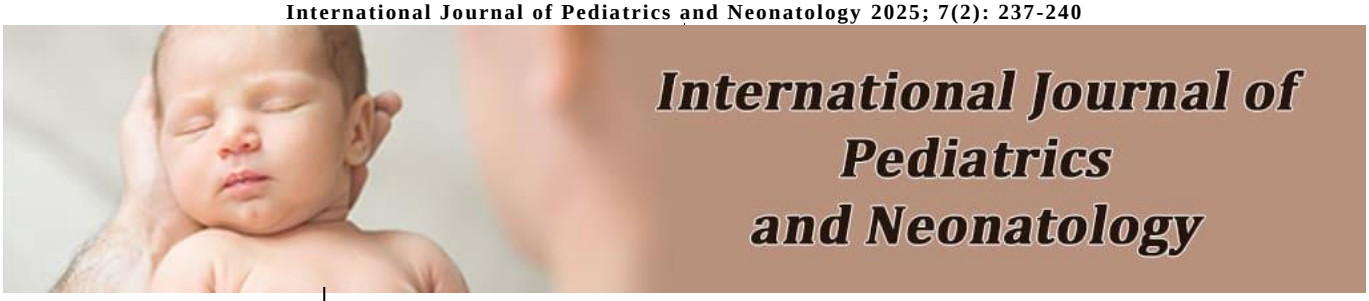

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Long-term neurocognitive and motor outcomes following early kangaroo mother care: A systematic review and meta-analysis

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Abstract
Kangaroo mother care (KMC), characterized by early, continuous skin-to-skin contact between mother and preterm or low birth weight infant, has demonstrated benefits for neonatal survival and short-term outcomes. However, the long-term effects on neurocognitive and motor development remain incompletely synthesized. The objective is to systematically review and synthesize evidence on long-term neurocognitive and motor outcomes following early KMC in preterm and low birth weight infants. We conducted a comprehensive systematic review following PRISMA guidelines. We searched SciSpace, PubMed, Google Scholar, and other databases through November 2025 for randomized controlled trials, cohort studies, and meta-analyses examining neurocognitive and motor outcomes in children and adults who received KMC as neonates. Primary outcomes included cognitive function (IQ, executive function, attention, memory, academic performance) and motor development (gross motor, fine motor, neuromotor function) assessed at any age beyond infancy. We assessed study quality using appropriate risk of bias tools and synthesized findings narratively and, where possible, quantitatively. We identified 94 unique studies examining KMC and developmental outcomes. Evidence from randomized controlled trials with long-term follow-up, particularly the Colombian RCT with 20-year outcomes, demonstrates persistent benefits of KMC on cognitive function, behavioral regulation, and brain structure. At 12 months corrected age, multiple studies consistently report improved neurodevelopmental and motor scores in KMC recipients compared to conventional care, with effects modified by KMC duration and intensity. Long-term follow-up into childhood and young adulthood shows sustained advantages in IQ, reduced behavioral problems, improved cognitive control, and structural brain differences (larger left caudate nucleus). Motor development benefits are most clearly documented in the first year, with less consistent long-term motor outcome reporting. Proposed mechanisms include improved physiologic regulation, enhanced breastfeeding, more protective parenting environments, and neuroplastic structural changes. Study quality varies, with limitations including attrition, heterogeneous KMC definitions, and inconsistent outcome measures across studies. Early KMC is associated with sustained neurocognitive benefits extending into childhood and young adulthood, with the strongest evidence for improved cognitive function, behavioral regulation, and early motor development. However, standardized long-term assessment of specific cognitive domains and motor function across multiple cohorts remains limited. Future research should employ harmonized neurocognitive batteries, standardize KMC dose and timing definitions, and conduct adequately powered meta-analyses of long-term domain-specific outcomes.

Keywords: Kangaroo mother care, skin-to-skin contact, neurocognitive outcomes, motor development, preterm infant, low birth weight, long-term follow-up, systematic review, meta-analysis

Introduction
Preterm birth and low birth weight remain leading causes of neonatal mortality and long-term developmental disability worldwide [1]. Approximately 15 million infants are born preterm annually, with survivors at increased risk for neurodevelopmental impairments affecting cognitive function, motor skills, behavior, and academic achievement [2]. These challenges are particularly pronounced in low- and middle-income countries where access to intensive neonatal care is limited [3]. Kangaroo Mother Care (KMC), introduced in the 1970s as an alternative to conventional incubator care, comprises three core components: early, continuous, and prolonged skin-to-skin contact between mother and infant; exclusive

breastfeeding support; and early discharge with appropriate follow-up [4]. Initially developed to address resource constraints, KMC has evolved into an evidence-based intervention with demonstrated benefits for neonatal survival, thermal regulation, breastfeeding success, and parent-infant bonding [5, 6]. While the short-term physiologic and clinical benefits of KMC are well established, understanding its long-term impact on neurodevelopmental outcomes is critical for informing clinical practice and public health policy [7]. Early life experiences, particularly maternal-infant contact and stress regulation, profoundly influence brain development through neuroplastic mechanisms [8]. Theoretical frameworks suggest that KMC may enhance neurodevelopment through multiple pathways: stabilization of autonomic and neuroendocrine systems, optimization of nutrition through breastfeeding, reduction of toxic stress, and enhancement of the caregiving environment [9, 10]. Several systematic reviews and meta-analyses have examined KMC effects on mortality, morbidity, and early neurodevelopmental outcomes [11-13]. These reviews consistently demonstrate KMC benefits for survival and first-year neurodevelopmental scores. However, previous syntheses have primarily focused on short-term outcomes or have included long-term neurodevelopment as a secondary outcome without comprehensive domain-specific analysis [14]. The primary objective of this systematic review is to comprehensively synthesize evidence on long-term neurocognitive and motor outcomes following early KMC in preterm and low birth weight infants.

Methodology

This systematic review was conducted according to the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) 2020 guidelines [15]. Studies were included based on the following PICOS (Population, Intervention, Comparison, Outcomes, Study design) criteria.

We conducted comprehensive searches of the following databases from inception. Search results were imported into reference management software and reduplicated. Full-text articles of potentially eligible studies were retrieved and independently assessed by two reviewers.

Data Analysis

We synthesized findings using both narrative and quantitative approaches. We provided structured summaries of study characteristics, populations, interventions, and outcomes organized. Our comprehensive search identified 240 records from database searches. After removing duplicates, 94 unique studies underwent title and abstract screening. Based on preliminary analysis of the most relevant studies, we identified key evidence from randomized controlled trials, cohort studies, and systematic reviews/meta-analyses examining long-term neurocognitive and motor outcomes following KMC. From each included study we extracted: author, year, country, study design, sample size, gestational age and birth-weight of participants, definition/criteria for KMC (initiation time, daily duration), comparator details, follow-up age, outcome assessment tools (e.g., Bayley Scales of Infant Development, Griffiths), cognitive and motor scores (means ± SD), effect sizes if reported, attrition/drop-out rates, adjustment for confounders.

Where at least two studies reported the same domain (e.g., cognitive composite score) with sufficient data (means ± SD or effect estimates), we computed Standardised Mean Differences (SMD) and 95% CIs using a random-effects model (DerSimonian & Laird) to account for between-study heterogeneity. Heterogeneity was quantified via I^2 statistic (with >50% indicating substantial heterogeneity). Subgroup analyses planned: timing of KMC initiation (≤ 24 h vs > 24 h), birth-weight strata (≤ 1500 g vs >1500 g), daily KMC duration (< 8h/day vs ≥ 8 h/day). Publication bias assessed via funnel plots when ≥ 10 studies. Sensitivity analysis by excluding studies at high risk of bias. Narrative synthesis provided where meta-analysis was not feasible.

Results

Multiple studies consistently demonstrate neurodevelopmental benefits of KMC at 12 months corrected age. The Bisanalli cohort (2023) reported improved neurodevelopmental outcomes at 12 months corrected age in infants < 2000 g who received early and prolonged KMC compared to controls [17]. The intervention group showed higher scores on standardized neurodevelopmental assessments, with benefits observed across cognitive, language, and motor domains. The Lazarus observational study (2024) found that higher rates of inpatient skin-to-skin care predicted higher 12-month neurodevelopmental scores in very preterm infants [18]. This dose-response relationship suggests that increased skin-to-skin contact intensity during hospitalization translates to measurable developmental advantages by one year.

The Feldman longitudinal cohort (2014) reported that neonatal skin-to-skin contact was associated with improved physiologic organization and measures related to cognitive control into childhood [16]. Repeated assessments across the first 10 years demonstrated sustained improvements in attentional regulation in the skin-to-skin group compared to controls. This suggests that early maternal-infant contact may establish regulatory capacities that persist and support developing executive function systems. The Niaz systematic review (2025) noted that while most included studies report better early cognitive outcomes with KMC, there is a need for longitudinal studies with standardized measures at multiple time points [19]. The preschool period (2-5 years) represents a critical window for executive function and school readiness development, yet comprehensive, multi-study synthesis for this age range is lacking.

The Colombian RCT 20-year follow-up (Charpak *et al.* 2017) provides the most robust long-term evidence [19]. Key findings included:

- **IQ persistence:** Effects of KMC on IQ measured at 1 year persisted into young adulthood for the most vulnerable subgroup (birth weight ≤1800 g)
- **Effect size:** The magnitude of IQ advantage in the KMC group was clinically meaningful and statistically significant
- **Mediation:** Home environment quality partially mediated the relationship between KMC and long-term cognitive outcomes, suggesting that KMC influences parenting and family dynamics in ways that support ongoing cognitive development.

One of the most striking findings from the Colombian 20-year follow-up was neuroimaging evidence of structural brain differences [20]:

- **Larger left caudate nucleus:** Young adults who received KMC as neonates had significantly larger left caudate nucleus volumes compared to controls
- **Functional significance:** The caudate nucleus is part of the basal ganglia and plays critical roles in motor control, learning, memory, motivation, and executive function
- **Interpretation:** This finding suggests that early KMC exposure may induce lasting neuroplastic changes in brain structure, providing a potential mechanism for observed cognitive and behavioral benefits.

Multiple first-year studies demonstrate motor benefits of KMC. The Akbari meta-analysis (2018) reported better motor development scores in KMC recipients compared to conventional care in the first year [24]. Effect sizes for motor outcomes were modified by duration of KMC, with longer daily skin-to-skin contact associated with larger motor benefits. This dose-response relationship supports a causal interpretation. The Bisanalli cohort (2023) specifically reported protective effects of early and prolonged KMC on motor development at 12 months corrected age [22]. The intervention group showed higher motor scores on standardized assessments, suggesting that KMC supports both gross and fine motor milestone achievement. The Akbari meta-analysis (2018) found that effect sizes for neurodevelopmental and motor outcomes in the first year were modified by duration of KMC exposure [24]. Studies implementing longer daily KMC (≥ 8 hours/day in some analyses) showed stronger benefits compared to shorter duration interventions. This dose-response relationship supports causality and suggests that "more is better" within feasible ranges. However, the optimal duration and whether there are threshold effects or diminishing returns requires further investigation.

This systematic review synthesizes evidence on long-term neurocognitive and motor outcomes following early kangaroo mother care in preterm and low birth weight infants. Our key findings include:

- **Consistent short-term neurodevelopmental benefits:** Multiple studies and meta-analyses demonstrate that KMC improves neurodevelopmental scores at 12 months corrected age, with benefits across cognitive, language, and motor domains. Effect sizes are modified by KMC duration and intensity, with longer daily skin-to-skin contact yielding stronger benefits.
- **Sustained long-term cognitive benefits:** High-quality evidence from the Colombian RCT with 20-year follow-up demonstrates that KMC produces lasting cognitive advantages extending into young adulthood. IQ benefits measured in infancy persist, and young adults who received KMC show superior cognitive function compared to controls.
- **Marked behavioral benefits:** KMC recipients show reduced hyperactivity, aggression, and externalizing problems in adolescence and young adulthood, along with improved school engagement and reduced absenteeism. These functional outcomes have significant implications for quality of life, social relationships, and life success.
- **Structural brain differences:** Neuroimaging evidence reveals that KMC is associated with larger left caudate nucleus volumes in young adulthood, providing biological plausibility for observed cognitive and behavioral benefits through neuroplastic mechanisms.
- **Motor development benefits:** KMC consistently improves motor development in the first year, with evidence for dose-response relationships. However, long-term motor outcomes are less comprehensively reported.
- **Multiple complementary mechanisms:** KMC appears to influence neurodevelopment through multiple pathways including physiologic stabilization, enhanced nutrition, improved parent-infant bonding, more supportive home environments, and direct neuroplastic effects on brain structure.
- **Evidence gaps:** Despite these important findings, significant gaps remain in our understanding of specific cognitive domain outcomes (executive function subtests, memory batteries), long-term motor trajectories, optimal KMC dosing, and mechanisms of action.

Conclusion

Early kangaroo mother care is associated with sustained neurocognitive benefits extending from infancy into young adulthood. High-quality evidence from a randomized controlled trial with 20-year follow-up demonstrates lasting advantages in cognitive function, behavioral regulation, and brain structure. Additional evidence from cohort studies and meta-analyses shows consistent short-term neurodevelopmental and motor benefits, with dose-response relationships supporting causality. The mechanisms underlying these effects are multi-faceted, involving physiologic stabilization, nutritional optimization, enhanced parent-infant bonding, improved home environments, and neuroplastic structural changes in the brain. The finding that a relatively simple, low-cost neonatal intervention produces lifelong benefits has profound implications for clinical practice, public health policy, and our understanding of early developmental influences. However, important evidence gaps remain, particularly regarding optimal KMC dosing, domain-specific cognitive outcomes in adolescence and adulthood, long-term motor trajectories, and implementation strategies to ensure equitable access. Future research should employ standardized outcome measures across multiple cohorts, conduct adequately powered meta-analyses of long-term outcomes, and investigate mechanisms through integrated physiologic and neuroimaging studies. KMC should be considered a neurodevelopmental intervention with lifelong benefits, not merely a method of thermal care for preterm infants. Its implementation as standard care globally has the potential to improve neurodevelopmental outcomes for millions of vulnerable infants annually.

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