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Embodied Pathways from Mindful Dance Training to Psychological Resilience in Adolescents: A Longitudinal Study of Interoceptive Awareness, Self-Compassion, and Emotion Regulation

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Abstract

Pathway studies of adolescent psychological resilience have predominantly focused on cognitive routes, leaving the role of interoceptive processes largely unexplored. Grounded in embodied cognition theory, this study examined whether mindful dance training promotes adolescent psychological resilience through multiple mediation pathways involving interoceptive awareness, self-compassion, and emotion regulation. A total of 647 adolescents (M age = 14.23, 56.7% female) from 14 classes across four secondary schools were assigned to a 16-week mindful dance training program or a regular dance training program, with core variables measured at four time points over 24 weeks. A between-group longitudinal mediation model revealed that the mindful dance group showed greater gains in psychological resilience, conveyed primarily through indirect pathways (total indirect effect = .0920, 95% CI [.0575, .1302]; direct effect β = .08, p = .118). Five of seven specific indirect pathways were significant, and self-compassion appeared in all five, with the single-mediator pathway through self-compassion yielding the largest point estimate (.0204, 22.2% of the total indirect effect). A supplementary within-group analysis produced a convergent pattern. Exploratory moderation analysis suggested that implementation fidelity moderated the engagement quality to interoceptive awareness path (β = .14, p = .018). These findings indicate that interoceptive awareness serves as a temporal starting point in the embodied pathway from mindful dance training to adolescent resilience, and that self-compassion functions as the most central mediator, contributing to resilience both through emotion regulation and independently of it.

1 Introduction

Adolescence marks a critical period of rapid physiological, cognitive, and social development, during which young people face psychological pressures stemming from academic competition, peer relationships, and identity formation. Rates of anxiety, depression, and emotional dysregulation among adolescents have continued to rise worldwide, and mental health problems have become a prominent challenge to the healthy development of this population. Psychological resilience, understood as the capacity to sustain adaptive functioning and achieve positive recovery in the face of adversity [1], has accordingly become a central focus of school-based mental health intervention research.

Existing programs designed to strengthen adolescent resilience have been predominantly cognitive-behavioral in orientation, building adaptive capacity by altering patterns of cognitive appraisal and behavioral coping. As two emerging intervention formats, mindfulness training and dance intervention have each accumulated a measure of empirical support in the field of adolescent mental health over recent years. Work in both areas, however, has concentrated on verifying whether interventions are effective, while the pathways that explain how they work have seen little rigorous longitudinal testing.

The core exercises of mindfulness training, such as breath awareness, body scanning, and attentional anchoring during movement, all constitute processes of perceiving internal bodily signals, and dance activity depends just as heavily on these signals. This shared characteristic suggests that body awareness may be a key starting point through which both formats advance psychological functioning. This embodied pathway has received almost no systematic scrutiny. Pathway studies of mindfulness interventions have

largely centered on cognitive mediators, and dance intervention studies have generally lacked a theoretical framework explaining how dance benefits mental health. Empirical research that integrates mindfulness training with dance activity and investigates its psychological pathways from an embodied cognition standpoint remains at an early stage.

The present study embedded mindfulness elements systematically within a dance curriculum, implemented a 16-week program of mindful dance training in school settings, and used longitudinal tracking data across four time points to test the embodied pathways through which mindful dance training fosters adolescent psychological resilience through interoceptive awareness, self-compassion, and emotion regulation. Specifically, the study first leveraged the between-group contrast of mindful dance training versus regular dance training to examine whether the intervention promotes resilience through the mediating roles of interoceptive awareness, self-compassion, and emotion regulation, and then turned to variation in engagement quality within the mindful dance group to probe how differences in the depth of individual participation relate to the operation of these pathways. As a complementary line of inquiry, the study explored whether implementation fidelity at the class level moderates the initial segment of the within-group pathway.

The study contributes in three respects. Theoretically, it grounds adolescent resilience development in an embodied cognition account, proposing and testing a longitudinal model in which interoceptive awareness serves as the embodied starting point from which multiple pathways, through self-compassion, emotion regulation, or both, connect mindful dance training to psychological resilience. Methodologically, it combines a between-group mediation analysis contrasting mindful dance training with regular dance training and a within-group process analysis examining how engagement quality relates to the same pathway variables, with temporally staggered measurement across four waves sharpening directional inferences. Practically, it offers a workable embodied mindfulness curriculum for school settings and provides exploratory evidence on implementation fidelity as a potential moderating condition for intervention effects.

2 Literature Review, Theoretical Framework, and Hypotheses

2.1 Psychological Resilience and Movement-Based Interventions in Adolescence

Adolescence is accompanied by pronounced changes in the neuroendocrine system and by rapid shifts in social roles, so that the psychological pressures confronting young people intensify markedly while anxiety, depression, and emotional dysregulation become increasingly common [2]. Against this developmental backdrop, psychological resilience has drawn broad attention in school-based mental health intervention research as a protective factor that buffers the impact of stress and supports positive adaptation. As empirical evidence accumulated, researchers came to recognize resilience not as a stable trait but as a dynamic adaptive process that can be cultivated under particular conditions [1, 3], supplying the theoretical grounds for fostering adolescent resilience through intervention.

Resilience-promotion programs delivered in schools have generated a substantial body of empirical research over the past decade. Meta-analytic findings indicate that school-based interventions exert a significant positive effect on adolescent psychological resilience, though the effect sizes show considerable heterogeneity, with intervention type, target population, and follow-up duration all bearing on the stability of outcomes [2, 4]. Programs currently in use are predominantly cognitive-behavioral in orientation, promoting adolescents' psychological adaptation through cognitive reappraisal training, problem-solving skills instruction, and the building of social support networks [4]. Interventions of this kind display a degree of short-term efficacy, yet evidence from extended follow-up remains relatively limited, and multicomponent and cognitive-behavioral interventions have shown significant effects only over comparatively short follow-up windows.

Interventions grounded in physical activity and exercise offer a further route to resilience promotion. A systematic review of mind-body therapies has shown that mind-body formats such as mindfulness training and martial arts confer some benefit for adolescent resilience, although the effects vary widely across intervention types and the overall consistency of evidence falls short [5]. Within sport psychology, the positive influence of physical activity on psychological resilience has attracted considerable support, with emotion regulation and self-efficacy regarded as important mediating pathways in this relationship [6, 7]. A shared limitation nevertheless runs through existing exercise-based intervention research at the level of pathway-level explanation: most studies attend to the global psychological benefits that exercise brings and seldom probe how the awareness and processing of internal bodily sensations during physical activity set psychological change in motion.

Its central claim holds that cognition and emotion are not abstract processes independent of the body but dynamic activities rooted in and continuously modulated by bodily states. Changes in respiratory rhythm, heart rate, and muscular tension can be perceived by the individual and can shape emotional experience, self-evaluation, and behavioral decision-making [8, 9]. Recent work has carried this perspective further into the domains of exercise, art, and mind-body practice, exploring the bidirectional links between bodily experience and psychological functioning [10]. Viewed through the lens of embodied cognition, the resilience-promoting effect of exercise-based interventions may derive not simply from improved physical fitness or social participation but from the way an individual's awareness and processing of internal bodily signals during movement initiate a cascade of adaptive psychological change. This theoretical vantage point supplies a unifying explanatory frame for the multiple mediation pathways argued across the sections that follow.

2.2 Mindful Dance Training and Interoceptive Awareness

The core exercises of mindfulness training, including breath awareness, body scanning, and attentional anchoring during movement, all involve active attention to and sustained awareness of internal bodily signals. The capacity trained by these exercises is conceptualized as interoceptive awareness, an individual's multifaceted awareness of physiological signals arising from within the body, encompassing the noticing, detection, appraisal, and integration of such signals [11, 12]. Individual differences in interoceptive awareness have been linked to anxiety, depression, eating disorders, and chronic pain [13],

and enhancing this capacity has come to be viewed as a potential intervention target for improving mental health.

Mindfulness training is regarded as an effective means of enhancing interoceptive awareness. A meta-analysis of 29 randomized controlled trials found that mindfulness interventions produced a small-to-moderate positive effect on self-reported interoceptive awareness (g = 0.31), with mindfulness-based programs yielding the most pronounced effect (g = 0.41) [14]. Mindful Awareness in Body-oriented Therapy (MABT) has systematized this process into three components of identifying, accessing, and appraising internal bodily signals [15], and an integrative review supports the view that mind-body interventions influence interoceptive processing through both top-down and bottom-up routes, thereby improving emotion regulation [16].

Dance activity holds distinctive potential for cultivating interoceptive awareness. Set against static mindfulness meditation, dance offers a dynamic and contextualized bodily experience for training interoceptive awareness, since participants must continuously integrate multiple signals arising from within and outside the body throughout movement [17]. Prior research has shown that dance intervention can improve participants' body awareness and bodily trust [18], and the experience of body awareness during dance has been identified as an important mediating factor in the promotion of mental health [19]. Mindfulness training supplies a systematic method of awareness while dance provides a dynamic context for that awareness, so that their combination allows body-awareness training to unfold in a structured manner within genuine movement experience.

The present study defines mindful dance training as a structured form of embodied mindfulness curriculum that embeds mindfulness elements systematically throughout each phase of dance instruction, including breath awareness, body scanning, the recognition of bodily signals during movement, and nonjudgmental awareness, with body awareness, emotional expression, and self-acceptance serving as its central pedagogical goals. Because this curriculum contains systematic mindfulness guidance that is absent from regular dance training, students in the mindful dance group receive structured prompts to attend to breathing, bodily tension, and movement-related signals throughout each session, whereas students in the regular dance group experience the same physical movements without this guided awareness component. The mindful dance group is therefore expected to show greater gains in interoceptive awareness than the regular dance group. Within the mindful dance training group, the quality of a student's engagement, comprising attendance, in-class involvement, completion of mindfulness exercises, and completion of after-class reflection, reflects the actual extent to which the student receives embodied mindfulness training. Students who engage at a higher level obtain fuller training in exercises such as breath-movement synchronization, body scanning, and awareness of the body's center of gravity, and their gains in interoceptive awareness are correspondingly greater. On the basis of this reasoning, the following hypothesis is proposed:

H1: Mindful dance training produces greater gains in interoceptive awareness than regular dance training.

2.3 Interoceptive Awareness and Self-Compassion

When an individual can clearly perceive changes in respiration, tension in the muscles, or a quickening heartbeat, these bodily signals furnish immediate feedback about one's present state. Awareness of this kind, arising at the bodily level, opens up space for the individual to reappraise and reshape the manner in which personal experience is met. It is within this space that self-compassion, understood as the capacity to treat oneself with warmth, understanding, and a nonjudgmental attitude in the face of pain, failure, or personal inadequacy [20], takes root. Neff [21] characterizes self-compassion as comprising three interrelated component pairs (self-kindness versus self-judgment, common humanity versus isolation, and mindful awareness versus overidentification), among which mindful awareness bears a natural functional connection to interoceptive awareness as both emphasize open attention to present experience. A developmental systematic review has shown that self-compassion is positively associated with a variety of mental health indicators in adolescent populations, yet longitudinal research into how self-compassion develops and what its antecedent conditions might be remains relatively scarce [22].

Interoceptive awareness may constitute an embodied antecedent of self-compassion. The MABT framework offers a concrete account of how this transition unfolds. In the first stage, identifying, the individual learns to notice and label internal bodily signals such as changes in breathing rate, muscular tightness, or heartbeat. In the second stage, accessing, the individual moves from passive noticing to actively turning attention toward these signals rather than avoiding or ignoring them. In the third stage, appraising, the individual evaluates these signals with an attitude of openness and acceptance rather than judgment [15], This progression from noticing to non-judgmental appraisal maps directly onto the mindfulness dimension of self-compassion, because the open, accepting quality of attention cultivated at the appraising stage is functionally the same stance that self-compassion requires when an individual encounters personal difficulty or inadequacy. Longitudinal research indicates that gains in mindful awareness can predict the subsequent development of self-compassion [23]. In the specific context of mindful dance training, the transformation of interoceptive awareness into self-compassion has a concrete practical vehicle. The curriculum incorporates a dedicated exercise segment devoted to accepting movement errors, reducing self-criticism, and using gentle self-directed language, so that once students perceive bodily signals such as tension in their movements, shortened breathing, or physical incoordination, they are guided to respond to these experiences with kindness and understanding. This training process, in which body awareness is turned into a changed mode of self-response, offers a structured route by which interoceptive awareness fosters the development of self-compassion. Even so, few studies have yet examined interoceptive awareness longitudinally as an embodied antecedent of self-compassion. These considerations lead to the following hypothesis:

H2: Interoceptive awareness positively predicts the development of self-compassion.

2.4 Self-Compassion, Emotion Regulation, and Psychological Resilience

In his process model, Gross [24] distinguished regulation strategies such as cognitive reappraisal and expressive suppression and noted that differences in strategy selection are closely tied to mental health outcomes. Among adolescents, those able to draw flexibly on adaptive strategies such as cognitive

reappraisal exhibit less emotional distress and better psychological functioning [25, 26], whereas adolescents who rely heavily on maladaptive strategies such as expressive suppression and rumination face elevated risk of anxiety and depression [27]. The benefit of mindfulness interventions for adolescent emotion regulation capacity has already been supported by a systematic review [28], yet the upstream psychological sources of improved emotion regulation, and the part played by self-compassion in particular, call for further longitudinal evidence.

Self-compassion may support the development of adaptive emotion regulation capacity through its core components. Self-kindness reduces the tendency toward avoidance and suppression when an individual confronts negative emotion, creating a precondition for the deployment of adaptive strategies such as cognitive reappraisal. Common humanity helps the individual interpret personal emotional distress as part of a shared human experience, lessening the sense of isolation that accompanies emotional experience. Mindful awareness enables attention to the present emotional state in a balanced and aware manner and guards against overidentification with negative emotion [21]. Empirical research bears out these connections, showing that self-compassion positively predicts the use of adaptive strategies such as cognitive reappraisal, acceptance, and problem-solving and negatively predicts maladaptive strategies such as avoidance and rumination [29]. Among adolescents, compassionate self-responding and reduced uncompassionate self-responding predict emotion regulation strategies in differentiated ways [30]. A within-person and between-person analysis further indicates that change in self-compassion can predict subsequent improvement in emotion regulation difficulties across both levels [31], and a comparable mediating pattern has been observed among adolescents and young adults living with chronic illness [32]. Taken together, this evidence, drawn from different age groups and different populations, indicates that the facilitative effect of self-compassion on adaptive emotion regulation holds with a degree of cross-population stability. This reasoning gives rise to the following hypothesis:

H3: Self-compassion positively predicts gains in emotion regulation capacity.

The development of emotion regulation capacity is in turn closely bound up with psychological resilience. Longitudinal and experience-sampling research has shown that resilience and emotion regulation are dynamically associated, with higher resilience predicting greater use of cognitive reappraisal and less reliance on suppression [26, 27], and emotion regulation mediating the link between resilience and psychosocial adjustment in school settings [25]. Serial mediation pathways involving emotion regulation have been confirmed in both general adolescent samples [7] and in the context of children's recovery from sports injury [6]. Within the framework of mindful dance training, the later phase of the curriculum uses tasks such as group performance, movement challenges, and moderate stress scenarios to create opportunities for students to apply their previously acquired emotion regulation capacity toward recovery and coping under genuine stress.

Self-compassion may also contribute to psychological resilience through a more direct route. Longitudinal evidence indicates that self-compassion can lower psychological distress by strengthening resilience [23], and among Chinese adolescents self-compassion has been shown to predict gratitude and prosocial behavior across a three-year follow-up [33], suggesting that the adaptive function of self-compassion

extends to outcomes that are not channeled through emotion regulation. The present study therefore tests whether self-compassion connects to psychological resilience through emotion regulation, directly, or through both routes. The foregoing evidence supports the following hypothesis:

H4: Self-compassion and emotion regulation positively predict the development of psychological resilience, with self-compassion contributing both through emotion regulation and independently of it.

2.5 The Integrated Model: Multiple Pathways and Exploratory Moderation

The preceding sections argued in turn for the relationships between mindful dance training and interoceptive awareness, between interoceptive awareness and self-compassion, between self-compassion and emotion regulation, between self-compassion and psychological resilience, and between emotion regulation and psychological resilience, advancing a pathway hypothesis for each. Under the theoretical framework of embodied cognition, these relationships converge on a model in which interoceptive awareness occupies the position of an embodied starting point. Mindful dance training raises an individual's awareness of internal bodily signals through systematic body-awareness exercises, and this heightened body awareness supplies an embodied foundation on which a nonjudgmental, self-accepting attitude can form. As argued in Section 2.4, the present study tests a model in which interoceptive awareness initiates several concurrent pathways to resilience, with the data permitted to reveal which routes carry the strongest associations.

This multipath model draws inspiration from the Mindfulness-to-Meaning Theory, which posits a cascading process from attentional control through decentering and broadened awareness to positive affect [34]. This process has been shown to persist and predict mental health improvement over a six-year follow-up [35]. In carrying this cascading logic forward, the present study redirects the theoretical lens from cognitive processing to embodied perception, placing interoceptive awareness at the origin of the pathway and thereby stressing the foundational role that awareness of internal bodily signals plays in setting subsequent psychological change in motion. The present model extends this cascading logic by allowing the embodied starting point to feed into psychological resilience through more than one route, an expectation grounded in the evidence reviewed above that self-compassion holds both a transmitting function through emotion regulation and an independent association with resilience. A longitudinally staggered data structure serves to sharpen inferences about the directionality of the pathway. Accordingly, the following hypothesis is advanced:

H5: Interoceptive awareness, self-compassion, and emotion regulation mediate the effect of mindful dance training on psychological resilience through multiple pathways.

This hypothesis is tested at two levels of analysis: a between-group mediation analysis leveraging the quasi-experimental contrast as the primary inferential basis, and a within-group process analysis examining how variation in engagement quality relates to the same pathway variables.

Beyond the mediation pathways themselves, the actual operation of these pathways in school settings is at the same time subject to the conditions of implementation. In school-based intervention research, implementation fidelity reflects the extent and quality of a teacher's execution of the prescribed curriculum in the course of actual teaching and stands as an important factor bearing on intervention effects [36]. Implementation fidelity bears directly on the completeness and depth of the mindfulness training stimulus that students actually receive. When teachers guide breath awareness, body scanning, and bodily signal recognition more fully, students obtain a higher-quality interoceptive awareness training experience for the same level of engagement. When these elements are simplified or omitted, engagement cannot be translated effectively into gains in interoceptive awareness.

This moderating effect should operate at the first segment of the within-group pathway, namely the juncture at which engagement quality is translated into interoceptive awareness. The later segments, running from interoceptive awareness to self-compassion, from self-compassion to emotion regulation, and from emotion regulation to psychological resilience, reflect more fully the natural transmission of students' internal psychological processes, and as an external input variable located at the teacher's end, implementation fidelity exerts relatively limited direct influence on these internal psychological transmissions. Given that this moderating role has received limited empirical attention in the context of embodied mindfulness interventions, the following research question is advanced as an exploratory inquiry:

RQ1: Does implementation fidelity moderate the association between engagement quality and interoceptive awareness within the mindful dance training group, such that higher implementation fidelity strengthens this association?

3 Method

3.1 Study Design and Participants

This study adopted a quasi-experimental design in which participating classes were assigned as intact units to either a mindful dance training group or a regular dance training group, and all core variables were tracked longitudinally across four measurement points. The research was conducted in four public secondary schools in Hunan Province, China. All participating schools were located in urban areas and were comparable in school size and student composition. The research protocol was approved by the research ethics committee for the humanities and social sciences of Dankook University (approval number: DKU 2026-01-013). Because all participants were minors, written informed consent from students' guardians and written informed assent from the students themselves were obtained before data collection began. The consent materials made clear to participants and their guardians that students had the right to withdraw from the study at any time and that a decision to withdraw would not affect their regular course arrangements or academic evaluation.

Participants were secondary school students aged 12 to 17. Inclusion criteria were enrollment in grades 7 through 11 at a participating school, a physical condition permitting dance-based physical activity, the

ability to complete the Chinese-language questionnaire independently, and signed consent from both student and guardian. Students were excluded if they had a serious motor impairment or medical contraindication to physical activity, were receiving ongoing psychological treatment or psychiatric medication, had participated in mindfulness training more than once per week within the preceding year, or failed to complete the baseline questionnaire.

A total of 14 classes across the four schools took part. Class assignment followed a within-school balanced procedure. Within each school, classes were assigned to the mindful dance training group or the regular dance training group according to teacher qualifications and scheduling conditions, ensuring that each school contained both experimental conditions. School A assigned three classes to the mindful dance group and one to the regular dance group; School B assigned two classes to each; School C assigned two classes to the mindful dance group and one to the regular dance group; and School D assigned one class to the mindful dance group and two to the regular dance group. Eight classes were ultimately assigned to the mindful dance training group and six to the regular dance training group. The unequal allocation of classes between the two groups stemmed from actual differences across schools in the number of classes available and in the configuration of teacher qualifications.

At baseline, 647 students completed the questionnaire, comprising 371 in the mindful dance training group and 276 in the regular dance training group. Participants had a mean age of 14.23 years (SD = 1.41), 56.7% were female, and the mean BMI was 20.14 (SD = 3.27). Measurement was completed by 612 students at T2 (attrition rate 5.4%), 589 at T3 (9.0%), and 561 at T4 (13.3%), with attrition arising from school transfer, extended sick leave, and consecutive absence. Attrited and retained students did not differ significantly in baseline demographics or core variable levels (all $p > .05$), supporting the assumption of data missing at random.

An a priori Monte Carlo simulation [37, 38] with each path set at $\beta = 0.20$ and $\alpha = .05$ showed that a sample of 500 yielded 81.3% power for the serial indirect effect. Given the nested structure and anticipated attrition, the recruitment target was set above 600, and the final sample of 647 satisfied this requirement. A supplementary evaluation using the simulation logic of powRICLPM [39] indicated 78.6% power for the moderation effect under a moderate interaction effect size.

3.2 Intervention

The mindful dance training group received a 16-week mindful dance training curriculum delivered twice weekly in sessions of 45 minutes, for a total training dose of 1,440 minutes. The mindfulness content of the curriculum was designed with reference to the quality framework for mindfulness-based programs [40], incorporating guided breath awareness, body scanning, nonjudgmental attentional anchoring, and self-compassion exercises as core components integrated within each session. The curriculum was taught by eight dance teachers who had undergone uniform training, with each teacher responsible for one class. All teachers held qualifications related to dance education and, before the curriculum began, completed a three-day, 24-hour specialized training program in mindful dance training that covered the principles of mindful awareness, body-scanning guidance techniques, methods for leading self-compassion exercises, the standardized curriculum procedure, and classroom emotion management strategies.

Each session followed a fixed six-part structure. It began with mindful entry (5 min), including breath awareness, body scanning, and attentional anchoring, followed by a body-awareness warm-up (8 min) involving slow joint mobilization, breath-movement synchronization, and awareness of the body's center of gravity. The main segment was mindful dance movement learning (15 min), covering basic dance steps, rhythm training, and coordination practice. Students then engaged in emotional expression and movement exploration (8 min), using movement to express experiences such as tension, relaxation, and joy. The session concluded with self-compassion practice (5 min), in which students practiced accepting movement errors, reducing self-criticism, and using gentle self-directed language, and reflective closing (4 min), in which they recorded bodily sensations, emotional changes, and experiences of self-acceptance.

The 16-week curriculum was divided into four progressive phases. Weeks 1 through 4 formed the body-awareness establishment phase, centered on training breath awareness, body scanning, and the recognition of bodily signals during movement. Weeks 5 through 8 formed the movement awareness and emotion recognition phase, in which students were guided to perceive emotional change through movement and to identify the relationships linking bodily tension, heartbeat, and respiration to emotion. Weeks 9 through 12 formed the self-compassion and emotion regulation phase, centered on reducing self-criticism following movement errors and learning to respond to oneself in a gentle, accepting, and nonjudgmental manner. Weeks 13 through 16 formed the integration and resilience development phase, which used group performance, movement challenges, and moderate stress scenarios to create opportunities for students to practice emotional recovery and positive coping. A detailed week-by-week protocol for each phase appears in Appendix A.

The regular dance training group received a curriculum of equal duration and frequency (16 weeks, twice weekly, 45 min per session), taught by six dance teachers. The curriculum contained the same dance technique content but no mindfulness elements. The 22 minutes devoted to breath awareness, body scanning, self-compassion, and reflection in the mindful dance group were replaced with additional technique practice and movement-combination rehearsal.

3.3 Procedure

Data were collected at four time points. T1 (baseline) was completed within the week before the curriculum began, T2 (mid-curriculum) within the week after week 8, T3 (post-curriculum) within the week after week 16, and T4 (follow-up) in week 8 after the curriculum ended. At each time point, trained research assistants administered the questionnaires collectively by class during regular class time, with each session lasting about 30 minutes. All core variables were measured at all four time points, control variables at T1, and engagement quality was recorded continuously from T1 to T3.

Brief after-class micro-records were collected at the end of each session as an auxiliary source for the mindfulness exercise completion dimension of engagement quality.

Implementation fidelity was assessed by two trained external observers. Prior to the study, both observers completed a six-hour training session in which they reviewed the curriculum protocol and rating criteria, independently scored two video-recorded pilot sessions, and discussed discrepancies until consensus was

reached on the application of each rating level. Each class received one classroom observation in weeks 2, 6, 10, and 16, with each observation covering one complete 45-minute session. Using a structured rating form, the observers scored six dimensions on a 1-to-5 scale: fidelity of mindfulness elements, completion of dance movements, quality of body-awareness guidance, quality of emotional expression tasks, quality of self-compassion practice, and completeness of classroom reflection. The inter-rater reliability of the two observers (ICC) was .84. The mean of each class's four observations served as that class's composite index of implementation fidelity. The rating form appears in Appendix B.

3.4 Measures

Engagement quality was a composite index that integrated information from four dimensions: attendance (teacher attendance records), in-class involvement (teacher session-by-session rating on a 1-to-5 scale), completion of mindfulness exercises (scores on the mindfulness-related items of the after-class micro-records), and completion of after-class reflection (completeness of the reflection record forms). Each dimension was standardized and then averaged into the composite score, which was computed only within the mindful dance training group.

The measurement instruments for the remaining core variables and the control variables are summarized in Table 1. All scales used Chinese-language versions adapted through a translation-back-translation procedure.

Interoceptive awareness was measured with the Chinese version of the Multidimensional Assessment of Interoceptive Awareness, Version 2 (MAIA-2C). The MAIA-2 was revised by Mehling et al. [12] from the original MAIA, and the Chinese version was translated and cross-culturally adapted by Teng et al. [41] following Beaton's translation-back-translation procedure, with the fit of its eight-factor structure and its reliability and validity verified in a sample of 627 Chinese adults. The MAIA-2C measures self-reported interoceptive awareness, that is, an individual's subjective appraisal of their capacity to notice and attend to internal bodily signals; it is conceptually distinct from objective interoceptive accuracy as assessed by behavioral tasks such as heartbeat detection [12]. The original validation sample of the MAIA-2C was an adult population, and the instrument has not yet undergone independent psychometric validation in adolescents; the present study confirmed item comprehensibility and factor structure in an adolescent sample during the pilot phase (n = 86; CFA: CFI = .912, RMSEA = .058, SRMR = .062), indicating an acceptable fit for the eight-factor structure in this age group.

Self-compassion was measured with the Self-Compassion Scale, Youth Version (SCS-Y). The SCS-Y was developed by Neff et al. [42] specifically for early adolescents aged 10 to 15, simplifying item wording and adjusting phrasing from the adult SCS [20] to suit the language comprehension level of adolescents [43]; it contains 17 items and retains the two-factor structure of the six subscales of self-kindness, self-judgment, common humanity, isolation, mindful awareness, and overidentification. The original validation age range of the SCS-Y was 10 to 15, whereas the present sample included some students aged 16 to 17. The Chinese version, adapted through a translation-back-translation procedure, was confirmed for factor structure, reliability, and validity in the pilot sample. In the formal sample, the psychometric properties of the SCS-Y among students aged 16 to 17 (n = 126; Cronbach's α = .88; CFA: CFI = .942, RMSEA = .051) were

comparable to those among students aged 12 to 15 (n = 245; Cronbach's α = .87; CFI = .948, RMSEA = .048), supporting the use of the SCS-Y across the full age range of the present sample.

Emotion regulation was measured with the Emotion Regulation Questionnaire for Children and Adolescents (ERQ-CA). The ERQ-CA was revised by Gullone and Taffe [44] from the adult ERQ [45], with wording adjusted to the language comprehension level of children and adolescents aged 10 to 18 and the response format changed from the 7-point scale of the adult version to a 5-point scale. The Chinese version, adapted through a translation-back-translation procedure, was used. In the mediation models, emotion regulation was operationalized as the cognitive reappraisal subscale score, because cognitive reappraisal is recognized as an adaptive regulation strategy with a more direct theoretical link to self-compassion and psychological resilience in the hypothesized pathways; expressive suppression data were retained for the between-group comparison but were not entered into the mediation models.

Psychological resilience was measured with the 10-item short form of the Connor-Davidson Resilience Scale (CD-RISC-10). Campbell-Sills and Stein [46] condensed and revised the original 25-item version [1] through exploratory and confirmatory factor analysis, arriving at a unidimensional 10-item version. The Chinese version has undergone translation-back-translation and reliability and validity verification in Chinese populations.

Among the control variables, sex (0 = male, 1 = female), age, and BMI were obtained through a demographic survey. Baseline mental health was assessed with the Chinese version of the 12-item General Health Questionnaire (GHQ-12). Sleep quality was assessed with the Chinese version of the Pittsburgh Sleep Quality Index (PSQI). Perceived stress was assessed with the Chinese version of the 10-item Perceived Stress Scale (PSS-10) [47]. Prior dance experience was captured by a single self-report item (whether the student had taken part in a dance class or training more than once per week within the preceding two years). Physical activity level was assessed with the Chinese version of the short form of the International Physical Activity Questionnaire (IPAQ-SF).

Table 1
Summary of Measurement Instruments

Variable	Scale	Developer	Items	Subscales	Response Format	Cronbach's α Range
Interoceptive awareness	MAIA-2C	Mehling et al. [12]; Chinese version Teng et al. [41]	37	Noticing, Not-Distracting, Not-Worrying, Attention Regulation, Emotional Awareness, Self-Regulation, Body Listening, Trusting	6-point, 0–5	.87–.91
Self-compassion	SCS-Y	Neff et al. [42]	17	Self-Kindness, Self-Judgment, Common Humanity, Isolation, Mindful Awareness, Overidentification	5-point, 1–5	.86–.90
Emotion regulation	ERQ-CA	Gullone & Taffe [44]	10	Cognitive Reappraisal (6 items), Expressive Suppression (4 items)	5-point, 1–5	CR .82–.86; ES .73–.78
Psychological resilience	CD-RISC-10	Campbell-Sills & Stein [46]	10	Unidimensional	5-point, 0–4	.88–.91
Baseline mental health	GHQ-12	Goldberg & Williams [48]	12	—	4-point, 0–3	.83
Sleep quality	PSQI	Buysse et al. [49]	7 components	—	0–3	.76
Perceived stress	PSS-10	Cohen et al. [47]	10	Unidimensional	5-point, 0–4	.82
Physical activity level	IPAQ-SF	Craig et al. [50]	7	—	Categorical scoring	—

Note. The Cronbach's α range refers to the reliability coefficients across the four measurement time points; for control variables measured only at T1, a single time-point reliability coefficient is reported. CR = Cognitive Reappraisal subscale; ES = Expressive Suppression subscale.

3.5 Data Analysis

Data analysis was performed in Mplus 8.10 and SPSS 28.0. Prior to analysis, all continuous variables were checked for normality and screened for multivariate outliers, and missing data were handled with full-information maximum likelihood estimation (FIML). Independent-samples t tests and chi-square tests were

conducted to compare the two groups on baseline demographic characteristics and core variable levels and to evaluate baseline equivalence between groups.

Between-group comparisons used repeated-measures analysis of variance to test the group × time interaction effect on each core variable, with effect sizes reported as partial η^2.

The primary mediation analysis used the full sample (N = 647). A longitudinal mediation model was built in Mplus with group assignment (0 = regular dance, 1 = mindful dance) as predictor, T2 interoceptive awareness, T3 self-compassion, and T3 emotion regulation as mediators, and T4 psychological resilience as outcome. Self-compassion and emotion regulation were entered as mediators at the same temporal layer. Eight covariates were controlled (sex, age, BMI, baseline mental health, sleep quality, perceived stress, prior dance experience, and physical activity level), and class was specified as the clustering variable via TYPE = COMPLEX. Multiple indirect pathways were estimated, including pathways through individual mediators, through pairs of mediators, and through all three mediators in sequence. Indirect effects were tested with bias-corrected bootstrap (5,000 resamples).

A supplementary within-group process analysis used the mindful dance training group data (n = 371). A longitudinal mediation model was built with T1 engagement quality as predictor, T2 interoceptive awareness as first mediator, T3 self-compassion and emotion regulation as subsequent mediators, and T4 psychological resilience as outcome. The same covariates and TYPE = COMPLEX specification were applied. Implementation fidelity was entered as a class-level moderator of the engagement quality to interoceptive awareness path.

For the cross-lagged analysis, a bivariate RI-CLPM [51] was built for each adjacent pair of variables, with time-invariance constraints imposed to test the cross-lagged directionality between adjacent variables.

The sensitivity analysis comprised three checks: re-estimating the mediation models after excluding students with attendance below 75%, estimating the model separately by sex, and estimating the model separately by groups split at the median of baseline psychological resilience.

4 Results

4.1 Descriptive Statistics and Preliminary Analyses

The valid sample sizes were 647 (T1), 612 (T2), 589 (T3), and 561 (T4), for a total attrition rate of 13.3%. Attrited and retained students did not differ significantly on any baseline variable (interoceptive awareness, $t(645) = 0.73$, $p = .466$; self-compassion, $t(645) = 0.51$, $p = .610$; cognitive reappraisal, $t(645) = 0.38$, $p = .704$; psychological resilience, $t(645) = 0.84$, $p = .401$; sex, $\chi^2(1) = 0.42$, $p = .517$; age, $t(645) = 1.12$, $p = .263$), nor did the two groups differ at baseline, indicating comparability before the intervention. The means and standard deviations of each core variable across the four time points appear in Table 2.

Table 2
Means and Standard Deviations of Core Variables Across Four Time Points

Variable	Group	T1 M (SD)	T2 M (SD)	T3 M (SD)	T4 M (SD)
Interoceptive awareness	Mindful dance (n = 371)	2.74 (0.68)	3.12 (0.71)	3.33 (0.65)	3.30 (0.67)
	Regular dance (n = 276)	2.71 (0.70)	2.83 (0.69)	2.91 (0.72)	2.88 (0.71)
Self-compassion	Mindful dance	2.89 (0.72)	3.04 (0.69)	3.35 (0.66)	3.31 (0.68)
	Regular dance	2.86 (0.74)	2.93 (0.71)	3.01 (0.73)	2.98 (0.72)
Cognitive reappraisal	Mindful dance	3.42 (0.83)	3.56 (0.80)	3.84 (0.76)	3.79 (0.78)
	Regular dance	3.39 (0.85)	3.47 (0.82)	3.54 (0.84)	3.51 (0.83)
Expressive suppression	Mindful dance	3.11 (0.91)	2.94 (0.88)	2.72 (0.85)	2.76 (0.87)
	Regular dance	3.14 (0.89)	3.08 (0.90)	3.02 (0.88)	3.04 (0.89)
Psychological resilience	Mindful dance	24.63 (6.41)	25.89 (6.18)	28.14 (5.87)	27.86 (5.93)
	Regular dance	24.41 (6.53)	24.97 (6.39)	25.38 (6.44)	25.21 (6.47)

Note. At T3 (post-curriculum), between-group Cohen's d values were: interoceptive awareness d = 0.61, self-compassion d = 0.49, psychological resilience d = 0.45, cognitive reappraisal d = 0.38, expressive suppression d = 0.35.

The mindful dance training group showed sustained increases from T1 to T3 across all core variables, with slight declines at T4 that remained clearly above baseline. The regular dance training group also improved modestly but by a far smaller margin.

Repeated-measures analysis of variance confirmed this contrast, with the group × time interaction reaching significance for every core variable. The interaction was most pronounced for interoceptive awareness ($F(3, 1935) = 14.27$, $p < .001$, partial $\eta^2 = .022$), followed by self-compassion ($F(3, 1935) = 11.83$, $p < .001$, partial $\eta^2 = .018$) and psychological resilience ($F(3, 1935) = 9.72$, $p < .001$, partial $\eta^2 = .015$), with cognitive reappraisal ($F(3, 1935) = 8.46$, $p < .001$, partial $\eta^2 = .013$) and expressive suppression ($F(3, 1935) = 5.91$, $p = .001$, partial $\eta^2 = .009$) showing smaller effect sizes, all in the small-to-moderate range consistent with school-based mindfulness intervention research.

The correlations among core variables and the Cronbach's α coefficients at each time point appear in Table 3. Adjacent variables correlated positively at a moderate level, and the same variable showed high autocorrelation across adjacent time points (e.g., r = .72 between T3 and T4 psychological resilience), consistent with expected variable stability in longitudinal data.

Table 3
Pearson Correlation Matrix and Reliability Coefficients for Core Variables in the Mindful Dance Training Group

1. Engagement quality T1	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**
	—							
2. Interoceptive awareness T1	.18**	(.87)						
3. Interoceptive awareness T2	.31**	.56**	(.89)					
4. Self-compassion T2	.22**	.39**	.44**	(.88)				
5. Self-compassion T3	.24**	.35**	.41**	.61**	(.89)			
6. Emotion regulation T3	.19**	.28**	.33**	.38**	.46**	(.85)		
7. Psychological resilience T3	.16**	.24**	.29**	.31**	.37**	.43**	(.90)	
8. Psychological resilience T4	.17**	.22**	.27**	.29**	.35**	.41**	.72**	(.91)

*Note. **p < .01. Values in parentheses on the diagonal are the Cronbach's α of the variable at the corresponding time point. Emotion regulation is scored on the cognitive reappraisal subscale. N = 371. Engagement quality is a composite index, for which Cronbach's α is not reported.*

As for implementation fidelity, the composite score of the eight mindful dance training classes had a mean of 3.87 (SD = 0.54), with class scores ranging from 3.12 to 4.51.

4.2 Between-Group Mediation Analysis

A longitudinal mediation model was estimated with the full sample (N = 647), using group assignment as predictor, T2 interoceptive awareness, T3 self-compassion, and T3 emotion regulation as mediators, and T4 psychological resilience as outcome. Eight covariates were controlled and class was specified as the clustering variable via TYPE = COMPLEX. The model fit the data adequately ($\chi^2(38) = 71.46$, $p = .001$, $\chi^2/df = 1.88$, CFI = .958, TLI = .939, RMSEA = .047 [90% CI .029, .064], SRMR = .038). The standardized path coefficients appear in Fig. 1, and detailed results appear in Tables 4 and 5.

Group assignment positively predicted T2 interoceptive awareness (β = .34, p < .001), supporting H1. T2 interoceptive awareness positively predicted T3 self-compassion (β = .22, p < .001), supporting H2. T3 self-compassion positively predicted T3 emotion regulation (β = .29, p < .001), supporting H3. T3 emotion regulation positively predicted T4 psychological resilience (β = .25, p < .001), and T3 self-compassion also directly predicted T4 psychological resilience (β = .17, p = .002), bypassing emotion regulation. These two paths were jointly consistent with H4. T2 interoceptive awareness directly predicted T3 emotion regulation (β = .14, p = .004), and group assignment directly predicted T3 self-compassion (β = .12, p = .021). The remaining cross-segment paths were nonsignificant (group → T3 emotion regulation, β = .05, p = .362; T2

interoceptive awareness → T4 psychological resilience, β = .06, p = .214). The direct effect of group assignment on T4 psychological resilience was nonsignificant (β = .08, p = .118), indicating that the between-group difference in psychological resilience was conveyed primarily through the mediating pathways.

Table 4
Path Coefficients of the Between-Group Mediation Model

Path	β	SE	p	95% CI
Group → Interoceptive awareness T2	.34	.05	< .001	[.24, .44]
Interoceptive awareness T2 → Self-compassion T3	.22	.05	< .001	[.12, .32]
Self-compassion T3 → Emotion regulation T3	.29	.05	< .001	[.19, .39]
Emotion regulation T3 → Psychological resilience T4	.25	.06	< .001	[.14, .36]
Self-compassion T3 → Psychological resilience T4	.17	.05	.002	[.07, .27]
Group → Self-compassion T3	.12	.05	.021	[.02, .22]
Interoceptive awareness T2 → Emotion regulation T3	.14	.05	.004	[.05, .23]
Group → Emotion regulation T3	.05	.05	.362	[− .05, .15]
Interoceptive awareness T2 → Psychological resilience T4	.06	.05	.214	[− .04, .16]
Group → Psychological resilience T4 (direct)	.08	.05	.118	[− .02, .18]

Note. β denotes the standardized coefficient. Group was coded 0 = regular dance, 1 = mindful dance. Eight covariates (sex, age, BMI, baseline mental health, sleep quality, perceived stress, prior dance experience, and physical activity level) were controlled. Class was specified as the clustering variable via TYPE = COMPLEX.

Seven specific indirect pathways were tested (Table 5). Five reached significance. The single-mediator pathway through self-compassion yielded the largest point estimate (.0204), followed by the two-mediator pathways through interoceptive awareness and self-compassion (.0127), through interoceptive awareness and emotion regulation (.0119), and through self-compassion and emotion regulation (.0087), and the full serial pathway (.0054). Two single-mediator pathways were nonsignificant, through interoceptive awareness alone (.0204, 95% CI [− .0027, .0447]) and through emotion regulation alone (.0125, 95% CI [− .0053, .0312]). Self-compassion appeared in all five significant pathways and also directly predicted psychological resilience (β = .17, p = .002), consistent with H4. The total indirect effect was .0920 (95% CI [.0575, .1302]) and the total effect was .1720 (95% CI [.1102, .2338]). The proportion of the total effect mediated was 53.5%. Because the direct effect did not reach significance, this ratio should be interpreted with caution. The relative contribution of each significant pathway to the total indirect effect was as follows. Self-compassion alone accounted for 22.2%, interoceptive awareness and self-compassion for 13.8%, interoceptive awareness and emotion regulation for 12.9%, self-compassion and emotion regulation for 9.5%, and the full serial pathway for 5.9%.

Table 5
Indirect Effects of the Between-Group Mediation Model

Indirect pathway	Effect	SE	95% CI
Full serial (Group → IA → SC → ER → Res)	.0054	.0019	[.0021, .0096]
Group → IA → SC → Res	.0127	.0042	[.0052, .0219]
Group → IA → ER → Res	.0119	.0041	[.0046, .0209]
Group → SC → ER → Res	.0087	.0038	[.0018, .0172]
Group → SC → Res	.0204	.0076	[.0063, .0367]
Group → IA → Res	.0204	.0118	[− .0027, .0447]
Group → ER → Res	.0125	.0091	[− .0053, .0312]
Total indirect effect	.0920	.0183	[.0575, .1302]

Note. IA = interoceptive awareness; SC = self-compassion; ER = emotion regulation; Res = psychological resilience. Indirect effects were tested with bias-corrected bootstrap (5,000 resamples). A 95% CI excluding zero indicates significance.

4.3 Within-Group Process Analysis

A supplementary mediation analysis was estimated with the data of the 371 students in the mindful dance training group to examine how variation in engagement quality related to the same pathway variables. The model used TYPE = COMPLEX to correct for class clustering and FIML to handle missing data. The model fit the data well ($\chi^2(33) = 55.83$, $p = .008$, $\chi^2/df = 1.69$, CFI = .966, TLI = .947, RMSEA = .043 [90% CI .022, .062], SRMR = .035). The standardized path coefficients appear in Fig. 2, and detailed results appear in Tables 6 and 7.

The coefficients of the four sequential segments all aligned in direction with the between-group findings. Engagement quality positively predicted T2 interoceptive awareness ($\beta = .27$, $p < .001$), T2 interoceptive awareness positively predicted T3 self-compassion ($\beta = .24$, $p < .001$), T3 self-compassion positively predicted T3 emotion regulation ($\beta = .31$, $p < .001$), and T3 emotion regulation positively predicted T4 psychological resilience ($\beta = .28$, $p < .001$). The model also estimated cross-segment paths. Two were significant: engagement quality → T3 self-compassion ($\beta = .11$, $p = .031$) and T2 interoceptive awareness → T3 emotion regulation ($\beta = .13$, $p = .006$). T3 self-compassion also directly predicted T4 psychological resilience ($\beta = .15$, $p = .004$), bypassing emotion regulation. The remaining cross-segment paths were nonsignificant (engagement quality → T3 emotion regulation: $\beta = .04$, $p = .438$; T2 interoceptive awareness → T4 psychological resilience: $\beta = .07$, $p = .173$). The direct effect of engagement quality on T4 psychological resilience was nonsignificant ($\beta = .06$, $p = .224$), indicating that the association between engagement quality and psychological resilience was conveyed mainly through the mediating pathways.

Table 6
Path Coefficients of the Within-Group Mediation Model

Path	β	SE	p	95% CI
Engagement quality → Interoceptive awareness T2	.27	.05	< .001	[.17, .37]
Interoceptive awareness T2 → Self-compassion T3	.24	.06	< .001	[.13, .35]
Self-compassion T3 → Emotion regulation T3	.31	.05	< .001	[.21, .41]
Emotion regulation T3 → Psychological resilience T4	.28	.06	< .001	[.17, .39]
Self-compassion T3 → Psychological resilience T4	.15	.05	.004	[.05, .25]
Engagement quality → Self-compassion T3	.11	.05	.031	[.01, .21]
Engagement quality → Emotion regulation T3	.04	.05	.438	[− .06, .14]
Interoceptive awareness T2 → Emotion regulation T3	.13	.05	.006	[.04, .22]
Interoceptive awareness T2 → Psychological resilience T4	.07	.05	.173	[− .03, .17]
Engagement quality → Psychological resilience T4 (direct)	.06	.05	.224	[− .04, .16]
Fidelity × Engagement quality → Interoceptive awareness T2	.14	.06	.018	[.02, .26]

Note. β denotes the standardized coefficient. EQ = engagement quality. Eight covariates were controlled. Class was specified as the clustering variable via TYPE = COMPLEX. The fidelity interaction term tests RQ1.

Seven specific indirect pathways were tested (Table 7). Five reached significance, paralleling the between-group results. The single-mediator pathway through self-compassion yielded the largest point estimate (.0165), followed by the two-mediator pathways through interoceptive awareness and emotion regulation (.0098), through interoceptive awareness and self-compassion (.0097), and through self-compassion and emotion regulation (.0095), and the full serial pathway (.0056). Two single-mediator pathways were nonsignificant, through interoceptive awareness alone (.0189, 95% CI [− .0024, .0418]) and through emotion regulation alone (.0112, 95% CI [− .0048, .0283]). As in the between-group analysis, self-compassion appeared in all five significant pathways. The total indirect effect was .0812 (95% CI [.0498, .1167]) and the total effect was .1412 (95% CI [.0893, .1931]). The proportion of the total effect mediated was 57.5%. Because the direct effect did not reach significance, this ratio should be interpreted with caution. The relative contribution of each significant pathway to the total indirect effect was as follows. Self-compassion alone accounted for 20.3%, interoceptive awareness and emotion regulation for 12.1%, interoceptive awareness and self-compassion for 11.9%, self-compassion and emotion regulation for 11.7%, and the full serial pathway for 6.9%.

Table 7
Indirect Effects of the Within-Group Mediation Model

Indirect pathway	Effect	SE	95% CI
Full serial (EQ → IA → SC → ER → Res)	.0056	.0019	[.0022, .0098]
EQ → IA → SC → Res	.0097	.0034	[.0038, .0174]
EQ → IA → ER → Res	.0098	.0036	[.0036, .0179]
EQ → SC → ER → Res	.0095	.0041	[.0018, .0193]
EQ → SC → Res	.0165	.0072	[.0031, .0328]
EQ → IA → Res	.0189	.0109	[− .0024, .0418]
EQ → ER → Res	.0112	.0082	[− .0048, .0283]
Total indirect effect	.0812	.0168	[.0498, .1167]

Note. EQ = engagement quality; IA = interoceptive awareness; SC = self-compassion; ER = emotion regulation; Res = psychological resilience. Indirect effects were tested with bias-corrected bootstrap (5,000 resamples). A 95% CI excluding zero indicates significance.

Regarding RQ1, the moderating effect of implementation fidelity on the engagement quality → interoceptive awareness path was significant (β = .14, p = .018). Simple slope analysis showed that under high implementation fidelity (+ 1 SD), the predictive effect of engagement quality on interoceptive awareness was β = .35 (p < .001), whereas under low implementation fidelity (− 1 SD) this effect dropped to β = .18 (p = .003) (Fig. 3).

This moderating effect carried through to the full serial pathway. The indirect effect of the full serial pathway was .0073 (95% CI [.0030, .0136]) under high implementation fidelity and .0038 (95% CI [.0012, .0077]) under low implementation fidelity, a difference of .0035 (95% CI [.0006, .0081]) whose confidence interval excluded zero. Given that this moderation analysis involved a class-level variable with only eight clusters, the TYPE = COMPLEX correction may underestimate standard errors [52], and these results should be regarded as exploratory.

4.4 Cross-Lagged and Sensitivity Analyses

A bivariate RI-CLPM was built separately for each of the three adjacent pairs of variables in the pathway model, using the data from T2 to T4 and imposing time-invariance constraints, with results summarized in Table 8.

Table 8
Cross-Lagged Effects of the Bivariate RI-CLPM

Variable Pair	Forward Effect β (p)	Reverse Effect β (p)	CFI	RMSEA
Interoceptive awareness → Self-compassion	.16 (.001)	.07 (.162)	.986	.045
Self-compassion → Emotion regulation	.19 (< .001)	.08 (.109)	.983	.049
Emotion regulation → Psychological resilience	.18 (.003)	.10 (.047)	.980	.053

Note. The forward effect denotes the hypothesized direction of the pathway model. Time-invariance constraints were imposed on all models.

The forward cross-lagged effects of all three variable pairs were significant, consistent with the mediation models reported in Sections 4.2 and 4.3. The reverse paths for interoceptive awareness → self-compassion and self-compassion → emotion regulation were both nonsignificant, supporting unidirectional relationships. The self-compassion → emotion regulation result is particularly relevant because both variables were measured at T3, so the directional relationship between them could not be established from temporal precedence within the mediation models; the RI-CLPM provides wave-to-wave evidence supporting the hypothesized direction. The reverse path for emotion regulation → psychological resilience reached significance at the threshold (β = .10, p = .047), but the forward effect (β = .18) clearly predominated. Overall, the RI-CLPM lent supplementary support to the hypothesized directionality.

The sensitivity checks examined the robustness of the within-group results from three angles. After excluding the 47 students with attendance below 75% (remaining n = 324), the direction and significance of each path coefficient matched the full sample, and the full serial indirect effect was .0063 (95% CI [.0026, .0116]), with path coefficients growing slightly as expected.

After splitting by sex within the mindful dance training group, the full serial indirect effect was .0061 (95% CI [.0021, .0118]) for the female subgroup (n = 213) and .0046 (95% CI [.0010, .0102]) for the male subgroup (n = 158), both significant and consistent in the direction of each segment. The indirect effect was slightly larger for the female subgroup, but the difference did not reach statistical significance (Δ = .0015, 95% CI [− .0029, .0062]), so the mediation pathway showed no significant sex difference.

After splitting at the median of baseline psychological resilience (Mdn = 24), the indirect effect was .0070 (95% CI [.0028, .0131]) for the low-resilience group (n = 186) and .0039 (95% CI [.0009, .0089]) for the high-resilience group (n = 185), a difference that reached marginal significance (Δ = .0031, 95% CI [.0001, .0074]). The mediation effect was thus more pronounced among adolescents with lower baseline resilience.

5 Discussion

5.1 The Embodied Pathway and the Role of Self-Compassion

The between-group mediation analysis revealed that the difference in psychological resilience between the mindful dance and regular dance groups was conveyed primarily through the mediating pathways, with the direct effect of group assignment nonsignificant (β = .08, p = .118). Among the seven specific indirect pathways tested, five reached significance, and self-compassion appeared in all five. The single-mediator pathway through self-compassion yielded the largest point estimate (.0204), accounting for 22.2% of the total indirect effect, while the full serial pathway through all three mediators contributed the smallest share (5.9%). Self-compassion also directly predicted psychological resilience (β = .17, p = .002), bypassing emotion regulation. The two single-mediator pathways that did not involve self-compassion, through interoceptive awareness alone and through emotion regulation alone, were both nonsignificant. These results indicate that self-compassion occupies a central position within the pathway model, functioning both as a transmitting link and as an independent contributor to resilience. The within-group process analysis produced a convergent pattern, with self-compassion appearing in all five significant pathways and yielding the largest single-mediator point estimate (.0165).

This finding reframes the role of interoceptive awareness in the pathway model. Interoceptive awareness served as the temporal starting point of the pathway, and group assignment was its strongest predictor (β = .34, p < .001), confirming that the mindfulness component of the curriculum drove gains in body awareness beyond what dance alone produced. However, the independent indirect effect of interoceptive awareness was nonsignificant in both the between-group and within-group analyses, indicating that its contribution to resilience was fully transmitted through subsequent variables. This result extends pathway research on mindfulness intervention from the level of cognitive processing to the level of embodied perception. Prior longitudinal work has attended chiefly to the indirect route by which mindfulness reduces adolescent depressive symptoms through stress appraisal and cognitive reactivity [53], whereas the present result suggests that awareness of internal bodily signals can serve equally well as a starting point from which mindfulness training sets psychological change in motion. By placing interoceptive awareness at the origin of the pathway model [34], the present study offers a complementary embodied account.

The segment where the innovation of the pathway model concentrates most is interoceptive awareness → self-compassion. This segment has lacked direct longitudinal evidence, and the present study supplies preliminary temporal support, with the RI-CLPM likewise showing a significant forward effect and a nonsignificant reverse path. A plausible explanation is that as individuals learn to perceive bodily signals with an open and accepting attitude, that nonevaluative mode of self-attention gradually transfers to how they respond to their own emotional states and behavioral performance. The curriculum's "accepting movement errors" segment furnishes a concrete setting for this transfer, in which students who notice bodily tension or incoordination are guided to respond gently rather than to judge themselves.

Self-compassion's central role echoes longitudinal findings that self-compassion indirectly lowers psychological distress by strengthening resilience [23] and predicts gratitude and prosocial behavior among Chinese adolescents [33]. The present results add that the self-accepting attitude cultivated

through interoceptive awareness may contribute to adaptive recovery without requiring the prior development of emotion regulation capacity.

In the within-group analysis, engagement quality also directly predicted self-compassion (β = .11, p = .031), suggesting that mindful dance training may foster self-compassion independently of interoceptive awareness. The curriculum's exercises in accepting movement errors and using gentle self-directed language offer a plausible route through direct behavioral rehearsal. This finding does not weaken the mediation pathways but indicates that the overall pattern is multipath. Similarly, interoceptive awareness directly predicted emotion regulation (β = .13, p = .006 in the within-group analysis; β = .14, p = .004 in the between-group analysis), consistent with integrative reviews proposing that mind-body interventions influence emotion regulation through both top-down and bottom-up interoceptive routes [16], and suggesting that heightened body awareness can support the deployment of adaptive regulation strategies without necessarily requiring the prior development of self-compassion.

The two-group contrast illuminates the distinctive contribution of the mindfulness component. The regular dance training group also improved modestly on each core variable [54, 55], but bodily experience alone was not enough to activate the complete pathway. The mindfulness component supplies the structure and guidance that turn bodily experience into systematic awareness, leading students not merely to perform movements but to notice what happens inside the body while performing them. That a significant difference emerged against an active control is notable, given that school-based mindfulness interventions often show nonsignificant effects against active controls [56], and that mindfulness in nonclinical adolescent samples has at times struggled to produce significant effects [57]. This suggests that embedding mindfulness within physical activity may hold an advantage over standalone meditation, partly because dance offers a more engaging vehicle that helps sustain adolescents' motivation [58].

The reverse path for emotion regulation → psychological resilience reached significance at the threshold (β = .10, p = .047), suggesting a degree of bidirectionality consistent with the finding that baseline resilience predicts subsequent adaptive emotion regulation [26]. This bidirectional relationship does not weaken the directional judgment of the pathway model, since the forward effect (β = .18) clearly predominated.

5.2 The Role of Implementation Fidelity

In the within-group analysis, the moderating effect of implementation fidelity on the engagement quality → interoceptive awareness path was significant, with the effect size nearly doubling under high versus low fidelity and carrying through to the full serial indirect effect. Students who engage equally thus obtain substantively different gains in interoceptive awareness depending on their class's implementation fidelity. Mindful dance training differs from the more highly standardized computerized interventions in that its effect depends heavily on the quality with which teachers guide the mindfulness elements in class. When cues for breath awareness, the leading of body scanning, and the modeling of a nonjudgmental attitude are simplified or omitted, students find it hard to develop interoceptive awareness fully from their participation, even with high attendance and strong in-class involvement.

That the moderating effect operates on the first segment of the within-group pathway rather than on the later segments carries a substantive implication. Implementation fidelity may influence the initial link at which engagement is translated into interoceptive awareness. Once interoceptive awareness has been successfully raised, the subsequent transmission from awareness to self-compassion, from self-compassion to emotion regulation, and from emotion regulation to psychological resilience depends more on students' internal psychological development, where the direct role of external input at the teacher's end is comparatively limited. These exploratory results tentatively suggest that quality control efforts in school-based mindfulness interventions might prioritize teachers' capacity to guide the mindful awareness elements [36]. Because this moderation was estimated with only eight class-level units, however, these findings require replication in a larger sample before firm practical recommendations can be drawn.

5.3 Practical Implications

The mediation analyses offer concrete reference for the design logic of school mental health curricula. That interoceptive awareness stands as the temporal starting point of the pathway model means the design priority should rest on cultivating body-awareness capacity. Many existing school mental health curricula teach emotion recognition and emotion regulation strategies directly, but if students lack a basic capacity to perceive their own bodily signals, the learning and application of these strategies want a perceptual foundation. The curriculum structure of mindful dance training places the body-awareness establishment phase at the very front, laying an awareness foundation for the later training in emotion recognition, self-compassion, and emotion regulation, and this progressively staged design logic can serve as a reference for the development of other school mental health curricula.

At the same time, the finding that self-compassion was the strongest mediator in both the between-group and within-group analyses suggests that the self-compassion training elements of the curriculum, including accepting movement errors, reducing self-criticism, and using gentle self-directed language, deserve at least equal attention in curriculum design and teacher preparation.

For teacher training, the exploratory moderating results suggest that guidance of breath awareness, body scanning, and nonjudgmental awareness should figure as core content alongside dance pedagogy. The between-class variation in implementation fidelity despite uniform initial training (three days, 24 hours) suggests that ongoing instructional supervision and peer observation may be necessary to narrow delivery differences in future dissemination. These recommendations regarding implementation fidelity are provisional given the limited number of class-level units and await confirmation in larger-scale studies.

The stratified results show that the mediation effect was more pronounced in the low-resilience group. Where school resources are limited, intervention resources may be allocated first to students with lower baseline resilience, screened with tools such as the CD-RISC-10 before the intervention.

5.4 Limitations and Future Directions

Several limitations attend this study. As regards the timing of measurement, self-compassion and emotion regulation were both measured at T3, so the directional relationship between them cannot be established from temporal precedence within the mediation models. Two considerations support the hypothesized

direction. The curriculum placed self-compassion practice (weeks 9–12) before the integration phase requiring emotion regulation under stress (weeks 13–16), and the RI-CLPM showed a significant forward effect with a nonsignificant reverse path. It should be noted, however, that the RI-CLPM tests wave-to-wave temporal precedence, which does not map directly onto the within-wave relationship in the mediation models. The concurrent measurement at T3 cannot statistically rule out reverse causation, and future research could separate the two by measuring self-compassion in week 12 and emotion regulation in week 14.

As regards research design, this study used a quasi-experimental design that assigned experimental conditions by class, and it cannot fully rule out systematic between-class differences on unmeasured variables. The baseline equivalence test of the two groups and the directional corroboration from the RI-CLPM ease this concern to some degree, yet the possibility of selection bias cannot be eliminated entirely. Future research could adopt a stricter randomized allocation where conditions permit. The 14 classes were nested within only four schools, which precluded the estimation of school-level random effects. The TYPE = COMPLEX correction for class-level clustering and the confirmation of baseline equivalence across schools partially address this limitation. The within-group process analysis, which used engagement quality as a non-randomized predictor, was accordingly positioned as supplementary, and the implementation fidelity moderation, estimated with only eight clusters, should be regarded as exploratory pending replication. The intervention also combined multiple active components, and the current design cannot attribute any specific pathway to any specific component; dismantling or factorial designs would be needed to address this limitation.

As regards measurement instruments, the original validation sample of the Chinese MAIA-2 was an adult population, and the instrument has not yet undergone independent psychometric validation in adolescents. This study confirmed item comprehensibility and factor structure during the pilot phase, but the development and validation of a formal adolescent version of the MAIA-2 remains work to be carried forward. The original validation age range of the SCS-Y was 10 to 15, and students aged 16 to 17 in the present sample fell outside that range. When future research includes an adolescent sample spanning a wider age range, it could administer the SCS-Y and the adult SCS together to compare the measurement equivalence of the two versions across age groups.

All core variables were measured by self-report questionnaire, an approach that calls for particular caution in the measurement of interoceptive awareness. Self-reported interoceptive awareness reflects an individual’s subjective appraisal of their own body-awareness capacity and is conceptually distinct from objective interoceptive accuracy as assessed by behavioral tasks such as heartbeat detection; the correspondence between the two is inconsistent in the literature [12]. The mediation pathways reported in this study pertain to self-reported interoceptive awareness and may not generalize to objective measures of interoceptive processing. Future research could add physiological indicators such as heart rate variability alongside self-report measurement to verify the influence of mindful dance training on interoceptive processing at an objective level, forming a multisource validation that joins subjective report with objective physiological data.

The participants of this study came from four public secondary schools in urban China, and the homogeneity of the sample in geographic and cultural background limits the generalizability of the results. The conceptual content of mindfulness and self-compassion may be moderated by cultural factors [21], and whether the pathways of mindful dance training hold consistent across different cultural backgrounds calls for future cross-cultural research to examine.

6 Conclusion

Through a two-level longitudinal mediation analysis, this study tested the embodied pathways by which mindful dance training fosters adolescent psychological resilience. The between-group comparison showed that the mindful dance group outperformed the regular dance group on psychological resilience primarily through indirect pathways, and the within-group process analysis produced a convergent pattern. The results indicate that awareness of internal bodily signals can serve as the temporal starting point of a pathway running from body to psychological adaptation, forming a longitudinal association with the development of psychological resilience by way of transmission through self-compassion and emotion regulation. Self-compassion emerged as the most central variable in the pathway model, contributing to resilience both through emotion regulation and independently of it. This finding offers an empirical answer to the question of how the body takes part in the construction of psychological resilience, and it opens a direction in which pathway research on mindfulness intervention can extend from a cognitive route toward an embodied one. The exploratory moderating role of implementation fidelity at the initial link of the within-group pathway suggests that the effect of embodied mindfulness intervention may rest not only on students' engagement but also on whether teachers can effectively activate the process of body awareness in class.

Seen from a broader vantage point, the results suggest that the cultivation of adolescent psychological resilience need not begin with the teaching of cognitive strategies, for the body itself can become a resource and an entry point for psychological development. As adolescents learn to perceive their own breathing, sense muscular tension, and notice changes in heartbeat, these seemingly slight awarenesses at the bodily level may set in motion a series of inward psychological shifts, from acceptance of one's own experience, to flexible regulation of emotional responses, to adaptive recovery in the face of adversity. This embodied perspective holds substantive value for the curriculum design of school mental health intervention, and it leaves room for future work to test and extend these pathways across more varied cultural backgrounds and educational settings.

Declarations

Author Contributions

FZ: Conceptualization, Methodology, Investigation, Data Collection, Formal Analysis, Visualization, Writing – Original Draft Preparation, and Project Administration.

JL: Conceptualization, Methodology, Supervision, Validation, Statistical Analysis Guidance, Writing – Review & Editing, and Correspondence.

YG: Literature Review, Data Curation, Resources, Validation, Writing – Review & Editing, and Manuscript Revision.

All authors contributed to the interpretation of the findings, critically reviewed the manuscript, and approved the final version of the manuscript.

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Institutional Review Board Statement

The study was conducted in accordance with the Declaration of Helsinki and approved by the Research Ethics Committee for the Humanities and Social Sciences of Dankook University (Approval No. DKU 2026-01-013).

Informed Consent Statement

Written informed consent was obtained from the legal guardians of all participants prior to their participation in the study. Written informed assent was also obtained from all adolescent participants.

Data Availability Statement

The data supporting the findings of this study are available within the article and its Supplementary Materials. Additional data are available from the corresponding author upon reasonable request.

Conflicts of Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Consent for Publication

All authors have reviewed and approved the final manuscript and consent to its publication.

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Figures

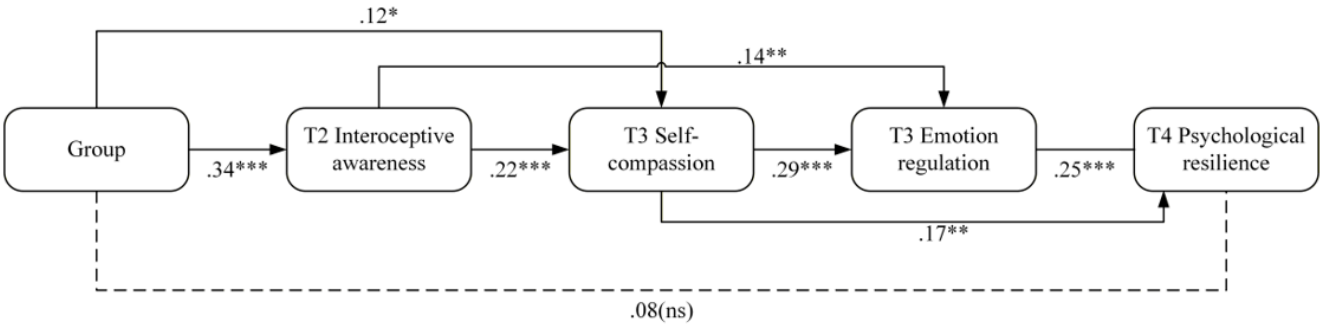


Figure 1

Path Diagram of the Between-Group Longitudinal Mediation Model

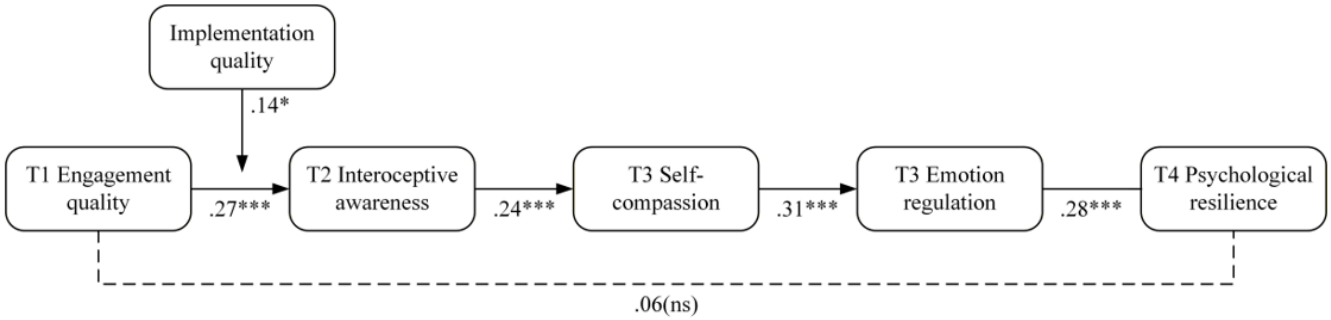


Figure 2

Path Diagram of the Within-Group Longitudinal Mediation Model

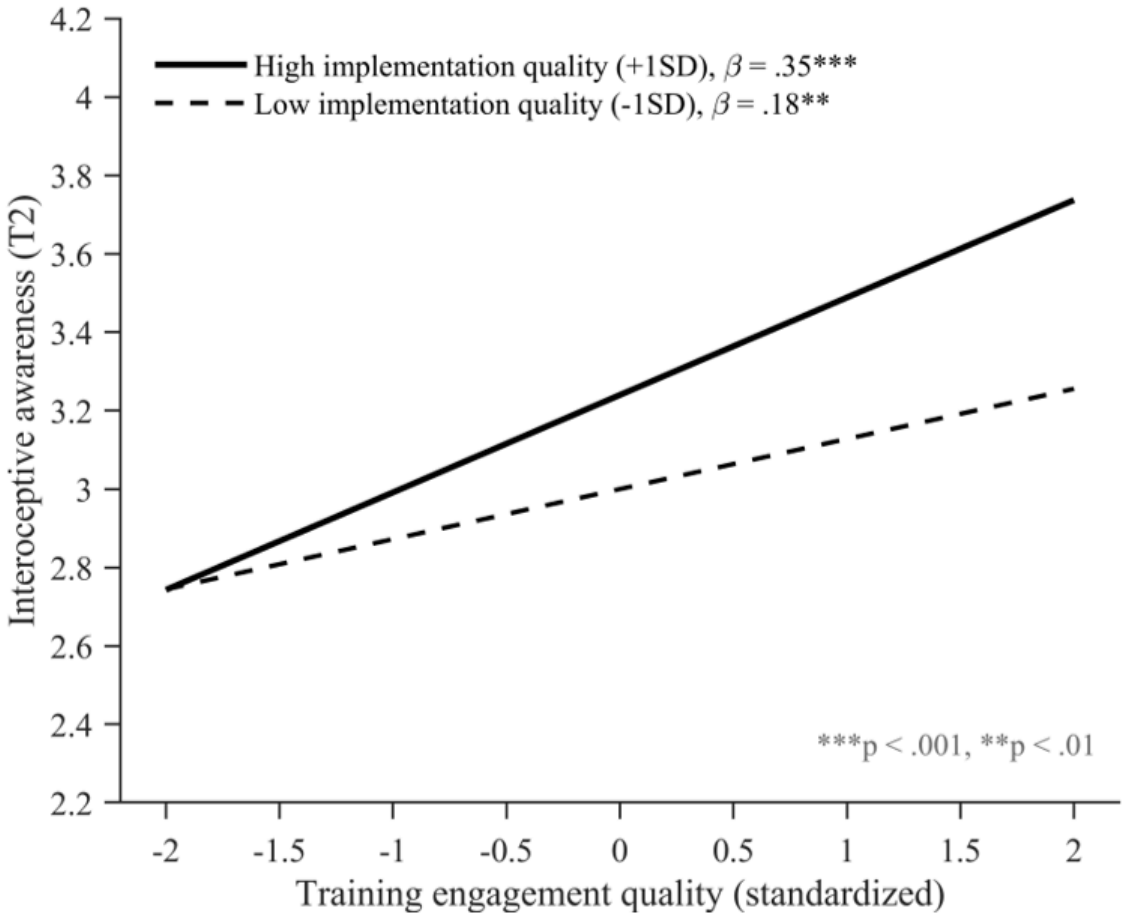


Figure 3

Moderating Effect of Implementation Fidelity on the Engagement Quality → Interoceptive Awareness Path

Supplementary Files

This is a list of supplementary files associated with this preprint. Click to download.

- Appendix1.docx
- mindfulnessdata.csv