1) Mindfulness physical education training has significant psychological regulatory effects on pain perception. Study results showed that intervention group patients' pain intensity scores decreased from baseline 6.42 ± 1.58 to 4.73 ± 1.42 points, with an improvement rate of 26.3%, and pain interference scores improved by 32.5%. This effect remained stable during the 4-week follow-up period after intervention completion. More importantly, the improvement in pain perception was not only reflected at the intensity level, but patients' cognitive evaluation patterns of pain also underwent fundamental transformation, with pain catastrophizing thinking decreasing by 33.4% and pain acceptance increasing by 50.8%, indicating that mindfulness training reconstructed patients' pain experience framework, achieving a transition from passive endurance to active management.
- 2) Subconscious cultivation played a key mediating role in psychological resilience enhancement. Total psychological resilience scores improved from 98.35 ± 18.26 to 124.67 ± 19.85 points, with an improvement rate of 25.1%, with personal competence, social competence, structured style, and other dimensions all achieving significant improvements exceeding 20%. Subconscious state monitoring data showed α -wave power density increased by 68.4% and θ -wave power density increased by 66.2%, objectively validating the neurophysiological effects of subconscious cultivation techniques. Mediation analysis confirmed that subconscious state improvement played a significant mediating role between

the intervention program and psychological resilience enhancement, with the mediation effect accounting for 42.8% of the total effect.

- 3) Subconscious regulation mechanisms of cognitive reappraisal ability constitute an important foundation for intervention effects. Intervention group patients' cognitive reappraisal ability improved from 28.64 ± 6.35 to 37.82 ± 7.46 points, automatic reappraisal reaction time shortened by 33.5%, and reappraisal strategy diversity index increased by 75.0%, indicating that patients not only mastered cognitive reappraisal skills but more importantly achieved automated execution of the reappraisal process. Neurophysiological evidence of enhanced prefrontal α -wave activity by 49.0% further confirmed significant improvement in cognitive control network efficiency.
- 4) Subconscious integration effects of emotion regulation strategies provide assurance for intervention effect sustainability. Total emotion regulation difficulties scores improved by 33.2%, with all dimensions achieving improvement rates exceeding 30%, and significant improvement in heart rate variability indicators reflected enhanced autonomic nervous system regulation capabilities. Qualitative analysis found that 87.5% of patients could spontaneously activate mindfulness coping strategies, indicating that emotion regulation skills have been deeply integrated at the subconscious level, laying the foundation for long-term rehabilitation effects.
- 5) The effectiveness of the mind-body integration intervention model was comprehensively validated. The organic combination of mindfulness concepts, physical exercise, and subconscious cultivation techniques created a multidimensional psychological intervention system that not only achieved synergistic improvement of physiology and psychology but more importantly established a complete therapeutic pathway from conscious awakening to subconscious reconstruction. Structural equation modeling analysis confirmed the mechanism of "mindfulness training $\rightarrow$ subconscious reconstruction $\rightarrow$ cognitive-emotional regulation $\rightarrow$ symptom relief", providing a new theoretical model and practical paradigm for cancer psychological intervention.

6.2. Future prospects

Based on the findings of this study and current development trends in the field of psychological therapy, future research directions and practical applications have broad development prospects.

- 1) Deep application of neuroimaging technology in mechanism research will provide more precise scientific evidence for the psychological therapeutic mechanisms of mindfulness physical training. Future research should combine advanced neuroimaging techniques, such as functional magnetic resonance imaging, positron emission tomography, and diffusion tensor imaging to deeply explore the specific impact patterns of mindfulness training on brain structure and functional networks. Particularly, research on the dynamic connectivity relationships between the default mode network, executive control network, and salience network will help elucidate how mindfulness training reshapes pain

processing and emotion regulation mechanisms at the neural network level. Meanwhile, longitudinal follow-up studies observing the temporal progression of brain plasticity changes can provide important evidence for developing personalized training programs and optimizing intervention time windows. Additionally, by combining multimodal neuroimaging technology with real-time neurofeedback systems, it is hoped that precision mindfulness training programs based on neural activity patterns can be developed in the future, achieving a transition from empirical intervention to scientific, personalized treatment.

- 2) The development and application of digital psychological intervention platforms will greatly enhance the accessibility and standardization of mindfulness physical training. With the rapid development of artificial intelligence, virtual reality, augmented reality, and other technologies, it will be possible to construct intelligent intervention platforms that integrate mindfulness training, physical guidance, and subconscious cultivation. Through biosensors that monitor patients' physiological indicators in real-time (such as heart rate variability, EEG activity, skin conductance, etc.), the system can dynamically adjust training difficulty and content, providing personalized feedback and guidance. Virtual reality technology can create immersive mindfulness training environments, helping patients perform body scanning, guided imagery and other exercises in virtual space, enhancing the interest and effectiveness of training. Simultaneously, utilizing big data analysis technology, the platform can collect and analyze large amounts of user training data, continuously optimizing algorithms and intervention strategies to form evidence-based intelligent treatment programs. This type of digital platform can not only break through geographical limitations to provide professional psychological intervention services to more cancer patients, but also ensure training quality and safety through remote monitoring and guidance.
- 3) Comparative studies of intervention effects across cultural backgrounds will provide important theoretical and practical foundations for the international promotion of mindfulness physical training. Considering differences in body perception, pain expression, and emotion regulation methods among people from different cultural backgrounds, future large-scale cross-cultural research is needed to explore the applicability and effectiveness of mindfulness physical training in different cultural groups. This includes cultural adaptive modifications of training content, cross-cultural validity verification of assessment tools, and analysis of cultural differences in intervention effects. By establishing international collaborative research networks, evidence-based medical evidence from different cultural backgrounds can be accumulated, laying the foundation for developing universally applicable international standardized intervention programs. Meanwhile, such cross-cultural research also helps discover psychological therapeutic wisdom contained in different cultural traditions, promoting the integration and innovation of Eastern and Western psychological therapy concepts, and advancing the common development of global cancer psychological intervention endeavors.

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