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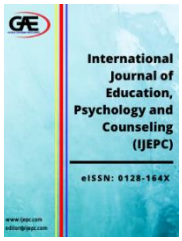

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EXPLORING EMOTION REGULATION: INTERVENTIONS, NEUROBIOLOGICAL MECHANISMS, AND DEVELOPMENTAL IMPACTS ACROSS CHILDREN WITH NEURODEVELOPMENTAL CONDITIONS: A SYSTEMATIC REVIEW

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Abstract:

This systematic literature review explores the role of emotional regulation (ER) across diverse populations, focusing on interventions, neurobiological mechanisms, and developmental impacts. The primary objective is to synthesize current research on how ER influences mental health and well-being across different age groups and conditions, with a particular emphasis on interventions targeting ER. The review uses advanced search techniques in Scopus and PubMed databases to identify relevant studies, resulting in 34 primary sources published between 2024. Following the PRISMA framework, the review categorizes the findings into four main themes: (1) Neurobiological and Cognitive Mechanisms Underlying Emotion Regulation (2) Adaptiveness and Variability in Emotion Regulation. (3) Interventions for Enhancing Emotion Regulation, (4) Developmental and Social Contexts of Emotion Regulation. The analysis highlights that ER plays a critical role in emotional and behavioral regulation, and interventions such as cognitive-behavioral therapy, mindfulness, and life skills training have shown positive outcomes in enhancing ER abilities. Moreover, neurobiological factors such as brain regions involved in ER are identified as key areas for future research. The review concludes that promoting ER through targeted interventions can significantly improve mental health outcomes, especially in populations with neurodevelopmental and mental health challenges.

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Keywords:

Autism, Behaviour, Co-Regulation, Development, Emotion Regulation, Early Intervention

Introduction

Parenting children with neurodevelopmental conditions (NDCs) like autism spectrum disorder (ASD), ADHD, and intellectual disabilities presents unique challenges (Khanna et al., 2023; Zanon et al., 2019). Emotional co-regulation, where parents and children mutually influence emotional states to foster self-regulation, is a vital yet underexplored aspect of parenting (Lavelli et al., 2019; Meier et al., 2023). This process plays a crucial role in socio-emotional development, resilience, and mental health, particularly for children with NDCs prone to emotional dysregulation (Paulus et al., 2021; Salazar de Pablo et al., 2023). Effective co-regulation is linked to improved emotional competence, adaptive functioning, and reduced behavioral challenges (Braund et al., 2021; Mänty et al., 2022). However, research often focuses on typically developing children, overlooking co-regulation dynamics in NDC-affected families (Gärtner et al., 2018). Challenges include fragmented research on parental strategies, socio-cultural neglect, limited longitudinal studies, and insufficient exploration of bidirectional influences. This article synthesizes existing evidence, identifies research gaps, and offers actionable recommendations for practitioners and policymakers to inform effective interventions for families navigating the complexities of NDCs.

Literature Review

Parental emotional co-regulation is essential for the development of children with neurodevelopmental conditions (NDCs) such as autism spectrum disorder (ASD) and related disabilities. These practices, where parents actively support their children in managing emotions, are particularly vital given the emotional regulation challenges faced by children with ASD. Emotional co-regulation profoundly influences developmental trajectories, helping mitigate social and behavioral issues, while psychological theories emphasize the importance of nurturing caregiving environments for emotional and cognitive growth (Ferrara et al., 2023; Provenzi et al., 2020). Parents often face stress, depression, and anxiety, which can impair effective co-regulation (Avdiu & Duraku, 2024). Interventions like video-feedback interventions (VFI) and cognitive-behavioral therapy (CBT) enhance emotional regulation and parent-child interactions (Provenzi et al., 2020; Weiss et al., 2018). Peer support and psychoeducational programs bolster parental self-efficacy, while promoting self-compassion improves adaptive functioning and co-regulation outcomes (Postma et al., 2024; Albon et al., 2024; Avdiu & Duraku, 2024). Despite advancements, research gaps persist in optimizing strategies for diverse conditions and evaluating long-term intervention outcomes, underscoring the need for continued investigation (Finlayson et al., 2020).

Research Question

A well-defined research question ensures clarity, data organization, and alignment with objectives. The PICo framework (Population, Interest, Context) by Lockwood et al. (2015) guided question development.

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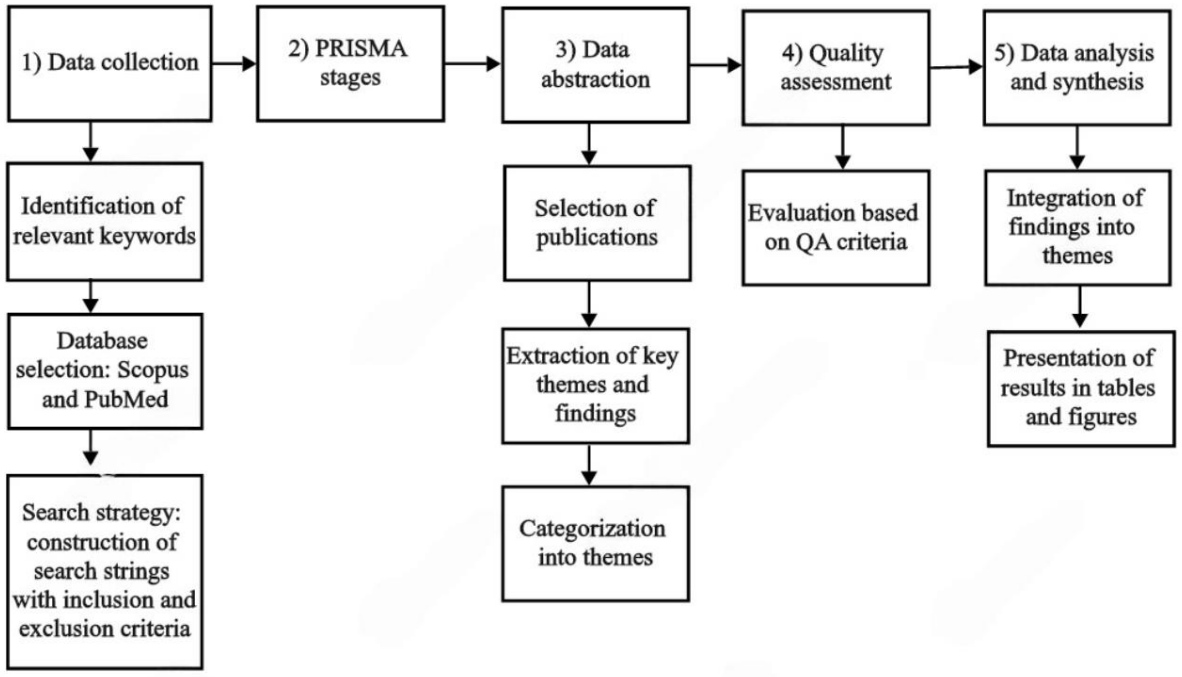
1. What neurobiological and cognitive mechanisms support emotion regulation in children with neurodevelopmental conditions?
2. What are the patterns of adaptiveness and variability in emotion regulation strategies among children with neurodevelopmental conditions?
3. How effective are interventions like cognitive-behavioral therapy or mindfulness in improving emotion regulation in children with neurodevelopmental conditions?
4. How do family, school, and social environments influence emotion regulation in children with neurodevelopmental conditions?

Methods

The PRISMA framework (Page et al., 2021) outlines four systematic review stages: identification, screening, eligibility, and data extraction. This structured process ensures reliable study selection and enhances evidence-based research and practical applications through rigorous evaluation and synthesis of relevant data.

Methodology Flow Chart



Identification

This study used a systematic approach to compile a comprehensive literature collection. Keywords were carefully selected, and related terms were identified using dictionaries, thesauri, encyclopedias, and prior research to expand the search scope. Search strings were constructed for Scopus and PubMed, chosen for their extensive scholarly repositories (see Table 1). This process yielded an initial pool of 6,885 publications covering diverse studies relevant to the research focus, providing a robust foundation for the systematic review.

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Table 1

Scopus	TITLE-ABS-KEY ("EMOTIONAL REGULATION" OR "EMOTIONAL CO*REGULATION") AND ("EARLY INTERVENTION" OR THERAPY) AND (LIMIT-TO (PUBYEAR , 2024)) AND (LIMIT-TO (SUBJAREA , "PSYC") OR LIMIT-TO (SUBJAREA , "MEDI") OR LIMIT-TO (SUBJAREA , "SOCI") OR LIMIT-TO (SUBJAREA , "NEUR")) AND (LIMIT-TO (DOCTYPE , "AR")) AND (LIMIT-TO (LANGUAGE , "ENGLISH")) AND (LIMIT-TO (AFFILCOUNTRY , "MALAYSIA") OR LIMIT-TO (AFFILCOUNTRY , "CHINA") OR LIMIT-TO (AFFILCOUNTRY , "TAIWAN") OR LIMIT-TO (AFFILCOUNTRY , "HONG KONG") OR LIMIT-TO (AFFILCOUNTRY , "JAPAN") OR LIMIT-TO (AFFILCOUNTRY , "SOUTH KOREA") OR LIMIT-TO (AFFILCOUNTRY , "INDIA") OR LIMIT-TO (AFFILCOUNTRY , "SINGAPORE") OR LIMIT-TO (AFFILCOUNTRY , "THAILAND") OR LIMIT-TO (AFFILCOUNTRY , "SRI LANKA") OR LIMIT-TO (AFFILCOUNTRY , "PHILIPPINES") OR LIMIT-TO (AFFILCOUNTRY , "INDONESIA") OR LIMIT-TO (AFFILCOUNTRY , "PAKISTAN")) AND (LIMIT-TO (SRCTYPE , "J")) AND (LIMIT-TO (PUBSTAGE , "FINAL") **DATE OF ACCESS: DECEMBER 2024**
PubMed	("EMOTIONAL REGULATION"[ALL FIELDS] OR "EMOTIONAL CO*REGULATION"[ALL FIELDS]) AND ("EARLY INTERVENTION"[ALL FIELDS] OR ("THERAPEUTICS"[MESH TERMS] OR "THERAPEUTICS"[ALL FIELDS] OR "THERAPIES"[ALL FIELDS] OR "THERAPY"[MESH SUBHEADING] OR "THERAPY"[ALL FIELDS] OR "THERAPY S"[ALL FIELDS] OR "THERAPYS"[ALL FIELDS])) AND ((FFRFT[FILTER]) AND (BOOKSDOCS[FILTER] OR CLINICALTRIAL[FILTER] OR META-ANALYSIS[FILTER] OR RANDOMIZEDCONTROLLEDTRIAL[FILTER]) AND (FFT[FILTER]) AND (HUMANS[FILTER]) AND (ENGLISH[FILTER]) AND (ALLCHILD[FILTER]) AND (2004:2024[PDAT]) **DATE OF ACCESS: DECEMBER 2024**

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Screening

Studies were assessed against predefined inclusion and exclusion criteria during the screening phase to ensure relevance to the research objectives. After removing duplicates, 6,637 irrelevant publications were excluded, leaving 248 studies for further evaluation (see Table 2). Criteria focused on English-language studies from 2024 in psychology, medicine, neuroscience, or social sciences within Asian contexts. Non-English, pre-2024 works, conference proceedings, books, reviews, and non-Asian studies were excluded. Three additional duplicates were removed, refining the selection for detailed analysis.

Table 2

Criterion	Inclusion	Exclusion
Language	English	Non-English
Timeline	2024	< 2023
Literature type	Journal (Article)	Conference, Book, Review
Publication Stage	Final	In Press
Country	Asia Regions	Besides Asia Regions
Subject Area	Psychology, Medicine, Neuroscience, Social Sciences	Besides Psychology, Medicine, Neuroscience, Social Sciences
Document type	Article	Besides Article

Eligibility

The eligibility stage involved a thorough evaluation of 245 articles to determine their relevance and alignment with the study's objectives. Titles and content were carefully reviewed to ensure compliance with inclusion criteria. This rigorous assessment excluded 211 articles for reasons such as irrelevant titles, abstracts not meeting the study’s focus, unavailability of full-text access, or lack of empirical evidence. Ultimately, 34 articles met the eligibility criteria, ensuring their meaningful contribution to the research and were retained for subsequent stages of the systematic review.

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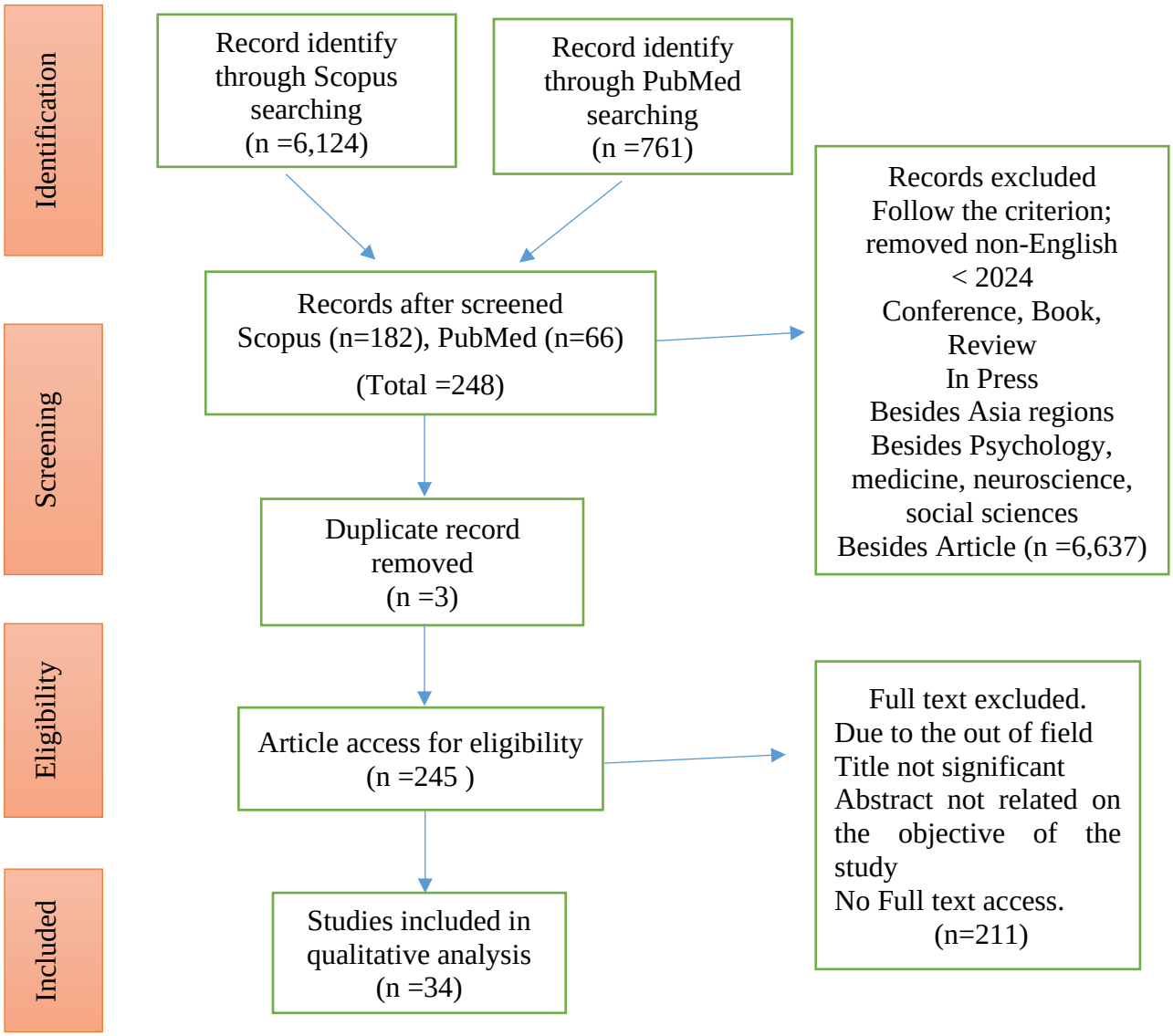

Figure 1. Flow Diagram Of The Proposed Searching Study

(Moher D, Liberati A, Tetzlaff J, 2009)

Data Abstraction and Analysis (TNR, 12, Bold, Italic, Tab Inside, Capitalize Each Word)

Previous systematic reviews often lacked a consistent quality assessment framework or failed to address regional variations in emotional regulation research. This study employed an integrative analysis approach to evaluate and synthesize findings from 34 selected publications, focusing on emotional co-regulation and associated methodologies. By employing the adapted framework from Abouzahra et al. (2020) and concentrating on Asian contexts, this study mitigated biases in study selection and ensures regionally relevant findings. Adhering to Kitchenham's (2007) guidelines, a quality assessment framework, incorporating six criteria (QA1–QA6), scored as "Yes" (1 point), "Partly" (0.5 points), or "No" (0 points), requiring a cumulative score above 3.0 for progression. Criteria evaluated clarity of purpose, relevance,

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methodology, conceptual definitions, comparisons with similar work, and acknowledgment of limitations. This rigorous process ensured only high-quality studies were included, maintaining the integrity and reliability of the systematic literature review.

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Table 3

NO	Authors	Title	QA1	QA2	QA3	QA4	QA5	QA6	Total
1	Shinpei Y., Kouga S., Keiichi O.	Diminished negative emotion regulation through affect labeling and reappraisal: insights from functional near-infrared spectroscopy on lateral prefrontal cortex activation	1	1	1	0.5	0.5	0.5	4.5
2	Huang, C., Gu, S., & Chen, H.	Effectiveness of music therapy in enhancing empathy and emotional recognition in adolescents with intellectual disabilities	1	1	1	1	0.5	0.5	5
3	Liu, T.-Y., Ko, W.-T., & Griffiths, M. D., et al.	The associations between levels of inattention/hyperactivity and social media addiction among young adults: The mediating role of emotional regulation strategies in self-blame and blaming others	1	1	1	1	0.5	0.5	5
4	Deng, C., Li, D., & Li, Y., et al.	Reciprocal relationships among parental psychological control, emotion regulation ability, and subjective well-being of adolescents: Disentangling between- and within-person effects	1	1	1	1	0.5	0.5	5
5	Zhao, D., & Zhang, J.	The effects of working memory training on attention deficit, adaptive and non-adaptive cognitive emotion regulation of Chinese children with Attention Deficit/Hyperactivity Disorder (ADHD)	1	1	1	1	0.5	0.5	5
6	Ma, C., Wang, X., & Blain, S. D., et al.	The Adaptiveness of Emotion Regulation Variability and Interoceptive Attention in Daily Life	1	1	1	1	0.5	0.5	5
7	Gao, K., Wong, A. B., & Li, S., et al.	The ventromedial prefrontal cortex plays an important role in implicit emotion regulation: A focality-optimized multichannel tDCS study in anxiety individuals	1	1	1	1	1	0.5	5.5
8	Nadaf, Z. A., Marbet, J., & Nazir, U., et al.	Role of Core Life Skills in Mitigating Academic Stress Among Students with Learning Disabilities	1	1	1	0.5	0.5	0.5	4.5
9	Huang, Z., Chen, S., & Chen, H.	Relationship between emotional awareness and self-acceptance: The mediating role of emotion regulation strategies	1	1	1	1	0.5	0.5	5
10	Cheung, H. Y. L., Brown, T., & Yu, M.-L., et al.	The Relationship Between School-Age Children's Self-Reported Perceptions of Their Interoceptive Awareness and Emotional Regulation: An Exploratory Study	1	1	1	0.5	0.5	0.5	4.5
11	Gu, J., Sugimura, Y. K., & Kato, F., et al.	Central amygdala-to-pre-Bötzinger complex neurotransmission is direct and inhibitory	1	1	1	1	1	0.5	5.5

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12	Lan, L., Liu, W., & Liu, C., et al.	Effects of Mindfulness and Life-Skills Training on Emotion Regulation and Anxiety Symptoms in Chinese Migrant Children: A Randomized Controlled Trial	1	1	1	1	0.5	0.5	5
13	Li, M., Xu, T., & Li, M., et al.	Negative family expressiveness and adolescents' externalizing problems: Respiratory sinus arrhythmia as a moderator and anger regulation as a mediator	1	1	1	1	1	0.5	5.5
14	Liu, C., Zhang, Q., & Liu, Y., et al.	The Association Between Autistic Traits and Depression in College Students: The Mediating Roles of Interpersonal Emotion Regulation and Social Self-Efficacy	1	1	1	1	0.5	0.5	5
15	Kim, M.	A Study on Mother Empathy and Social Support Affecting Emotional Regulation of Children with ADHD Symptoms	1	1	0.5	0.5	0.5	0.5	4
16	Bu, H., Liu, I. K.-F., & Yu, N. X.	A Randomized Controlled Trial of Two Parenting Interventions on Enhancing Parental Resilience Resources and Reducing Children's Problem Behaviors in Chinese Cross-Boundary Families	1	1	1	1	0.5	0.5	5
17	Islamiah, N., Breinholst, S., & Walczak, M. A.	Associations Between Parents' Cognitions About Child Anxiety and Emotion Dysregulation in Clinically Anxious Children: The Unique Contribution of Fathers	1	1	1	1	0.5	0.5	5
18	Prasad, R., Tarai, S., & Bit, A.	Emotional reactivity and its impact on neural circuitry for attention-emotion interaction through regression-based machine learning model	1	1	1	1	1	0.5	5.5
19	Toh, W. X., & Yang, H.	To Switch or Not to Switch? Individual Differences in Executive Function and Emotion Regulation Flexibility	1	1	1	1	1	0.5	5.5
20	Yan, H., Zhou, A., & Li, Q., et al.	The association between emotional regulation dimensions and somatic symptom disorders: A systematic review and meta-analysis	1	1	1	1	0.5	0.5	5
21	Wang, J., Yang, Z., & Klugah-Brown, B., et al.	The critical mediating roles of the middle temporal gyrus and ventrolateral prefrontal cortex in the dynamic processing of interpersonal emotion regulation	1	1	1	1	1	0.5	5.5
22	Chen, Y. Y., Ting, C. H., & Ghazali, S. R., et al.	Enhancing children's well-being using Malaysian-adapted version Super Skills for life (M-SSL) among primary school children in Malaysia	1	1	1	1	0.5	0.5	5
23	Wang, X., Shao, S., & Cai, Z., et al.	Reciprocal effects between negative affect and emotion regulation in daily life	1	1	1	1	1	0.5	5.5

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24	Ishii-Takahashi, A., Hamada, J., & Yamaguchi, R., et al.	Efficacy of behavioral parent training on attachment security in children with attention deficit hyperactivity disorder: a randomised controlled trial	1	1	1	1	0.5	0.5	5
25	Sakarias, S., & Madhavan, J.	The Role of Outdoor Mindfulness Intervention in Optimizing Mental Well-Being in Adolescents with Specific Learning Disabilities	1	1	1	1	0.5	0.5	5
26	Takamatsu, N., Nakashima, M., & Matsuura, K., et al.	A multicenter, single-group, open feasibility study of a new individual cognitive behavioral therapy program for adult Japanese patients with ADHD	1	1	1	1	0.5	0.5	5
27	Rucklidge, J. J., Eggleston, M. J. F., & Johnstone, J. M., et al.	Vitamin-mineral treatment improves aggression and emotional regulation in children with ADHD: A fully blinded, randomized, placebo-controlled trial	1	1	1	1	1	0.5	5.5
28	Skowron, E. A., Nekkanti, A. K., & Skoranski, A. M., et al.	Randomized trial of parent-child interaction therapy improves child-welfare parents' behavior, self-regulation, and self-perceptions	1	1	1	1	1	0.5	5.5
29	Hadley, W., Barker, D., & Thamotharan, S., et al.	Relationship Between Unsupervised Time and Participation in an Emotion Regulation Intervention and Risk Outcomes	1	1	1	1	0.5	0.5	5
30	Engelstad, A. M., Joffe-Nelson, L., & Hurewitz, S. R., et al.	The JASPER (Joint Attention, Symbolic Play, Engagement and Regulation) Intervention in Down Syndrome: A pilot study	1	1	1	1	0.5	0.5	5
31	Njardvik, U., Smaradottir, H., & Öst, L. G.	The Effects of Emotion Regulation Treatment on Disruptive Behavior Problems in Children: A Randomized Controlled Trial	1	1	1	1	1	0.5	5.5
32	Romero-Ayuso, D., Alcántara-Vázquez, P., & Almenara-García, A., et al.	Self-Regulation in Children with Neurodevelopmental Disorders "SR-MRehab: Un Colegio Emocionante": A Protocol Study	1	1	1	1	0.5	0.5	5
33	Kuroda, M., Kawakubo, Y., & Kamio, Y., et al.	Preliminary efficacy of cognitive-behavioral therapy on emotion regulation in adults with autism spectrum disorder: A pilot randomized waitlist-controlled study	1	1	1	1	0.5	0.5	5

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34	Tobe, H., Sakka, M., & Kamibeppu, K.	The efficacy of a resilience-enhancement program for mothers in Japan based on emotion regulation: Study protocol for a randomized controlled trial	1	1	1	1	0.5	0.5	5

Result

The review findings are organized into four primary themes that encapsulate the breadth of emotion regulation research: (1) Neurobiology and Cognitive Mechanisms Underlying Emotion Regulation, (2) Adaptiveness and Variability in Emotion Regulation, (3) Interventions for Enhancing Emotion Regulation, and (4) Developmental and Social Contexts of Emotion Regulation. These themes structure the analysis of findings and provide a comprehensive framework for presenting the key insights, as summarized in Table 4.

Table 4

Theme	Authors	Key Findings	Significance
Neurobiology And Cognitive Mechanisms	Shinpei et al. (2024)	Affect labelling and reappraisal modulate dorsolateral and ventral prefrontal cortical activity.	Highlights the role of the prefrontal cortex in emotional processing.
	Gao et al. (2024)	Implicit emotion regulation enhanced through tDCS in the VMPFC.	Identifies neural targets for emotion regulation interventions.
	Zhao and Zhang (2024)	Working memory training improves adaptive regulation and attention in children with ADHD.	Validates cognitive training as a targeted intervention for ADHD.
	Toh and Yang (2024)	Executive function is linked to better emotion regulation in high-intensity situations.	Demonstrates flexibility in emotion regulation strategies.
	Wang et al. (2024)	Middle temporal gyrus and ventrolateral prefrontal cortex mediate interpersonal emotion regulation.	Advances understanding of social-emotional neural mediators.
	Gu et al. (2024)	Central amygdala regulates survival-related emotional responses.	Deepens insights into physiological survival-linked emotional responses.
	Prasad et al. (2024)	Redirecting attention from negative to positive stimuli reduces distress and enhances well-being.	Establishes attentional strategies as key to emotional regulation.
Adaptiveness And Variability	Liu et al. (2024)	ADHD symptoms linked to social media addiction, mediated by externalizing emotion regulation strategies.	Emphasizes the need for resilience-building and mindfulness interventions.
	Takamatsu et al. (2024)	CBT tailored for adults with ADHD improves emotional regulation.	Validates tailored CBT as effective for mental health challenges.

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	Ma et al. (2024)	Interoceptive awareness (IA) predicts emotion regulation variability and reduces negative affect.	Highlights the value of IA-focused therapies for adaptive regulation.
	Cheung et al. (2024)	IA correlates with emotional and academic self-regulation in children.	Supports IA-based interventions for children's well-being.
	Wang et al. (2024)	Negative emotions reduce strategy variability, fostering maladaptive strategies like rumination.	Demonstrates the cyclical relationship between negative affect and regulation.
	Huang et al. (2024); Yan et al. (2024)	Emotion regulation promotes self-acceptance and mental health.	Underlines the efficacy of adaptive regulation strategies.
Interventions For Enhancing Regulation	Huang and Gu (2024)	Music therapy improves empathy and emotional recognition in adolescents with intellectual disabilities.	Validates accessible emotional development tools.
	Engelstad et al. (2024)	JASPER improves joint attention and emotional engagement in children with Down syndrome.	Demonstrates the scalability of parent-mediated interventions.
	Lan et al. (2024)	Mindfulness-based life skills training reduces anxiety among migrant children.	Highlights the role of social integration in intervention outcomes.
	Sakarias & Madhavan (2024)	Outdoor mindfulness improves emotional regulation in adolescents with learning disabilities.	Stresses the integration of mindfulness in educational contexts.
	Kuroda et al. (2022)	CBT improves emotional regulation and stress management in autistic adults.	Demonstrates the efficacy of tailored interventions for neurodivergent groups.
	Bu et al. (2024); Ishii-Takahashi et al. (2024); Skowron et al. (2023)	Parenting interventions improve children's emotional regulation and foster positive parenting.	Highlights dual benefits for children and parents.
	Rucklidge et al. (2018)	Micronutrient supplementation enhances emotional regulation and reduces aggression in children with ADHD.	Offers low-risk, effective strategies for emotional and behavioral support.
Developmental And Social Contexts	Deng et al. (2024)	Parental psychological control influences adolescents' well-being, mediated by emotional regulation.	Highlights the need to address negative cycles in family dynamics.
	Li et al. (2024)	Anger regulation mediates the effect of family expressiveness on externalizing behaviors.	Stresses the importance of family expressiveness and physiological resilience.
	Chen et al. (2024); Nadaf et al. (2024)	Life skills training reduces stress and fosters resilience in vulnerable groups.	Validates the importance of life skills in promoting well-being.
	Kim (2024); Islamiah et al. (2024)	Maternal empathy and father-inclusive strategies enhance children's emotional regulation.	Highlights culturally inclusive family-focused approaches.

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	Romero-Ayuso et al. (2020)	Virtual reality tools improve self-regulation in neurodevelopmental conditions.	Showcases scalable technological interventions.
	Liu et al. (2024)	Emotion regulation mediates depression and enhances social confidence in neurodivergent individuals.	Highlights lifelong importance of emotion regulation strategies.

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Neurobiology And Cognitive Mechanisms Underlying Emotion Regulation

Research into the neurobiology and cognitive mechanisms of emotion regulation highlights the critical role of specific brain regions and cognitive functions in shaping emotional responses. Studies by Shinpei et al. (2024) and Gao et al. (2024) highlight the centrality of the prefrontal cortex, demonstrating that affect labelling combined with reappraisal modulates dorsolateral and ventral prefrontal cortical activity, though reappraisal alone proves more effective in reducing negative emotions. Gao et al. also emphasized the ventromedial prefrontal cortex's (VMPFC) role in implicit regulation, showing significant emotional improvements through focality-optimized transcranial direct current stimulation (tDCS). Zhao and Zhang (2024) observed enhanced adaptive emotion regulation and attention in children with ADHD following working memory training, while Toh and Yang (2024) demonstrated greater flexibility in emotion regulation strategies among individuals with higher executive function in high-intensity situations. Interpersonal emotion regulation (IER) involves dynamic neural connectivity, with Wang et al. (2024) identifying the middle temporal gyrus and ventrolateral prefrontal cortex as key mediators, and Gu et al. (2024) highlighting the central amygdala's role in survival-related emotional responses. Prasad et al. (2024) revealed that redirecting attention from negative stimuli reduces distress, while focusing on positive stimuli enhances well-being. Collectively, these findings provide a robust framework for developing interventions targeting cognitive, neural, and attentional mechanisms to enhance emotion regulation. Past research has often focused on isolated aspects of neural mechanisms, such as the role of the prefrontal cortex, without integrating findings across regions like the ventromedial prefrontal cortex (VMPFC) or the amygdala. Additionally, studies frequently neglected the practical implications of neural connectivity for interventions. This review synthesizes insights from studies like Gao et al. (2024) and Shinpei et al. (2024), which emphasize dynamic neural interactions. It also bridges the gap by offering a framework to translate these findings into targeted interventions, such as cognitive-behavioral approaches that enhance executive functions and attentional control.

Adaptiveness And Variability In Emotion Regulation

Research highlights the intricate connections among ADHD symptoms, emotion regulation strategies, and behavioral outcomes. Liu et al. (2024) identified strong links between ADHD symptoms, such as attention deficit and hyperactivity/impulsivity, and social media addiction, with externalizing strategies like blaming others mediating this relationship, emphasizing the need for interventions enhancing resilience and mindfulness. Takamatsu et al. (2024) demonstrated that cognitive-behavioral therapy (CBT) tailored for adults with ADHD improves emotional regulation and mitigates mental health challenges. Variability in emotion regulation strategies and the influence of interoceptive awareness (IA) on reducing negative affect are critical areas of interest. Ma et al. (2024) showed IA significantly predicts strategy variability, especially when combined with emotional awareness, while Cheung et al. (2024) linked IA to enhanced emotional and academic self-regulation in children, underscoring the value of IA-focused therapies. The bidirectional relationship between negative affect and emotion regulation reveals that negative emotions reduce strategy variability, fostering maladaptive approaches, while adaptive strategies like reappraisal lower subsequent negative affect (Wang et al., 2024). Huang et al. (2024) and Yan et al. (2024) emphasized the role of emotion regulation in promoting self-acceptance and mental health, highlighting the efficacy of adaptive strategies such as self-efficacy and clarity. These findings highlight the need for individualized interventions integrating IA training and dynamic frameworks to enhance emotional regulation and mental well-being. Existing literature has largely focused on the

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bidirectional relationship between negative affect and emotion regulation but often fails to address interoceptive awareness (IA) as a mediating factor. Studies have also been fragmented in exploring emotion regulation variability across contexts. This review consolidates findings from Liu et al. (2024) and Cheung et al. (2024), offering a more comprehensive view of IA's role in adaptive regulation. The analysis highlights gaps in longitudinal research, suggesting the need to explore how variability in strategies evolves over time and impacts long-term well-being.

Interventions For Enhancing Emotion Regulation

Interventions targeting emotion regulation in children and adolescents with neurodevelopmental conditions have demonstrated diverse efficacy across various contexts. Music therapy significantly enhances empathy and emotional recognition in adolescents with intellectual disabilities, as noted by Huang and Gu (2024), emphasizing its value as an accessible tool for emotional development. Similarly, JASPER, a parent-mediated approach, effectively improves joint engagement and emotion regulation in children with Down syndrome, with remote delivery expanding its applicability (Engelstad et al., 2024). Mindfulness-based interventions paired with life-skills training have shown promise in reducing anxiety in Chinese migrant children, although outcomes depend on social integration levels (Lan et al., 2024). Outdoor mindfulness practices also enhance emotional regulation and mental well-being in adolescents with learning disabilities, highlighting the importance of integrating mindfulness into educational settings (Sakarias & Madhavan, 2024). Cognitive-behavioral therapy (CBT) tailored for neurodivergent groups, such as autistic adults, has demonstrated efficacy in improving emotional regulation and stress management (Kuroda et al., 2022). Parenting interventions, including Behavioral Parent Training (BPT) and Parent-Child Interaction Therapy (PCIT), have significantly reduced stress, improved children's emotional regulation, and fostered positive parenting practices (Bu et al., 2024; Ishii-Takahashi et al., 2024; Skowron et al., 2023). Additionally, micronutrient supplementation has shown potential in improving emotional regulation, aggression, and general functioning in children with ADHD (Rucklidge et al., 2018), offering a low-risk, effective strategy for emotional and behavioral support. Previous studies have predominantly examined interventions in isolated settings without exploring their adaptability across populations. For example, music therapy and CBT are often applied without considering their integration into culturally diverse or remote settings. This review adds depth by examining the scalability of interventions like JASPER for Down syndrome and mindfulness-based approaches for children with learning disabilities. It also highlights the need for further research into combining parent-focused strategies with child-specific therapies, such as pairing Behavioral Parent Training (BPT) with micronutrient supplementation.

Developmental And Social Contexts Of Emotion Regulation

Research on family dynamics highlights the critical role of parental behaviors in shaping adolescents' emotional regulation and well-being. A bidirectional link between parental psychological control and adolescents' subjective well-being, mediated by emotional regulation, highlights the need for interventions to break this negative cycle (Deng et al., 2024). Family expressiveness also influences externalizing behaviors, with anger regulation acting as a mediator, while physiological factors like respiratory sinus arrhythmia amplify vulnerabilities to adverse environments (Li et al., 2024). Integrating life skills training into education reduces stress and fosters resilience in vulnerable groups. Programs such as the Malaysian-adapted "Super Skills for Life" have been effective in alleviating depressive symptoms and social

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worries while improving emotional regulation (Chen et al., 2024; Nadaf et al., 2024). Parental attitudes and social support play crucial roles in enhancing children's emotional regulation, with maternal empathy and father-inclusive strategies showing notable benefits, especially in ADHD and anxiety contexts (Kim, 2024; Islamiah et al., 2024). Structured interventions like the virtual reality-based "SR-MRehab" offer scalable solutions for improving self-regulation in neurodevelopmental conditions, while combining emotion regulation with supervised environments effectively reduces adolescent risk behaviors (Romero-Ayuso et al., 2020; Hadley et al., 2017). These findings emphasize emotion regulation strategies' lifelong significance, including in mediating depression and enhancing social confidence among neurodivergent individuals (Liu et al., 2024). Research on family dynamics often overlooks how physiological factors (e.g., respiratory sinus arrhythmia) amplify vulnerabilities in stressful environments. Similarly, studies have inadequately addressed how cultural adaptations of life skills training influence outcomes in diverse populations. By examining programs like "Super Skills for Life," this review emphasizes the significance of tailoring interventions to sociocultural contexts while identifying the need for long-term evaluations to measure their sustained impact. Additionally, this study emphasizes the dual importance of maternal empathy and father-inclusive strategies, areas often underrepresented in past research.

Discussion and Conclusion

Emotion regulation plays a vital role in supporting positive emotional and mental health across various populations. The prefrontal cortex, particularly its involvement in strategies like reappraisal and affect labelling, is central to these processes. Interventions targeting cognitive functions have proven effective in improving adaptive regulation. Unlike earlier research that often focused on isolated aspects of emotion regulation, this review connects neurobiological mechanisms, cognitive strategies, and socio-emotional contexts, offering a more holistic perspective. Emotional regulation variability, shaped by interoceptive and emotional awareness, has been found to help individuals manage negative emotions and support self-regulation, especially in children and neurodivergent individuals.

Methodologically, the PRISMA framework ensured a rigorous and transparent review process, strengthening the reliability of the findings. This study accessed a wide repository of high-quality, peer-reviewed publications using Scopus and PubMed. Compared to prior approaches, this study offers a more integrative perspective by incorporating neurobiological, developmental, and intervention-based themes. Earlier reviews often neglected reciprocal co-regulation dynamics or cultural adaptability in interventions, which this review addresses by emphasizing strategies like culturally tailored programs and parent-child interaction therapy.

However, certain limitations must be acknowledged. The exclusion of non-English studies and a focus on publications from 2024 may have narrowed the scope, potentially overlooking relevant insights. Previous reviews with broader timelines and diverse populations may provide more global perspectives, whereas this study prioritizes precision and recent findings. Future research could integrate mixed methods or include grey literature to complement the systematic review approach.

These insights highlight the importance of individualized, culturally relevant strategies that integrate neural, cognitive, and interpersonal elements. By combining these approaches, this review emphasizes resilience, adaptability, and stronger emotional regulation, providing

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practical and scalable solutions for clinical and educational settings. Such improvements will further advance emotion regulation research and its applications across diverse contexts.

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