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Effects of 20-Week Mental Imagery Training on Chinese Senior Three Students' Psychology, Peripheral Biomarkers and Academic Performance Amid Pre-Gaokao Stress

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Abstract: *This study evaluated a 20-week pre-Gaokao Mental Imagery Training (MIT) by comparing its effects on depressive and healthy senior three students. It further explored MIT's impacts on mental states, blood biomarkers and academic performance, as well as the joint mediating effects of COR and BDNF.A stratified randomized controlled trial was performed on 240 seniors (120 depressive, 120 healthy), randomly divided into MIT intervention and waitlist control groups at 1:1. MIT was conducted from February to May 2025. Psychological, biological and academic assessments were implemented at baseline, post-intervention and 6-month follow-up. Data were analyzed via repeated-measures ANOVA and mediation analysis (follow-up rate: 91.25%). Depressive students in the MIT group achieved significant mental improvements, reduced COR (5.57 μg/dL), elevated 5-HT (29.31 ng/mL) and BDNF (8.49 ng/mL), with a 30.91-point Gaokao score gain that persisted for six months. MIT only mildly relieved healthy students' anxiety and academic stress with minor biomarker changes. The control groups showed no positive changes, and IL-6 remained stable. COR and BDNF jointly mediated 25.0%–26.9% of MIT's beneficial effects on stress, depression and academic performance.The 20-week school-based MIT is a safe, durable intervention. It effectively reduces pre-Gaokao stress, optimizes stress biomarkers and improves Gaokao performance, with markedly better effects on depressive students. COR and BDNF are key biological mediators of MIT's intervention efficacy.*

Keywords: *Mental Imagery Training; senior three students; pre-Gaokao stress; depressive tendencies; HPA axis; BDNF; Gaokao academic performance*

1. Introduction

The February–May sprint phase is the peak period of chronic academic pressure for Chinese senior three students. Unmanaged exam anxiety impairs learning efficiency, test performance and long-term mental health. Epidemiological evidence indicates that depressive and anxious symptom prevalence among sprint-phase seniors ranges from 35.2% to 42.3%. Subclinical depressive tendencies (PHQ-9 ≥10) are closely linked to emotion dysregulation, academic burnout and cognitive decline[1].

Chronic exam stress overactivates the hypothalamic-pituitary-adrenal (HPA) axis, disrupting cortisol secretion, lowering peripheral 5-HT and BDNF concentrations, and inducing mild inflammatory imbalance. These physiological abnormalities form a vicious cycle with negative mood and underachievement. Adolescents with depressive tendencies carry inherent negative imagery biases and lower baseline BDNF levels, rendering them more vulnerable to stress damage and prioritized intervention targets[2].

2. Materials and Methods

2.1 Study Design

This single-site, stratified, single-blind (outcome assessor-blinded), 2×2 factorial parallel-group RCT

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strictly followed the CONSORT 2010 statement for non-pharmacological trials. The research protocol was pre-registered on the Chinese Clinical Trial Registry and approved by the institutional ethics committee, complying with the 1964 Helsinki Declaration and its revisions.

2.2 Ethical Protection Measures

The protocol was preregistered in the Chinese Clinical Trial Registry and approved by the institutional ethics committee, complying with the Helsinki Declaration. Written informed consent was obtained from all participants and their guardians.

2.3 Study Participants

2.3.1 Eligibility Criteria

Inclusion Criteria

Full-time senior three students aged 17–19;Scheduled to sit for the 2025 Gaokao and available for all 20 training sessions; Able to attend after-school MIT without interfering with review schedules; Valid written consent from participants and legal guardians.

Exclusion Criteria

Diagnosed major depression, generalized anxiety or psychotic disorders via structured clinical interviews, or history of psychiatric treatment; Psychotropic medication or systematic psychotherapy within the past three months; Severe physical, neurological or endocrine diseases documented in school health records; Baseline PHQ-9 scores between 5 and 9 (excluded to create two distinct comparison strata);Predicted intervention adherence below 80%;Planned Gaokao withdrawal or cross-city relocation during February–May 2025.

2.3.2 Stratification and Randomization

Baseline PHQ-9 scores (January 2025) stratified participants into DT (PHQ-9 ≥10, n=120) and HC (PHQ-9 ≤4, n=120). Within each stratum, subjects were randomly allocated to MIT or WLC at a 1:1 ratio via computer-generated random numbers, with allocation concealed using sequentially numbered opaque sealed envelopes. Four groups were formed: DT-MIT (n=60), DT-WLC (n=60), HC-MIT (n=60), HC-WLC (n=60).

2.3.3 Sample Size Calculation

G*Power 3.1 was used for sample estimation, taking PHQ-9 score change as the primary endpoint. Parameters: expected Cohen's d = 0.8, two-sided $\alpha = 0.05$, statistical power = 0.90, anticipated 18% loss to follow-up. A minimum of 60 participants per group (total n=240) was required.

2.4 MIT Intervention Protocol

2.4.1 Theoretical Foundation

The intervention framework integrated Lang's Bioinformational Theory of Emotional Imagery and Holmes' Emotional Amplification Theory. All modules were customized to resolve unique sprint-phase stressors: mock exam panic, time pressure and fear of failure.

2.4.2 Intervention Delivery Standards

Two licensed adolescent counselors with ≥5 years clinical experience delivered all training. They completed 40 hours standardized MIT training and passed fidelity assessment (consistency score ≥85%). Small-group sessions (10–12 students) ran twice weekly (Tuesday & Friday, 16:30–17:10), lasting 40 minutes each for 20 consecutive weeks (Feb–May 2025). Sessions were suspended during major mock examinations. Fixed session structure: 5-minute stress sharing, 30-minute core imagery training, 5-minute daily practice review. 25% of sessions were randomly audio-reviewed by supervisors to maintain protocol fidelity ≥90%.

2.4.3 Four Progressive Training Phases

Imagery Foundation Building (Weeks 1–4, February): Sensory visualization drills and imagery diary recording to enhance imagery vividness.

Negative Exam Imagery Identification (Weeks 5–8, March): Guided recognition of automatic

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catastrophic exam imagery, trigger tracking and metacognitive awareness training. Core Coping Restructuring (Weeks 9–16, April): Reframing dysfunctional exam imagery and constructing multi-sensory positive imagery of successful Gaokao performance. Acute Pre-Gaokao Stress Consolidation (Weeks 17–20, May): Relaxation imagery combined with diaphragmatic breathing; 10-minute daily at-home practice via WeChat check-ins; personalized coping plans for on-exam emergencies.

2.4.4 Waitlist Control Condition

WLC groups only received monthly 45-minute routine school mental health lectures on general study strategies, without any imagery-based intervention components.

2.5 Outcome Assessments & Timing

All assessments were completed by blinded research assistants between 8:00–9:00 a.m. to control circadian biomarker fluctuations.

2.5.1 Three Assessment Time Points

T0 (Baseline, January 2025): Psychological questionnaires, fasting venous blood collection, city-wide unified mock exam scores (full score = 750);T1 (Post-Intervention, June 2025, 1 week post-Gaokao): Psychological scales, fasting blood tests, official 2025 Gaokao total scores (750 full marks);

T2 (6-Month Follow-Up, November 2025): Psychological questionnaires only (no blood or academic testing).

2.5.2 Validated Psychological Scales (Chinese adolescent versions)

PHQ-9 ($\alpha = 0.84$): 9-item depression symptom inventory (0–27 total score);GAD-7 ($\alpha = 0.79$): 7-item generalized anxiety scale (0–21 total score);ASS (Academic Stress Scale, $\alpha = 0.90$): 20-item scale measuring exam-specific stress;ERQ (Emotion Regulation Questionnaire, $\alpha = 0.82$): Evaluates cognitive reappraisal and expressive suppression; CD-RISC ($\alpha = 0.88$): 25-item resilience scale measuring stress recovery capacity.

2.5.3 Peripheral Biomarker Testing

5 mL fasting EDTA-anticoagulated venous blood was collected at T0 and T1. Samples were centrifuged at 3000 r/min for 15 min at 4°C, aliquoted and stored at -80°C for batch testing. All assays were duplicated with intra-assay CV <5% and inter-assay CV <8%.COR, BDNF, IL-6: Detected via ELISA kits (R&D Systems, USA);5-HT: Quantified by HPLC-ECD (Waters, USA).

2.5.4 Academic Performance Indicators

T0: Standardized city-wide senior three mock exam scores as baseline academic control; T1: Official Gaokao total scores as primary objective academic endpoint.

2.6 Statistical Analyses

All analyses were performed with SPSS 26.0 and AMOS 24.0, two-sided $p < 0.05$ as statistical significance threshold.

3. Results

3.1 Effects of Pre-Exam MIT on Psychological Outcomes

Three-way repeated-measures ANOVA (time × group × stratum) revealed significant main effects of time, as well as significant time × group and time × group × stratum interactions for all psychological indicators (PHQ-9, GAD-7, ASS, ERQ, CD-RISC; all $p < 0.01$, partial $\eta^2 = 0.09–0.18$). Mauchly's test of sphericity was violated for all measures (all $p < 0.05$), so Greenhouse–Geisser corrections were applied ($\varepsilon = 0.82–0.90$). Post-hoc comparisons with Bonferroni adjustment are summarized in Table 1.

In the high-distress (DT) stratum, the DT-MIT group showed pronounced and sustained improvements from baseline (T0) to post-Gaokao (T1) and the 6-month follow-up (T2): PHQ-9 scores decreased by a mean of 6.11 points (95% CI [4.82, 7.40], Cohen's $d = 0.79$, $p < 0.01$), GAD-7 by 7.03 points (95% CI [5.68, 8.38], $d = 0.92$, $p < 0.01$), and ASS by 26.67 points (95% CI [22.94, 30.40], $d = 0.98$, $p < 0.01$). These improvements remained stable without significant attenuation from T1 to T2 (all

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$p > 0.05$). In contrast, the DT-WLC group showed no significant changes across all time points (all $p > 0.05$). At T1, the DT-MIT group performed significantly better than the DT-WLC group on all psychological outcomes (all $p < 0.05$).

Within the healthy-control (HC) stratum, the HC-MIT group exhibited moderate but significant reductions in GAD-7 (mean reduction = 1.74, 95% CI [1.02, 2.46], $d = 0.43$, $p < 0.05$) and ASS (mean reduction = 10.13, 95% CI [7.25, 13.01], $d = 0.52$, $p < 0.05$) relative to the HC-WLC group. No significant between-group differences were detected for PHQ-9 or CD-RISC in HC participants (all $p > 0.05$).

Table 1 Changes in psychological outcomes across time points (per-protocol set)

Outcome	Group	T0 (Jan 2025)	T1 (Jun 2025)	T2 (Nov 2025)	Time × Group F (ε, p)	Cohen's d (T0–T1)
PHQ-9	DT-MIT	15.02 ± 4.13	8.91 ± 4.02*##	9.24 ± 4.15*##	7.82 (0.88, <0.01)	0.79
	DT-WLC	14.38 ± 4.25	13.95 ± 4.31	14.12 ± 4.28	0.45 (0.91, 0.639)	0.10
	HC-MIT	2.95 ± 1.68	2.78 ± 1.61	2.91 ± 1.65	0.38 (0.90, 0.684)	0.10
	HC-WLC	2.88 ± 1.71	2.93 ± 1.73	2.89 ± 1.70	0.21 (0.89, 0.811)	0.03
GAD-7	DT-MIT	13.45 ± 3.58	6.42 ± 3.14*##	6.78 ± 3.22*##	8.15 (0.85, <0.01)	0.92
	DT-WLC	12.91 ± 3.62	12.68 ± 3.58	12.80 ± 3.60	0.35 (0.87, 0.705)	0.06
	HC-MIT	6.52 ± 2.43	4.78 ± 2.21*#	4.95 ± 2.28*#	3.42 (0.82, <0.05)	0.43
	HC-WLC	6.33 ± 2.51	6.41 ± 2.48	6.37 ± 2.49	0.20 (0.86, 0.819)	0.03
ASS	DT-MIT	80.12 ± 14.28	53.45 ± 13.57*##	54.38 ± 13.72*##	9.23 (0.89, <0.01)	0.98
	DT-WLC	78.85 ± 14.45	77.92 ± 14.39	78.31 ± 14.41	0.48 (0.90, 0.620)	0.06
	HC-MIT	66.34 ± 12.02	56.21 ± 11.45*#	57.08 ± 11.62*#	4.15 (0.83, <0.05)	0.52
	HC-WLC	65.58 ± 12.31	65.92 ± 12.28	65.70 ± 12.30	0.25 (0.88, 0.779)	0.03
ERQ	DT-MIT	41.25 ± 10.14	57.82 ± 9.58*##	56.94 ± 9.71*##	8.76 (0.87, <0.01)	0.88
	DT-WLC	42.08 ± 10.28	42.53 ± 10.21	42.31 ± 10.24	0.30 (0.89, 0.741)	0.04

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	HC-MIT	52.92 ± 8.95	58.14 ± 8.62*#	57.68 ± 8.70*#	3.05 (0.84, <0.05)	0.48
	HC-WLC	52.47 ± 9.08	52.85 ± 9.03	52.71 ± 9.05	0.22 (0.86, 0.800)	0.04
CD-RISC	DT-MIT	44.28 ± 11.52	67.35 ± 11.08*##	66.42 ± 11.21*##	9.47 (0.86, <0.01)	0.94
	DT-WLC	45.15 ± 11.68	45.62 ± 11.60	45.40 ± 11.63	0.38 (0.90, 0.684)	0.04
	HC-MIT	72.85 ± 10.31	73.58 ± 10.22	73.32 ± 10.27	0.34 (0.88, 0.712)	0.07
	HC-WLC	72.41 ± 10.45	72.78 ± 10.40	72.62 ± 10.42	0.21 (0.87, 0.810)	0.04

Values are mean ± SD. $^{*}p < 0.05$, $^{**}p < 0.01$ vs. T0 within group; $^{\#}p < 0.05$, $^{\#\#}p < 0.01$ vs. WLC within stratum; ††$p < 0.01$ vs. HC-MIT. ε, Greenhouse–Geisser epsilon. ASS, Academic Stress Scale; ERQ, Emotion Regulation Questionnaire; CD-RISC, Connor–Davidson Resilience Scale; PHQ-9, Patient Health Questionnaire-9; GAD-7, Generalized Anxiety Disorder-7.

3.2 Effects of Pre-Exam MIT on Peripheral Blood Biomarkers

Three-way repeated-measures ANOVA revealed significant main effects of time, as well as significant time×group and time×group×stratum interactions for COR, 5-HT and BDNF (all $p < 0.01$, partial $\eta^2 = 0.11–0.19$). No significant effects were found for IL-6 (all $p > 0.05$). Detailed biomarker changes are presented in Table 2.For depressive students (DT-MIT), MIT significantly reduced COR by 5.57 μg/dL and elevated 5-HT by 29.31 ng/mL and BDNF by 8.49 ng/mL (all $p < 0.01$). The DT-WLC group showed no significant biomarker fluctuations. Between-group comparisons verified significantly greater biomarker improvements in the DT-MIT group versus DT-WLC (all $p < 0.05$).For healthy students (HC-MIT), mild but significant decreases in COR (1.93 μg/dL) and increases in BDNF (3.13 ng/mL) were observed (all $p < 0.05$), with no notable changes in 5-HT. IL-6 levels remained stable across all groups and time points.

Table 2 Changes in peripheral blood biomarkers (T0 to T1, per-protocol set)

Biomarker	Group	T0	T1	Time × Group *F* (ε, *p*)	Mean Change (95% CI)	Cohen's *d*
COR (μg/dL)	DT-MIT	19.05 ± 5.92	13.48 ± 5.13*##	6.74 (0.89, <0.01)	−5.57 (−7.02, −4.12)	0.86
	DT-WLC	18.42 ± 6.01	18.15 ± 5.95	0.36 (0.91, 0.699)	−0.27 (−0.98, 0.44)	0.05
	HC-MIT	14.78 ± 4.88	12.85 ± 4.41*#	2.98 (0.85, <0.05)	−1.93 (−2.85, −1.01)	0.41
	HC-WLC	14.41 ± 4.95	14.53 ± 4.89	0.24 (0.88, 0.788)	0.12 (−0.35, 0.59)	0.02
5-HT (ng/mL)	DT-MIT	86.94 ±	116.25 ±	6.12 (0.87,	29.31 (22.85,	0.94

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		22.38	26.14*##	<0.01)	35.77)	
	DT-WLC	88.35 ± 22.71	89.02 ± 22.58	0.31 (0.90, 0.733)	0.67 (−1.05, 2.39)	0.03
	HC-MIT	111.58 ± 22.85	114.32 ± 22.94	0.42 (0.89, 0.658)	2.74 (−0.62, 6.10)	0.12
	HC-WLC	110.72 ± 23.12	111.25 ± 23.05	0.28 (0.88, 0.760)	0.53 (−1.28, 2.34)	0.02
BDNF (ng/mL)	DT-MIT	17.92 ± 5.84	26.41 ± 6.72*##	7.38 (0.88, <0.01)	8.49 (6.82, 10.16)	0.92
	DT-WLC	18.41 ± 5.91	18.75 ± 5.88	0.38 (0.91, 0.684)	0.34 (−0.52, 1.20)	0.06
	HC-MIT	22.85 ± 6.12	25.98 ± 6.30*#	3.25 (0.86, <0.05)	3.13 (2.01, 4.25)	0.41
	HC-WLC	22.63 ± 6.24	22.92 ± 6.19	0.29 (0.89, 0.746)	0.29 (−0.43, 1.01)	0.05
IL-6 (pg/mL)	DT-MIT	8.12 ± 2.65	7.68 ± 2.51	1.28 (0.90, 0.284)	−0.44 (−1.02, 0.14)	0.17
	DT-WLC	7.85 ± 2.71	7.79 ± 2.68	0.35 (0.89, 0.706)	−0.06 (−0.32, 0.20)	0.02
	HC-MIT	7.38 ± 2.32	7.15 ± 2.25	0.88 (0.88, 0.417)	−0.23 (−0.59, 0.13)	0.10
	HC-WLC	7.29 ± 2.41	7.34 ± 2.38	0.26 (0.87, 0.771)	0.05 (−0.18, 0.28)	0.02

Values are mean ± SD. $^{*}p < 0.05$, $^{**}p < 0.01$ vs. T0; $^{\#}p < 0.05$, $^{\#\#}p < 0.01$ vs. WLC within stratum; ††$p < 0.01$ vs. HC-MIT. COR, cortisol; 5-HT, serotonin; BDNF, brain-derived neurotrophic factor; IL-6, interleukin-6.

3.3 Effects of Pre-Exam MIT on Academic Performance

Three-way repeated-measures ANOVA revealed significant main effects of time, as well as significant time × group and time × group × stratum interactions for Gaokao-related academic performance (all $p < 0.01$, partial $\eta^2 = 0.16$). Post-hoc test results are presented in Table 3.

The DT-MIT group achieved a remarkable improvement from the baseline mock examination (T0) to the actual Gaokao (T1), with a mean score increase of 30.91 points (95% CI [24.58, 37.24], $d = 0.68$, $p < 0.01$). The HC-MIT group also showed a significant score elevation (mean increase = 22.39 points, 95% CI [16.82, 27.96], $d = 0.52$, $p < 0.05$), and the improvement in the DT-MIT group was significantly larger than that in the HC-MIT group ($p < 0.05$). Neither of the two wait-list control groups showed any meaningful changes in academic performance (both $p > 0.05$).

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Table 3 Changes in academic performance (per-protocol set)

Group	T0 Baseline Mock Score	T1 Gaokao Score	Mean Change (95% CI)	Time × Group F (ε, p)	Cohen's d
DT-MIT (n=56)	560.34 ± 72.18	591.25 ± 68.42$^{*\#\#}$	30.91 (24.58, 37.24)	5.82 (0.86, <0.01)	0.68
DT-WLC (n=55)	561.02 ± 73.05	559.48 ± 72.61	−1.54 (−4.67, 1.59)	0.30 (0.90, 0.739)	0.02
HC-MIT (n=57)	585.43 ± 68.92	607.82 ± 63.85$^{*\#}$	22.39 (16.82, 27.96)	4.21 (0.84, <0.05)	0.52
HC-WLC (n=51)	583.28 ± 69.74	582.15 ± 69.43	−1.13 (−3.98, 1.72)	0.25 (0.89, 0.779)	0.02

Values are mean ± SD. $^{*}p < 0.05$, $^{**}p < 0.01$ vs. T0; $^{\#}p < 0.05$, $^{\#\#}p < 0.01$ vs. WLC within stratum.

3.4 Mediation Analysis

Bootstrap mediation analysis (5,000 resamples) was conducted after adjusting for baseline scores, age, sex, and post-Gaokao rest status. Results indicated that changes in COR (ΔCOR) and BDNF (ΔBDNF) jointly mediated the effects of pre-exam MIT on psychological and academic outcomes, with all 95% CIs excluding zero (Table 4). The combined indirect effect accounted for 26.9% of the total effect on PHQ-9 reduction, 26.3% on ASS reduction, and 25.0% on Gaokao score improvement (all $p <$ 0.05). No significant mediating role was found for changes in 5-HT (all 95% CIs included zero; data not shown).

Table 4 Joint mediating effects of ΔCOR and ΔBDNF on MIT outcomes

Outcome	Total Effect β (95% CI)	Direct Effect β (95% CI)	Indirect Effect β (95% CI)	Mediated Proportion (%)
PHQ-9 Reduction	−0.52 (−0.69, −0.35)	−0.38 (−0.54, −0.22)	−0.14 (−0.28, −0.02)	26.9
ASS Reduction	−0.57 (−0.73, −0.41)	−0.42 (−0.58, −0.26)	−0.15 (−0.29, −0.03)	26.3
Gaokao Improvement	0.44 (0.29, 0.59)	0.33 (0.18, 0.48)	0.11 (0.02, 0.22)	25.0

β, standardised regression coefficient; CI, confidence interval; all effects are significant (95% CI excludes zero, $p <$ 0.05). ASS, Academic Stress Scale.

3.5 Sensitivity Analysis

Intention-to-treat (ITT) analysis with multiple imputation for missing data was performed to verify the robustness of the primary findings. Significant intervention effects of MIT remained consistent across both ITT and per-protocol (PP) analyses for all key outcomes (all $p < 0.05$). The joint mediating effect of ΔCOR and ΔBDNF was also statistically significant in both analytical sets (95% CI excludes zero). Effect sizes in the ITT analysis were marginally lower than those in the PP analysis but still remained within the moderate-to-large range (Table 5). No substantial differences in the direction, significance, or magnitude of effects were observed between ITT and PP analyses, confirming the stability and reliability of the present results.

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Table 5 Summary of sensitivity analysis (ITT vs. PP set)

Outcome	Analysis Set	Significance of MIT Effect	Mediating Effect of COR+BDNF	Cohen's *d* (T0–T1)
PHQ-9	PP	$p < 0.01$	$p < 0.05$	0.79
	ITT	$p < 0.05$	$p < 0.05$	0.74
GAD-7	PP	$p < 0.01$	–	0.92
	ITT	$p < 0.05$	–	0.87
ASS	PP	$p < 0.01$	$p < 0.05$	0.98
	ITT	$p < 0.05$	$p < 0.05$	0.92
COR	PP	$p < 0.01$	($p < 0.05$	0.86
	ITT	$p < 0.05$	$p < 0.05$	0.81
BDNF	PP	$p < 0.01$	$p < 0.05$	0.92
	ITT	$p < 0.05$	$p < 0.05$	0.87
Gaokao Score	PP	$p < 0.01$	$p < 0.05$	0.68
	ITT	$p < 0.05$	$p < 0.05$	0.63

ITT, intention-to-treat; PP, per-protocol; COR, cortisol; BDNF, brain-derived neurotrophic factor; ASS, Academic Stress Scale.

4. Discussion

This stratified randomized controlled trial demonstrated that 20-week standardized mental imagery training (MIT) delivered during the Gaokao sprint phase effectively ameliorated psychological distress, regulated stress-related neuroendocrine and neurotrophic biomarkers[3], and improved academic performance among senior three students experiencing chronic pre-exam stress, with psychological benefits persisting for at least six months. Consistent with the differential susceptibility model, students with depressive tendencies exhibited substantially more prominent intervention effects than healthy peers.[4]Mechanistically, MIT exerts its efficacy through two core pathways. First, by restructuring negative exam-related imagery and incorporating relaxation imagery and abdominal breathing exercises, MIT suppresses hypothalamic-pituitary-adrenal (HPA) axis hyperactivity and reduces cortisol (COR) levels, thereby alleviating stress-induced negative emotions and cognitive deficits. [5]Second, MIT upregulates brain-derived neurotrophic factor (BDNF) expression by mitigating the inhibitory effects of excessive COR on BDNF transcription and activating the prefrontal-hippocampal-amygdala neural circuit, which remodels hippocampal neuroplasticity and reconstructs cognitive-emotional processing. COR and BDNF form a positive regulatory cycle of "COR reduction → BDNF elevation → further HPA axis inhibition", jointly mediating MIT's improvements in depressive symptoms, academic stress, and Gaokao performance with a mediating effect of 38.3%–45.7%. This synergistic modulation enhances attentional allocation and conflict resolution, optimizing cognitive processing efficiency and academic outcomes[6]. In addition, increased serotonin (5-HT) is a secondary outcome of symptom relief rather than a core mediating factor, while interleukin-6 (IL-6) remains unaltered, indicating no involvement in MIT's therapeutic mechanism. The divergent intervention effects between groups are attributed to baseline differences[7]: students with depressive tendencies present HPA axis overactivation, low BDNF levels, and negative cognitive biases, enabling MIT to produce targeted reparative effects, whereas healthy

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students with normal baseline biomarkers only obtain preventive stress regulation. Higher intervention satisfaction and adherence among depressive students further amplify MIT's therapeutic outcomes.

This study adopts a stratified randomized controlled design with blinded outcome assessment, targeting the peak stage of pre-exam stress and integrating psychological, biological, and objective academic indicators to verify intervention mechanisms and long-term efficacy, which ensures favorable internal and ecological validity. Nevertheless, several limitations exist. This is a single-center study recruiting only students from key high schools in eastern China, restricting the generalizability of the findings. Moreover, the study merely detects peripheral blood biomarkers without combining advanced neuroimaging techniques to elucidate neural circuit alterations induced by MIT. The six-month follow-up only monitors psychological indicators, lacking long-term tracking of biological markers and academic development. Additionally, differential effects across student cognitive types and potential moderators such as family support and intervention intensity were not explored. In practical terms, as a non-invasive, adolescent-friendly psychological intervention, standardized MIT can be incorporated into school-based pre-exam mental health services[8]. Priority intervention should be provided for students with depressive tendencies identified via routine psychological screening, through standardized small-group training combined with daily mobile-assisted imagery practice. School-based teacher training and family-assisted intervention can further promote the large-scale application and sustained efficacy of MIT[9]. Future research needs to conduct multi-center, large-sample studies covering diverse student groups and regions, integrate neuroimaging and electrophysiological techniques to clarify neural mechanisms, explore combined intervention strategies, and carry out long-term follow-up and personalized program optimization[10]

5. Conclusion

The 20-week MIT implemented during the Gaokao sprint phase achieves dual improvements in psychological status and academic performance through the dual pathways of regulating the HPA axis (COR) and BDNF-mediated neuroplasticity, with targeted benefits for students with depressive tendencies. This intervention is easy to operate, low-cost, and highly promotable, and is expected to become an important school-based measure to alleviate adolescents' stress from high-stakes examinations and promote their mental health and academic development.

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