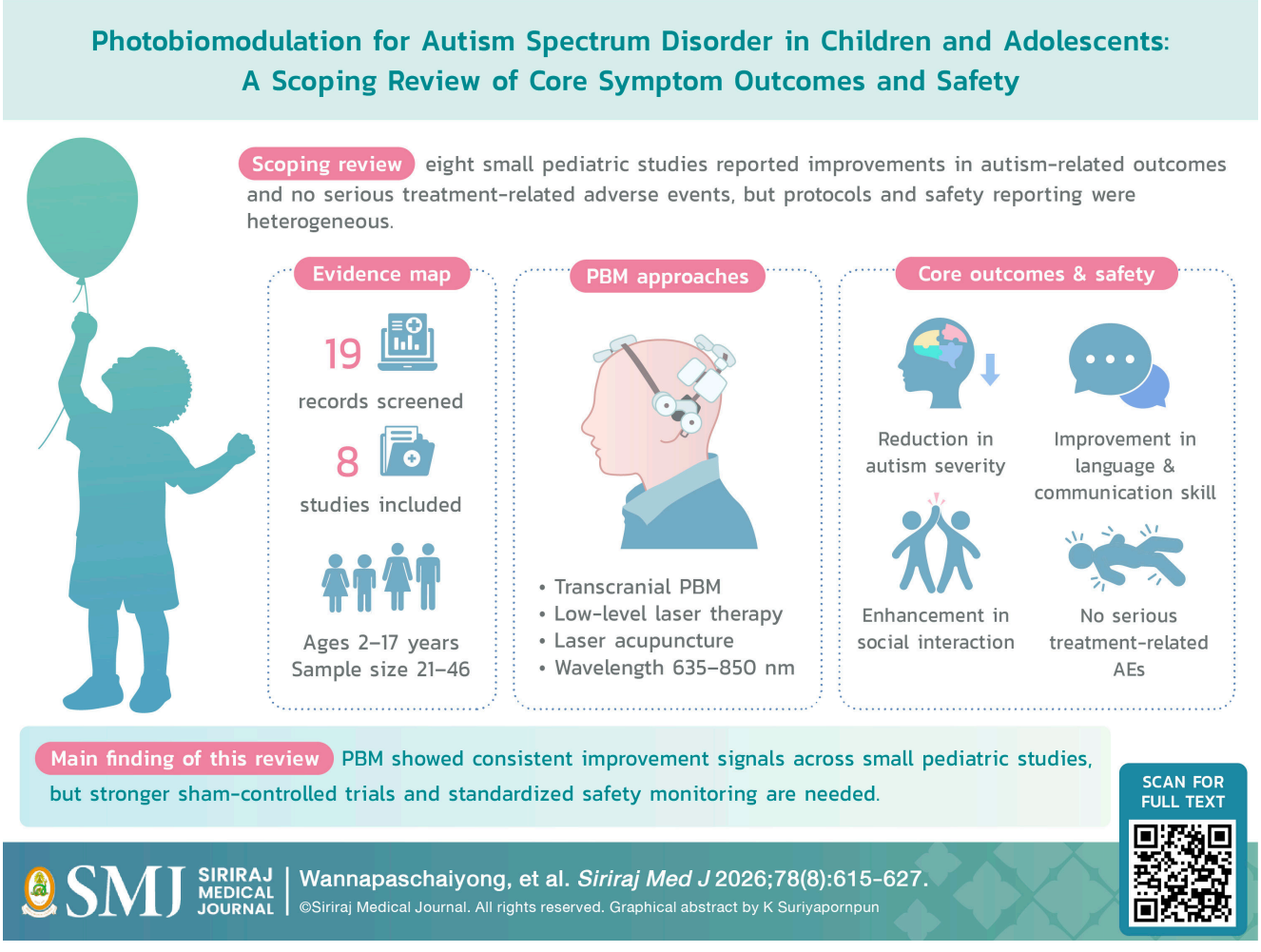
Photobiomodulation for Autism Spectrum Disorder in Children and Adolescents: A Scoping Review of Core Symptom Outcomes and Safety

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ABSTRACT

Objective: Photobiomodulation (PBM) has emerged as a potential noninvasive intervention for autism spectrum disorder (ASD), but pediatric evidence remains limited and fragmented. This scoping review aimed to map the current literature on PBM for children and adolescents with ASD, focusing on core symptom outcomes and safety.

Materials and Methods: PubMed/MEDLINE, Scopus, Embase, and the Cochrane Library were searched from inception to February 1, 2026. The searches identified 53 records, comprising 51 database records and 2 records from supplementary searching. After deduplication and screening, 8 reports representing 6 independent cohorts were included.

Results: The included studies involved children and adolescents aged 2 to 17 years, with sample sizes ranging from 21 to 46 participants. PBM modalities included transcranial photobiomodulation, low-level laser therapy, and laser acupuncture, with wavelengths ranging from 635 to 850 nm. Treatment schedules ranged from 8 sessions over 4 weeks to home-based treatment for up to 6 months. The reports described improvement in selected autism-related outcomes. Controlled studies reported greater improvements in autism severity, language, communication, and social interaction outcomes, including a between-group Childhood Autism Rating Scale difference of 7.23 points in one trial. No serious treatment-related adverse events were reported; however, safety monitoring and adverse-event ascertainment were incomplete and inconsistent.

Conclusion: PBM appears promising but remains investigational for children and adolescents with ASD. Further rigorous sham-controlled trials with standardized outcome measures and clearer safety reporting are needed.

Keywords: Photobiomodulation; autism spectrum disorder; children; adolescents; safety (Siriraj Med J 2026;78(8): 615-627)

INTRODUCTION

Autism spectrum disorder (ASD) is a heterogeneous neurodevelopmental condition characterized by differences in social communication and the presence of restricted repetitive behaviors, with substantial variability in symptom presentation, functional impact, and support needs between individuals.[1] In recent years, the reported prevalence of ASD has increased considerably, reflecting improvements in awareness, screening, diagnostic practices, and access to services, while also increasing demands on health, educational, and social care systems. Globally, the World Health Organization estimates that about 1 in 127 people are autistic.[2] At the same time, recent surveillance data from the United States suggest that approximately 1 in 31 children aged 8 years have been identified with ASD[3], underscoring the growing public health and service burden associated with the condition. Despite a lower estimated prevalence of ASD among young Thai children, at approximately 1 in 160,[4] ASD remains an important local burden because many children are diagnosed late. Recent Thai studies reported that many children with ASD were diagnosed after 3-4 years of age. This delay may postpone access to early intervention and appropriate management, making later care more difficult for children, families, and healthcare services.[5,6]

The current management of ASD is diverse and typically includes behavioral, developmental, educational, parent-mediated, and psychosocial interventions tailored to the child's needs. These approaches are central to care, but pharmacological treatment remains limited and is used mainly for associated symptoms, such as irritability, hyperactivity, anxiety, or sleep problems, rather than for core ASD symptoms.[1,7] Therefore, there is continuing interest in novel interventions that can safely address these core symptoms in children and adolescents with ASD.

Photobiomodulation (PBM) has emerged as a biologically plausible candidate intervention for ASD because it is thought to modulate mitochondrial activity, with cytochrome c oxidase considered one of its principal photoacceptors, leading to downstream effects on adenosine triphosphate production, nitric oxide, reactive oxygen species, and calcium signaling. These mechanisms may influence neuroinflammation, neuronal metabolism, cortical oscillatory activity, and broader brain network function.[8] This rationale is particularly relevant because evidence suggests that at least a subset of autistic individuals may exhibit alterations in mitochondrial function, oxidative stress, neuroinflammatory pathways, and atypical neural connectivity.[9,10] Although ASD is biologically heterogeneous and cannot be explained by a single pathway, these findings support interest in PBM as a noninvasive intervention that may have the potential to affect neural processes related to core symptoms.

Despite growing interest in photobiomodulation as a noninvasive neuromodulatory approach for ASD, the clinical evidence remains preliminary, with published pediatric studies to date consisting largely of early-phase or open-label designs and limited sample sizes. Recent reports have suggested possible benefits for autism-related symptoms, but the extent of improvement in core symptom domains and the safety profile of this intervention in children and adolescents remains unclear. Therefore, this review aimed to map the available evidence on photobiomodulation on core symptoms of autism spectrum disorder, particularly social communication difficulties and restricted/repetitive behaviors, as well as safety outcomes in children and adolescents.

MATERIALS AND METHODS

This scoping review was conducted to map the extent, characteristics and reported outcomes in the published literature on photobiomodulation (PBM) to address the core symptoms of autism spectrum disorder (ASD) and its safety in children and adolescents. The review was guided by the Joanna Briggs Institute approach for scoping reviews[11] and is reported in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses extension for Scoping Reviews (PRISMA-ScR).[12] No a priori protocol was developed or registered for this review. No major deviations from the planned review methods occurred during the review process.

Eligibility criteria

Studies were eligible if they: (1) included children or adolescents with a clinical diagnosis of autism spectrum disorder (ASD); (2) evaluated a photobiomodulation (PBM)-based intervention, including transcranial photobiomodulation, low-level laser therapy, laser acupuncture, near-infrared light, red light therapy or related light-based therapeutic approaches; and (3) reported outcomes related to core ASD domains, particularly social communication and/or restricted and repetitive behaviors, including direct autism symptom measures or functionally relevant communication and social interaction outcomes, and/or safety outcomes such as adverse events or tolerability. Laser acupuncture was included as a PBM-based modality because it uses low-intensity laser light to produce photobiological effects; however, it was not assumed to be mechanistically or dosimetrically equivalent to transcranial PBM or cranial LLLT. Original quantitative studies, including randomized controlled trials, non-randomized interventional studies, pilot studies, and observational studies, were eligible for inclusion. Reviews, editorials, commentaries, conference abstracts without sufficient results, animal studies and studies that did not involve participants under 18 years of age were excluded. Studies focusing solely on associated symptoms without reporting on core ASD domain-related or safety outcomes were also excluded.

Information sources and search strategy

A structured literature search was conducted in PubMed/MEDLINE, Scopus, Embase, and the Cochrane Library from database inception to February 1, 2026. The search strategy combined terms related to photobiomodulation and autism spectrum disorder as follows: ("photobiomodulation" OR "low-level laser therapy" OR "low level laser therapy" OR LLLT OR "transcranial photobiomodulation" OR tPBM OR "near-infrared light" OR "near infrared light" OR "red light therapy") AND ("autism spectrum disorder" OR autism OR ASD) AND (child OR children OR adolescent OR adolescents OR pediatric OR paediatric). Because the review aimed to capture the broad pediatric PBM literature in ASD, the search strategy was based primarily on population and intervention terms rather than restricted to specific outcome keywords. The complete database-specific search strategies, interfaces, dates searched, restrictions, and numbers of records retrieved are provided in Supplementary Table S1. Citation and reference lists of relevant articles were also searched to identify additional reports.

Study selection

All identified records were imported into reference management software and duplicates were removed before screening (Fig 1). Two reviewers independently screened titles and abstracts according to the predefined eligibility criteria. The full texts of potentially relevant articles were then assessed for final inclusion. Studies were included if they involved children or adolescents with ASD, evaluated a PBM-based intervention, and reported outcomes related to core ASD domains, particularly social communication and/or restricted and repetitive behaviors, including either direct autism symptom measures or domain-specific communication and social interaction outcomes, and/or safety outcomes. Associated outcomes, including irritability, sleep, parental stress, attention, and general functional performance, were treated as secondary outcomes.

Data charting

Data were mapped from the included studies using a structured extraction framework. The following variables were collected where available: author, publication year, country, study design, sample size, participant age, ASD

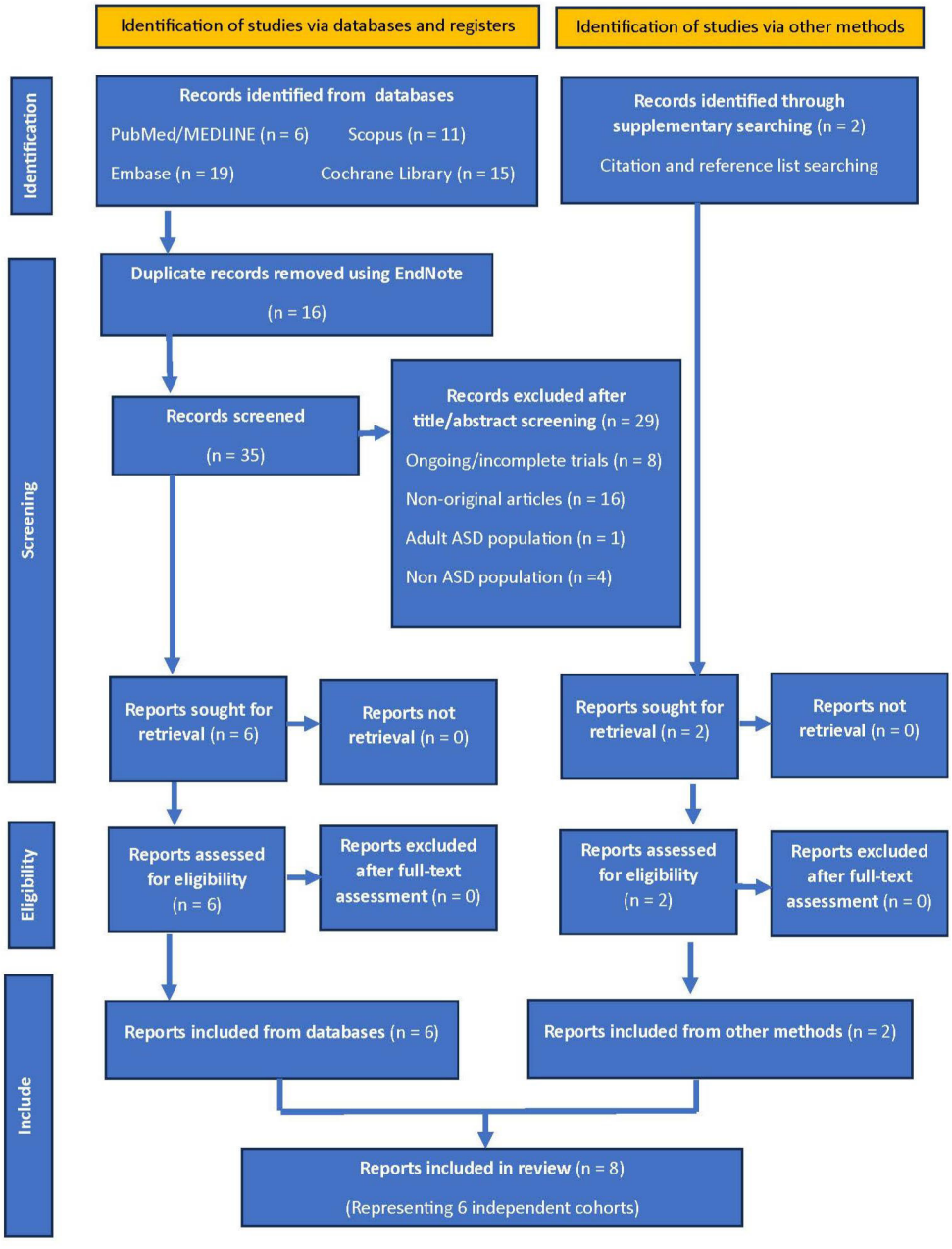


Fig 1. PRISMA flow diagram for study selection.

diagnostic criteria, PBM modality, wavelength, power or irradiance, fluence or dose, treatment site, session duration, number of sessions, comparator, outcome measures, main findings, adverse events, and duration of follow-up. Additional information on secondary outcomes, including neurophysiological and biomarker findings, was also extracted when reported.

Data synthesis

The data extracted were synthesized descriptively in narrative and tabular form. The review focused on mapping study characteristics, PBM intervention parameters, reported effects on core domains related to ASD, secondary mechanistic outcomes, and safety findings. Due to substantial heterogeneity in study design, intervention protocols, outcome measures, and participant age ranges, no meta-analysis was performed.

Critical appraisal

As this scoping review was intended to map the available evidence, no formal risk-of-bias assessment was performed. Therefore, the findings were synthesized descriptively and were not used to establish treatment efficacy or safety. Methodological limitations, including small sample sizes, incomplete reporting, lack of control groups in some studies, and limited applicability to older children and adolescents, were considered when interpreting the evidence.

RESULTS

Search results

The database searches identified 51 records. After removal of 16 duplicates, 35 unique records underwent title and abstract screening. Twenty-nine records were excluded: ongoing or incomplete trials (n = 8), non-original publications (n = 16), one study involving an adult ASD population (n = 1), and studies involving non-ASD populations (n = 4). Six reports proceeded to full-text assessment. Two additional reports were identified through citation and reference-list searching. All eight reports met the eligibility criteria and were included in the review, representing six independent cohorts (Fig 1).

Characteristics of the included studies

As shown in Table 1, eight studies evaluated PBM-based interventions in pediatric ASD. These comprised randomized sham or placebo-controlled trials, randomized controlled laser acupuncture studies, a retrospective study, an open-label single-arm study, a 12-month follow-up report, and a post hoc age-group analysis. The sample sizes ranged from 21 to 46 participants and the age range in the studies was 2 to 17 years, although several studies enrolled predominantly younger children.[13-20] Of note, three reports from Cuba were related to the same LLLT cohort, including the original trial, a post hoc age-group analysis, and a 12-month follow-up report.[13-15]

Intervention characteristics

The PBM protocols varied substantially in all included studies and comprised transcranial photobiomodulation[16-18], low-level laser therapy[13-15], and laser acupuncture.[19,20] In the studies reporting wavelength, the values ranged from 635 to 850 nm. The treatment schedules ranged from 8 sessions over 4 weeks to intensive home-based regimens delivered for up to 6 months, and application sites included cortical scalp regions, skull base and temporal areas, intranasal stimulation and acupuncture points. Detailed technical characteristics of each protocol are summarized in Table 2. In addition, the reporting of some PBM parameters remained incomplete in several studies despite full-text availability. Specifically, fluence or dose was not reported in 5 of 8 studies (62.5%), pulse frequency in 4 of 8 (50.0%), and session duration in 1 of 8 (12.5%).

Effects on core ASD symptoms

Several included studies reported an improvement in core ASD-related outcomes following PBM, although the outcome measures and effect estimates differed between studies (Table 3). In the sham-controlled randomized trial of 30 children aged 2 to 6 years, Fradkin et al.[16] found a difference between groups in CARS change of 7.23 points (95% CI 2.357 to 12.107; p = 0.011). Mean CARS scores decreased from 43.5 to 33.7 in the intervention group and from 40.6 to 38.0 in the sham group, and 87% of intervention participants versus 35% of sham participants achieved at least a 4.5 point reduction in CARS.[16] In the open-label study, Fradkin et al.[18] enrolled 23 children and analyzed 22 completers; mean CARS-2 scores decreased from 36.5 (SD 5.6) to 29.7 (SD 5.5), corresponding to a 7 point reduction ($t = 10.23$, $p < 0.0001$). Pallanti et al.[17] reported significant reduction in CARS scores during six months of home-based treatment ($p < 0.001$). Elsheikh et al.[19] found that autism severity and language measures improved in both groups, but improvements were greater in the laser acupuncture group, with significant between-group differences for CARS severity and language performance ($p = 0.002$ and $p = 0.03$, respectively).

Secondary and mechanistic outcomes

Several studies also reported associated clinical and mechanistic outcomes (Table 3 and 4). Leisman et al.[13] reported significant improvement in irritability and related behavioral outcomes, with an adjusted mean between-group difference of −15.17 points on the ABC irritability subscale at endpoint ($F = 99.34$, $p < 0.0001$); 17 of 21 intervention participants (81%) versus 0 of 19 placebo participants met responder criteria. In the 12-month follow-up report derived from the same LLLT cohort, Machado et al.15 found that mean ABC irritability scores in the active group improved from 30.52 at baseline to 15.71 at endpoint, 11.81 at 8 weeks, 6.71 at 6 months, and 9.42 at 12 months, whereas placebo scores remained relatively unchanged, ranging from 29.58 to 31.37 over time. The post hoc age-group analysis suggested greater short-term global improvement in younger children: at 8 weeks, a CGI-I rating of "very much improved" was observed in 54.5% of children aged 5 to 6 years, 40% of those aged 7 to 8 years, and 25% of those aged 9 to 12 years.[14]

Surapaty et al.[20] found greater improvement with verum laser puncture than placebo in WeeFIM-assessed comprehension, expression, and social interaction. Odds of improvement favored the intervention for comprehension (OR 18.88, 95% CI 4.09 to 87.17; $p < 0.001$), expression (OR 50.28, 95% CI 5.61 to 450.2; $p < 0.001$), and social interaction (OR 7.27, 95% CI 1.68 to 31.42; $p = 0.005$), whereas the parental sensory-profile report did not differ significantly (OR 1.20, 95% CI 0.36 to 3.87; $p = 0.765$).

In the randomized sham-controlled trial, EEG data

TABLE 1. Characteristics of included studies.

Study	Country	Study design	Sample size	Age range	Main outcome measures	Assessment time points
Leisman/ Machado cohort, 2018–2020[13-15]	Cuba	Primary randomized placebo-controlled trial	40 (intervention 21, placebo 19)	5-17 years	ABC, CGI	Baseline, week 2, week 4 (endpoint of treatment), and week 8 (post-procedure)
		Post-hoc age-group analysis of active-treated cohort	40 (intervention 21, placebo 19)	5-17 years	ABC global/ subscales, CGI-S, CGI-I	Baseline to week 8 analysis
		12-month follow-up of the previously randomized intervention/placebo cohort	40 (intervention 21, placebo 19)	5-17 years	ABC global/ subscales, CGI-S, CGI-I	Baseline, week 4 (endpoint of treatment) week 8, 6 months, and 12 months post-treatment
Surapaty et al., 2020[20]	Indonesia	Randomized, double-blind, placebo-controlled clinical trial	46 (intervention 23, placebo 23)	2–6 years	WeeFIM for speech ability and social interaction, parental sensory -profile report	Baseline and end of treatment at 6 weeks
Pallanti et al., 2022[17]	Italy	Retrospective study	21	5-15 years	CARS-2	Baseline, 3 months, and 6 months (during treatment)
Elsheikh et al., 2023[19]	Egypt	Randomized controlled trial	30 (intervention 15, control 15)	3-6 years	CARS-2, PLS-4	Baseline and end of 6-week treatment
Fradkin et al., 2024[16]	United States	Randomized, double-blind, sham-controlled trial	30 (intervention 16, sham 14)	2-6 years	CARS-2	Baseline and end of 8-week treatment
Fradkin et al., 2025[18]	United States	Open-label, single-arm	22	2-7 years	CARS-2	Baseline and end of 10-week treatment

Note: Leisman et al. (2018), Machado et al. (2019), and Machado et al. (2020) represent related reports from the same or overlapping primary LLLT cohort.

Abbreviations: ABC = Aberrant Behavior Checklist; CGI = Clinical Global Impression; CGI-S = Clinical Global Impression – Severity; CGI-I = Clinical Global Impression – Improvement; CARS-2 = Childhood Autism Rating Scale, Second Edition; WeeFIM = Functional Independence Measure for Children; PLS-4 = Preschool Language Scale, Fourth Edition

TABLE 2. Photobiomodulation intervention characteristics.

Study	PBM modality	Wave length	Power / irradiance	Fluence / dose	Treatment site	Session duration	Number of sessions	Pulse frequency
Leisman/ Machado cohort, 2018–2020[13-15]	LLLT	635 nm	15 mW	NR	Base of the skull and temporal areas	5 minutes	8 sessions over 4 weeks	NR
Surapaty et al., 2020[20]	LLLA	785 nm	40 mW	1 J/ acupuncture point	GV20, HT7, LI4, SP6, ST36, GB34, LR3, and scalp acupuncture of the speech area	50 seconds/ site	18 sessions over 6 weeks	Nogier G 18,688 Hz modulation wave
Pallanti et al., 2022[17]	Transcranial PBM (NIR, LED)	810 nm	75–100 mW/cm²	45-60 J/cm²	FPz, Cz, T3, T4 (DMN targets) + intranasal ventral brain stimulation	20 minutes	2/day, 5 days/ week for 6 months	10 Hz (alpha), 40 Hz (gamma)
Elsheikh et al., 2023[19]	LLLA	850 nm	200 mW	3 J/cm²	GV20, Ex-HN1, GV24, GB20, GV26, Ex-HN3, bilateral LI4, ST36, SP6 and speech area on scalp	12 seconds/ site (16 sites)	12 sessions over 6 weeks	NR
Fradkin et al., 2024[16]	Transcranial PBM (NIR, LED)	850 nm	<300 mW Total	NR	DMN nodes, Broca/Wernicke areas, occipital lobe	NR	16 sessions over 8 weeks	40 Hz
Fradkin et al., 2025[18]	Transcranial PBM (NIR, LED)	850 nm	150 mW per LED (6 LEDs)	NR	DMN nodes, Broca/Wernicke, occipital lobe, prefrontal cortex	2-12 min (titrated)	20 sessions over 10 weeks	40 Hz

Abbreviations: PBM = photobiomodulation; LLLT = low-level laser therapy; NIR = near-infrared; LED = light-emitting diode; LLLA = low-level laser acupuncture; nm = nanometer; mW = milliwatt; J/cm² = joules per square centimeter; FPz = frontal pole midline; Cz = central midline; T3 = left temporal region; T4 = right temporal region; DMN = default mode network; Hz = hertz; NR = not reported

from 17 of 30 participants showed a significant condition effect for theta power (coefficient = 9.547, 95% CI 0.027 to 19.067; p = 0.049), with time dependent trends for delta and theta activity (both p = 0.07).[16] In the open-label study, Fradkin et al.[18] reported decreased delta power and increased gamma and beta power, with a significant pre to post increase in gamma power [t(14) = 2.30, p = 0.047]. EEG data were available only from children who tolerated the EEG cap; 15 of 22 completers provided at least three EEG recording. The paired first-to-final session analysis therefore included 15 participants [t(14)]. Correlations with treatment sessions used 194 session-level observations [r(192)] pooled across repeated recordings from the same participants. The original study did not report adjustment for within- participant dependence or multiplicity across frequency-band analyses. EEG changes were also correlated with treatment exposure and symptom change: delta power decreased with more sessions [r(192) = -0.18, p = 0.013], gamma and beta power increased with more sessions [r(192) = 0.19,

TABLE 3. Effects on Core ASD Symptoms and Associated Clinical Outcomes.

Study	Primary Measure	Magnitude of Effect	Statistical Significance	Follow-up Duration
Leisman/ Machado cohort, 2018-2020[13-15]	Primary trial: ABC, CGI	Adjusted mean difference in ABC irritability change: -15.17 favoring intervention; ABC global/subscales and CGI improved progressively.	ABC irritability: F = 99.34, p < 0.0001; CGI-S/CGI-C improvement: p < 0.00001.	4 weeks post-treatment (8 weeks total study)
	Post hoc age analysis: ABC global/subscales, CGI-S, CGI-I	Descriptive age-group analysis showed greater improvement in younger children; age 5-6 years showed the largest gains by week 8.	No report for between-age comparison (descriptive post-hoc analysis).	8 weeks
	Long-term follow-up: ABC global/subscales, CGI-S, CGI-I	ABC irritability in the intervention group decreased from 30.52 at baseline to 9.42 at 12 months; placebo remained largely unchanged.	Additional 5.1-point improvement from week 8 to 12 months in the intervention group: t = 3.31, p = 0.0035; placebo NS.	12 months post-treatment
Surapaty et al., 2020[20]	WeeFIM for speech ability and social interaction, parental sensory-profile report	Greater improvement with verum laserpuncture than placebo in comprehension, expression, and social interaction; ORs 18.88, 50.28, and 7.27, respectively.	Comprehension p < 0.001; expression p < 0.001; social interaction p = 0.005; parental report p = 0.765	End of 18 sessions over 6 weeks
Pallanti et al., 2022[17]	CARS-2	Progressive reduction in CARS from baseline to 3 and 6 months, including further improvement between 3 and 6 months.	Repeated-measures ANOVA: F(2,40) = 137.143, p < 0.001; pairwise comparisons all p < 0.001.	6 months (during treatment)
Elsheikh et al., 2023[19]	CARS-2, PLS-4	Greater reduction in ASD severity and greater improvement in language performance in the laser acupuncture group than in the control.	Between-group improvement favored intervention: CARS-2 p = 0.002; PLS-4 p = 0.03.	End of 6-week treatment (no post-treatment follow-up)
Fradkin et al., 2024[16]	CARS-2	Between-group difference in CARS change: 7.23 points favoring intervention.	95% CI 2.357 to 12.107; p = 0.011.	End of 8-week treatment
Fradkin et al., 2025[18]	CARS-2	Mean CARS-2 decreased from 36.45 to 29.68; mean change 6.77 points (about a 7-point reduction).	95% CI 5.36 to 8.19; t = 10.23, p < 0.0001.	End of 10-week treatment

Abbreviations: ABC = Aberrant Behavior Checklist; CGI = Clinical Global Impression; CGI-S = Clinical Global Impression – Severity; CGI-I = Clinical Global Impression – Improvement; CGI-C = Clinical Global Impression – Change scale; CARS-2 = Childhood Autism Rating Scale, Second Edition; WeeFIM = Functional Independence Measure for Children; OR = odds ratio; PLS-4 = Preschool Language Scale, Fourth Edition; CI = confidence interval; ANOVA = analysis of variance; ASD = autism spectrum disorder; NS = not significant

TABLE 4. Secondary and neurophysiological outcomes.

Study	EEG Changes	Biomarkers	Behavioral/Functional Measures
Pallanti et al., 2022[17]	NR	NR	Improved noncompliant behavior (HSQ-ASD), parental stress (APSI), rigidity (MERS-R), sleep quality (PSQI), and attention (SDAG).
Elsheikh et al., 2023[19]	NR	BDNF decreased only in the intervention group (P < 0.001). miR-320 expression did not change after treatment (P = 0.641), but was lower in children with ASD than in neurotypical controls and showed diagnostic value.	Language performance improved, including receptive and expressive language; parents of nonverbal children reported more sounds/ vocalizations.
Fradkin et al., 2024[16]	EEG showed a trend towards a greater reduction in delta power and an increase in theta power over time versus sham; net theta differed significantly between the groups. A negative correlation between the delta and theta change was also reported.	NR	Parental interviews suggested an improvement in eye contact, concentration, and receptive/ expressive language. Weekly questionnaire also captured tantrums, night waking, command following/responsiveness, anxiety, eating/chewing, and other behavioral changes.
Fradkin et al., 2025[18]	EEG showed decreased delta power and increased gamma and beta power over time; gamma change was statistically significant. Changes in delta and beta power correlated with CARS-2 improvement.	NR	CARS-2 subscale changes suggested improvement in communication, social interaction, and sociability; authors also noted family-relevant functional gains not fully captured by CARS-2.

Abbreviations: EEG = electroencephalography; NR = not reported; BDNF = brain-derived neurotrophic factor; miR-320 = microRNA-320; ASD = autism spectrum disorder; HSQ-ASD = Home Situations Questionnaire, Autism Spectrum Disorder; APSI = Autism Parenting Stress Index; MERS-R = Montefiore Einstein Rigidity Scale–Revised; PSQI = Pittsburgh Sleep Quality Index; SDAG = Scale for the Assessment of Attention Deficit with Hyperactivity; CARS-2 = Childhood Autism Rating Scale, Second Edition; FDA = US Food and Drug Administration

p = 0.007; r(192) = 0.15, p = 0.04], and improvement in CARS-2 scores correlated negatively with changes in delta and beta power [r(15) = -0.59, p = 0.020; r(15) = -0.54, p = 0.037].[18] Elsheikh et al.[19] reported that plasma BDNF levels decreased only in the intervention group (p < 0.001), whereas miR-320 expression did not change significantly after treatment (p = 0.641). Pallanti et al.[17] also reported significant improvements in several associated outcomes, including noncompliant behavior [HSQ-ASD: $\chi2(2) = 38$, p < 0.001], parental stress [APSI: $\chi2(2) = 39.4$, p ≤ 0.001], and sleep quality [PSQI: $\chi2(2) = 18.9$, p ≤ 0.001].

Safety outcomes

In Table 5, safety outcomes were reported in six studies.[13,16-20] No moderate or severe adverse events were described in the reports that provided safety data. In the sham-controlled randomized trial, no serious adverse events were observed; four intervention participants showed

TABLE 5. Reported adverse events and safety-monitoring methods.

Study	Adverse Events Reported	Serious Adverse Events	Discontinuations due to adverse events	Safety Monitoring
Leisman/ Machado cohort, 2018–2020[13-15]	No side effects necessitating discontinuation reported.	NR	None	NR
Surapaty et al., 2020[20]	No side effects reported	None	None	NR
Pallanti et al., 2022[17]	Occasional headaches (n = 2, 9.5%)	None (no seizures, syncope, or neurological complications)	None	Weekly assessment of AEs and vital signs
Elsheikh et al., 2023[19]	Parents reported no adverse effects.	None	None	NR
Fradkin et al., 2024[16]	Overexcitement (n = 4), mild headaches (n = 2), transient tics (n = 1)	None	One withdrawal (unconfirmed seizure, sham group)	Weekly parental interviews
Fradkin et al., 2025[18]	Headaches (n = 4), hyperactivity (n = 17)	None	None	NR

Abbreviations: AEs = adverse events; IRB = Institutional Review Board; FDA = US Food and Drug Administration; NR = not reported

transient overexcitement, two reported mild headache, and one participant in the sham group withdrew after a possible but unconfirmed absence seizure.[16] Because the event occurred in a participant who did not receive active NIR light exposure, attribution to PBM-related optical stimulation is unlikely. It was described as unconfirmed because it was based on caregiver report of staring-like behavior and was not confirmed by EEG recording during the event. The original report did not provide sufficient detail to determine whether procedural stress or the research environment contributed to the event. In the open-label study, no moderate or severe side effects were reported; among 22 completers, four experienced headache and 17 had parent reported hyperactivity at least once during treatment.[18] Pallanti et al.[17] reported no dropouts, no seizures, syncope, or neurological complications, and occasional headache in 2 of 21 participants (9.5%). Elsheikh et al.[19] described laser acupuncture as safe and reported no side effects. Surapaty et al.[20] likewise reported no side effects and no treatment discontinuations across 18 sessions. Safety reporting in the LLLT studies was less detailed, especially in the follow-up analyses, which limited assessment of longer-term tolerability.[13-15]

DISCUSSION

This scoping review mapped the currently available literature on PBM for core symptoms of ASD and its safety in children and adolescents. Among the eight included studies, all of which were available in full text, PBM was consistently associated with an improvement in autism-related outcomes, and no serious treatment-related adverse events were reported; however, safety monitoring was incomplete and inconsistent.[13-20] However, the evidence base remains preliminary and should be interpreted cautiously because of substantial heterogeneity in study design, intervention protocols, outcome measures, and reporting quality.

A notable finding is that positive results were reported in different PBM modalities and across both clinician-rated and caregiver-reported outcomes.[13-20] At the same

time, the apparent consistency of the benefit should not be overinterpreted. Several studies were small, some were uncontrolled or retrospective, and two articles were secondary analyses of the same underlying LLLT cohort rather than independent replications.[13-15] In addition, one of the placebo-controlled laser acupuncture trials delivered concurrent sensory-occupational integrative therapy in both groups, making isolation of the specific PBM effect more difficult even though between-group differences favored verum treatment.[20] The credibility of blinding also warrants closer scrutiny, particularly in laser acupuncture studies. Although a sham laser can function as a plausible placebo control because laser acupuncture often produces minimal somatic sensation, successful masking cannot be assumed, especially when visible light cues or device-related expectations may differ between groups. In the LLLT studies using a 635- nm Erchonia® laser, the sham device was externally identical and reproduced some device-related cues, such as acoustic signals and indicator lights, while not delivering therapeutic laser exposure.[13-15] However, it was not clearly reported whether the sham device also reproduced the visible red-light cue from the active laser. In the absence of explicit blinding assessment, incomplete reporting of sham procedures leaves open the possibility of expectancy and performance bias.[21] Future trials should clearly report whether sham devices reproduce visible light, device sounds, treatment duration, therapist contact, and other procedural cues while remaining therapeutically inactive. Therefore, the body of evidence is promising but not yet cumulative in a robust confirmatory sense.

Controlled efficacy signals were seen in more than one design. Fradkin et al.[16] demonstrated a 7.23 point between-group difference in CARS change and a higher proportion of participants reaching the prespecified responder threshold in the intervention group. A 4.5-point improvement on CARS-2 has been proposed through expert elicitation as a minimum clinically relevant change[22]; however, this threshold was not prospectively validated in the included PBM trials. Accordingly, responder rates based on this cutoff should be interpreted as exploratory. This finding should not be interpreted as demonstrating superiority over established behavioral interventions, since no head-to-head trials were available and effect estimates across behavioral intervention meta-analyses are typically reported using different outcome constructs and standardized metrics rather than directly comparable CARS point changes.[23] Surapaty et al.[20] also found substantially greater odds of improvement in comprehension, expression, and social interaction with verum laser puncture than with placebo.

Another key finding is the marked heterogeneity of the PBM protocols. The included literature encompassed transcranial devices using pulsed near infrared light, low level laser therapy directed to skull base or temporal regions, and laser acupuncture approaches.[13-20] Wavelength, treatment site, session duration, treatment frequency, cumulative exposure, and treatment setting all varied substantially. This heterogeneity limits the comparability between studies and prevents any firm conclusion about the optimal PBM modality, dose, or treatment schedule for children and adolescents with ASD.

The mechanistic findings are also of interest but remain exploratory. Two studies by Fradkin et al.[16,18] suggested that PBM may influence cortical electrophysiology, with reductions in lower frequency activity and increases in selected higher frequency bands, and one of these studies found correlations between EEG changes and symptom improvement. Elsheikh et al.[19] also reported a post-treatment decrease in plasma BDNF after laser acupuncture. This finding is intriguing, but should be interpreted cautiously. Peripheral BDNF findings in ASD have been inconsistent between studies, although meta-analytic data suggest that, on average, children with ASD may have higher peripheral BDNF levels than controls.[24] From this perspective, a post-treatment decrease could hypothetically reflect partial normalization rather than harm; however, this remains speculative because peripheral BDNF findings are heterogeneous between studies, peripheral BDNF levels may not directly reflect central nervous system BDNF activity, and their relationship to clinical improvement in core symptoms of ASD has not been established. These observations provide a biological context for possible treatment effects, but they have not yet established a mechanism, and their relationship to clinically meaningful improvement in core symptoms of ASD requires confirmation in larger and methodologically stronger studies.

With respect to safety, the currently available data are cautiously reassuring. No moderate or severe adverse events were reported in the studies that described safety outcomes, and the most commonly reported adverse events were mild headache, transient overexcitement, and parent reported hyperactivity.[13,16-20] However, adverse event monitoring was not reported with equal detail in all studies, and longer-term safety data remain limited even when follow-up outcomes were available.[13-15] No serious treatment-related adverse events were reported; however, small cohorts and incomplete, inconsistent adverse-event monitoring preclude conclusions about the short- or long-term safety profile of PBM.

This review has several limitations. First, only eight

studies met the inclusion criteria. Second, the included evidence was methodologically heterogeneous and included small trials, retrospective data, and follow-up or post hoc analyses of prior cohorts.[13-20] Third, although all included studies were retrievable in full text, some still lacked complete reporting of technical PBM parameters, safety monitoring procedures, and adverse-event causality assessment. This incomplete reporting limits reproducibility, hinders comparison across studies, and makes interpretation of dose-response relationships and safety attribution more difficult. Fourth, some interventions were delivered alongside concurrent co-interventions, which made attribution of benefit specifically to PBM less certain.[13,20] In addition, the adequacy of participant and caregiver blinding in laser acupuncture studies remains uncertain because formal blinding assessment was not clearly reported. Fifth, because this was a scoping review, formal risk of bias assessment was not used to exclude studies. These limitations reduce certainty about the magnitude and generalizability of the reported effects.

Together, the available evidence suggests that PBM is a promising but still investigational intervention for children and adolescents with ASD. Future studies should prioritize adequately powered randomized sham-controlled trials, clearer and more complete reporting of PBM parameters, explicit separation of core ASD outcomes from associated behavioral outcomes, standardized outcome measurement in the communication and autism severity domains, and systematic monitoring of adverse events and the durability of benefit over time. Independent replication across non-overlapping cohorts will also be important before PBM can be considered an established treatment option.

CONCLUSIONS

PBM has been evaluated in small, heterogeneous pediatric studies that reported signals of improvement in ASD-related outcomes. No serious treatment-related adverse events were reported, but safety monitoring was incomplete. However, the available literature remains preliminary and heterogeneous, with limited high-quality controlled evidence. PBM should therefore be regarded as a promising but not yet established intervention for pediatric ASD. Future studies should prioritize standardized PBM protocols with clearly defined treatment parameters and adequately powered sham-controlled trials with rigorous blinding and systematic adverse-event monitoring.

Data Availability Statement

This study is a scoping review and did not generate any primary datasets. All sources cited in this review are publicly available in the published literature and can be accessed through the referenced journals and databases.

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Conflict of Interest

The authors declare that they do not have conflicts of interest.

Registration Number of Clinical Trial

Not applicable because this study was a scoping review and was not a clinical trial.

Author Contributions

Conceptualization: PW; Investigation: PW, NK, SB; Data curation: PW; Validation: NK, SB; Writing – original draft: PW; Writing – review & editing: PW, NK, SB. All authors discussed the findings, critically reviewed the manuscript and approved the final version of the manuscript.

Use of Artificial Intelligence

We used ChatGPT and Grammarly to check grammar and improve readability in some parts of the manuscript. Data collection, analysis, interpretation, and figure creation were all performed by the authors.

Institutional Review Board Statement

Ethical approval was not required because this study was a scoping review of previously published literature and did not involve direct contact with human participants or access to identifiable personal data.

REFERENCES

1. Lord C, Charman T, Havdahl A, Carbone P, Anagnostou E, Boyd B, et al. The Lancet Commission on the future of care and clinical research in autism. Lancet. 2022;399(10321):271-334.
2. World Health Organization. Autism. 2025. Available at: https://www.who.int/news-room/fact-sheets/detail/autism-spectrum-disorders (Accessed on Apr 16, 2026).
3. Shaw KA, Williams S, Patrick ME, Valencia-Prado M, Durkin MS, Howerton EM, et al. Prevalence and early identification of autism spectrum disorder among children aged 8 years — Autism and Developmental Disabilities Monitoring Network,

16 sites, United States, 2022. MMWR Surveill Summ. 2025;74(2): 1-22.
4. Asia-Pacific Development Center on Disability. Autism at a Glance in ASEAN Under the Autism Mapping Project in the ASEAN Region: Part II Country Profiles. Bangkok, Thailand: Asia-Pacific Development Center on Disability Foundation; 2020. 428 p.
5. Teekavanich S, Wannapaschaiyong P. Factors associated with age at diagnosis of autism spectrum disorder in pediatric patients at Sawanpracharak Hospital, Thailand. Siriraj Med J. 2023;75(11): 778-83.
6. Chantaraseno S, Amornphetchakul T, Wannapaschaiyong P. Socioeconomic factors and clinical characteristics associated with age at autism spectrum disorder diagnosis. Siriraj Med J. 2024;76(9):589-94.
7. Hyman SL, Levy SE, Myers SM; Council on Children with Disabilities, Section on Developmental and Behavioral Pediatrics. Identification, evaluation, and management of children with autism spectrum disorder. Pediatrics. 2020;145(1):e20193447.
8. Lin H, Li D, Zhu J, Liu S, Li J, Yu T, et al. Transcranial photobiomodulation for brain diseases: review of animal and human studies including mechanisms and emerging trends. Neurophotonics. 2024;11(1):010601.
9. Akhtar A, Rahaman SKB. The interplay of oxidative stress, mitochondrial dysfunction, and neuroinflammation in autism spectrum disorder: behavioral implications and therapeutic strategies. Brain Sci. 2025;15(8):853.
10. Usui N, Kobayashi H, Shimada S. Neuroinflammation and oxidative stress in the pathogenesis of autism spectrum disorder. Int J Mol Sci. 2023;24(6):5487.
11. Peters MDJ, Marnie C, Tricco AC, Pollock D, Munn Z, Alexander L, et al. Updated methodological guidance for the conduct of scoping reviews. JBI Evid Synth. 2020;18(10):2119-2126.
12. Tricco AC, Lillie E, Zarin W, O'Brien KK, Colquhoun H, Levac D, et al. PRISMA extension for scoping reviews (PRISMA-ScR): checklist and explanation. Ann Intern Med. 2018;169(7):467-73.
13. Leisman G, Machado C, Machado Y, Chinchilla-Acosta M. Effects of low-level laser therapy in autism spectrum disorder. Adv Exp Med Biol. 2018;1116:111-30.
14. Machado C, Machado Y, Chinchilla M, Ariosa-Acuna MC, Foyaca-Sibat H. Low lever laser therapy (LLLT) in autism: age group analysis. Internet J Neurol. 2019;21(1).
15. Machado C, Machado Y, Chinchilla M, Machado Y. Follow-up assessment of autistic children 12 months after finishing low lever laser therapy. Internet J Neurol. 2020;21(2).
16. Fradkin Y, De Taboada L, Naeser M, Saltmarche A, Snyder W, Steingold E. Transcranial photobiomodulation in children aged 2-6 years: a randomized sham-controlled clinical trial assessing safety, efficacy, and impact on autism spectrum disorder symptoms and brain electrophysiology. Front Neurol. 2024;15:1221193.
17. Pallanti S, Di Ponzio M, Grassi E, Vannini G, Cauli G. Transcranial photobiomodulation for the treatment of children with autism spectrum disorder (ASD): a retrospective study. Children (Basel). 2022;9(5):755.
18. Fradkin Y, Anguera JA, Simon AJ, De Taboada L, Steingold E. Transcranial photobiomodulation for reducing symptoms of autism spectrum disorder and modulating brain electrophysiology in children aged 2-7: an open label study. Front Child Adolesc Psychiatry. 2025;4:1477839.
19. Elsheikh MS, Ashaat EA, Ramadan A, Mohamed NH, Elaraby NM, El-Hariri HM, et al. Efficacy of laser acupuncture for children with autism spectrum disorder: clinical, molecular, and biochemical study. Pediatr Neurol. 2023;147:44-51.
20. Surapaty IA, Simadibrata C, Rejeki ES, Mangunatmadja I. Laser acupuncture effects on speech and social interaction in patients with autism spectrum disorder. Med Acupunct. 2020;32(5): 300-9.
21. Irnich D, Salih N, Offenbächer M, Fleckenstein J. Is sham laser a valid control for acupuncture trials? Evid Based Complement Alternat Med. 2011;2011:485945.
22. Jurek L, Baltazar M, Gulati S, Novakovic N, Nunez M, Oakley J, et al. Response (minimum clinically relevant change) in ASD symptoms after an intervention according to CARS-2: consensus from an expert elicitation procedure. Eur Child Adolesc Psychiatry. 2022;31(8):1-10.
23. Sandbank M, Bottema-Beutel K, LaPoint SC, Feldman JI, Barrett DJ, Caldwell N, et al. Autism intervention meta-analysis of early childhood studies (Project AIM): updated systematic review and secondary analysis. BMJ. 2023;383:e076733.
24. Zheng Z, Zhang L, Zhu T, Huang J, Qu Y, Mu D. Peripheral brain-derived neurotrophic factor in autism spectrum disorder: a systematic review and meta-analysis. Sci Rep. 2016;6:31241.