

Neurodevelopmental outcomes and occupational participation of preterm children at school age: a scoping review

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Abstract

Preterm children may experience major challenges that affect their occupational participation and daily functioning, especially at school age. This scoping review aims to examining and synthesizing the available literature about adverse neurodevelopmental outcomes and occupational participation restrictions of preterm children born < 37 weeks of gestation. The MEDLINE, Science Direct, CINAHL databases were searched from January 2013 to December 2023, for published cohort studies that assessed the neurodevelopmental outcomes and occupational participation of school-aged preterm children, compared to full-term born peers. Out of 6631 identified articles, 13 studies met the inclusion criteria and involved 958 preterm children, aged 6-10 years old. Studies included in the current scoping review reported adverse neurodevelopmental outcomes, such as cognitive impairment, executive function and sensory processing deficits, emotional and behavioral problems, language and visual perception difficulties, as well as occupational participation restrictions, like feeding difficulties, academic challenges and peer relationship problems. Findings suggest that neurodevelopmental deficits and occupational participation restrictions, especially in extremely preterm children, not only exist in early childhood but persist during school age. Future research should focus on exploring potential differences or patterns in neurodevelopmental outcomes and occupational participation between preterm groups with different gestational age ranges.

Keywords: preterm, neurodevelopmental outcomes, occupational participation, children, school age

Resultados do neurodesenvolvimento e participação ocupacional de crianças prematuras na idade escolar: uma revisão de escopo

Resumo

As crianças nascidas pré-termo pode enfrentar grandes desafios que afetam sua participação ocupacional e funcionamento diário, especialmente na idade escolar. Esta revisão de escopo tem como objetivo examinar e sintetizar a literatura disponível sobre resultados adversos de neurodesenvolvimento e restrições de participação ocupacional de crianças nascidas pré-termo com menos de < 37 semanas de gestação. Os bancos de dados MEDLINE, Science Direct e CINAHL foram pesquisados de janeiro de 2013 a dezembro de 2023, em busca de estudos de coorte publicados que avaliaram os resultados do neurodesenvolvimento e a participação ocupacional de crianças pré-termo em idade escolar, em comparação com seus pares nascidos a termo. Dos 6.631 artigos identificados, 13 estudos atenderam aos critérios de inclusão e envolveram 958 crianças pré-termo, com idades entre 6 e 10 anos. Os estudos relataram resultados adversos de neurodesenvolvimento, como comprometimento cognitivo, função executiva e déficits de processamento sensorial, problemas emocionais e comportamentais, dificuldades de linguagem e percepção visual, bem como restrições de participação ocupacional, como dificuldades de alimentação, desafios acadêmicos e problemas de relacionamento com colegas. Os resultados sugerem que os déficits de neurodesenvolvimento e as restrições de participação ocupacional, especialmente em crianças extremamente pré-termo, não só existem na primeira infância, mas persistem durante a idade escolar. Pesquisas futuras devem se concentrar na exploração de possíveis diferenças ou padrões nos resultados do

neurodesenvolvimento e na participação ocupacional entre grupos de pré-termo com diferentes faixas de idade gestacional.

Palavras-chave: pré-termo, resultados de neurodesenvolvimento, participação ocupacional, crianças, idade escolar

1. Introduction

The incidence of premature birth has been increasing over the past decade, as reported by UNICEF in 2023. According to the World Health Organization, approximately 13.4 million preterm infants are born before 37 weeks of gestation annually (WHO, 2023). Prematurity is the leading cause of mortality in children, accounting for more than 1 in 5 deaths occurring in children before the age of five (Pan American Health Organization, 2023).

The growth of perinatal care services in neonatal intensive care units (NICUs) has been linked to a reduction in mortality rates among extremely preterm infants, even when considering that 76% of all preterm births fall into this category (Norman et al., 2019). The development of technological equipment related to medical care, along with the educational and training provisions for nursing staff in neonatal clinics, is beneficial in improving the health status of preterm infants (Pearlman, 2022).

Nevertheless, the decrease in mortality rates among preterm infants does not necessarily lead to a reduction in the developmental deficits they may experience during childhood and adulthood (Linsell et al., 2018). Recent cohort and prospective studies highlight deficits in preterm school-age children's skills areas such as motor and cognitive functioning, visual perception and executive functions, while emotional as well as behavioral problems are also reported (Allotey et al., 2017; Doyle et al., 2021; Roze et al., 2021).

Previous review studies (Synnes; Hicks, 2018; Song, 2022) attempted to address the neurodevelopmental outcomes of school-aged preterm children, aiming at specific skill domains, like cognitive ability and behavior. However, no scoping or systematic review studies were identified in recent literature that specifically investigated the occupational participation of preterm children at school age. A number of studies suggest that school-aged preterm children may experience difficulties in academic achievement, peer relationships and self-care (Killeen et al., 2014).

This scoping review aims to highlight adverse neurodevelopmental outcomes and occupational participation restrictions of preterm children during school age. Specifically, it is expected to gather existing knowledge from very recent studies on 1) the existence of specific deficits in the perceptual and cognitive-learning skill domains, as well as the preterm children's behavioral and emotional manifested problems, and 2) the impact of prematurity on childhood occupations such as self-care skills, academic achievement and social relationships with peers. The findings will not only consolidate existing knowledge but also highlight gaps in the literature, paving the way for future research and targeted interventions to enhance the well-being and development of this population.

2. Materials and Methods

The framework for scoping studies (Arksey; O'Malley, 2005; Levac et al., 2010) is underpinned by six stages as follows: 1) Identifying the research question, 2) Identifying the relevant studies, 3) Study selection, 4) Charting the data, 5) Collating, summarizing and reporting the results, 6) Consultation (optional).

2.1. Identifying the research questions

This scoping review intends to address the following review questions: a) Which are the adverse neurodevelopmental outcomes of school-aged preterm children in the recent literature? b) Which are the occupational participation restrictions of school-aged preterm children in the recent literature?

2.2. Identifying the relevant studies and selecting studies

This scoping review was conducted following the preferred reporting items for scoping reviews and meta-analyses (PRISMA) guidelines (Tricco et al., 2018). The study's PICO (population, intervention, comparison and outcome) framework focused on searching for differences between school-aged preterm children and their full-term born peers regarding neurodevelopmental outcomes (cognitive ability, behavior, adaptive functioning)

(Levac et al., 2010). The MEDLINE, CINAHL and Science Direct databases were searched for articles published in English between January 2013 and December 2023, in order to capture the available data in the last decade.

The search strategy consisted of controlled search terms relevant to the search topic, such as “preterm”, “children”, “school-age”, “developmental” and “cohort”. Inclusion criteria for studies were a) study sample consisting of preterm children, both male and female, aged 6-12 years old with < 37 weeks of gestation; b) use of a term-born comparison group; c) neurodevelopmental outcomes and occupational participation assessed by validated, standardized tests and reporting mean (SD) scores; d) cohort, prospective or cross-sectional studies published in peer-reviewed journals in English.

Table 1. PICO’s framework for research question (Levac et al., 2010).

Question Components	Components in review
P – Patient or Population	Preterm children < 37 weeks of gestation, at school age
I – Intervention; Prognostic Factor; Exposure	Neurodevelopmental outcomes and occupational performance
C – Comparison	Neurodevelopmental outcomes of full-term born children
O – Outcomes	Cognitive ability, behavior and emotion, adaptive functioning, peer relationship, academic performance, self care

Source: Authors, 2023.

2.3. Charting the data

Charting of selected articles was undertaken by the first author, as guided by Arksey & O’Malley (2005). This charting process ensured extraction of relevant details including year, author, location of study, objective, study design, study methods, study population, as well as brief summaries of study findings.

2.4. Collating, summarizing and reporting results

The authors independently screened all initially retrieved papers based on their titles and abstracts, followed by a full-text review. This was crosschecked in both phases. The study selection was guided by the review question and inclusion and exclusion criteria. Disagreements were resolved through joint discussion until a consensus was reached, using the predefined criteria for study selection.

For the studies that reported outcomes besides neurodevelopmental abilities or performance and for the data that collected through non standardized tests or in different administration conditions, there was an exclusion process from this scoping review. Additionally, articles that were not available in full text or open access were excluded.

3. Results

In this scoping review, 6631 potential articles were identified via database and citation searches. After reviewing the titles and abstracts, a total of 6618 articles were excluded based on the inclusion and exclusion criteria of PICO’s framework (Levac et al., 2010). This scoping review included a total of 13 articles composed of 958 preterm children and 750 full term children (see Table 1). Included studies conducted in the United States (n = 1), New Zealand (n = 2), Netherlands (n = 3), Switzerland (n = 2), Australia (n = 1), Korea (n = 1), Norway (n = 1), Spain (n = 1) and Turkey (n = 1).

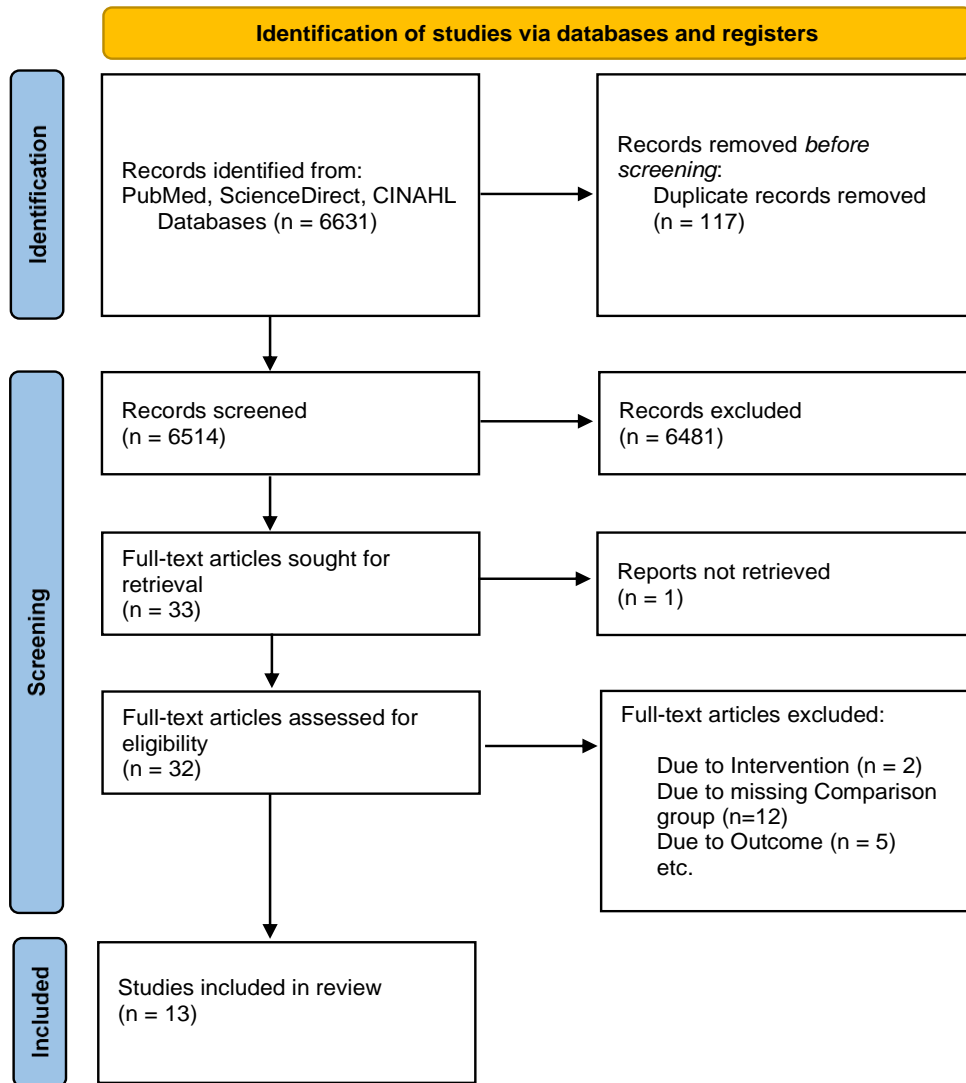


Figure 1. PRISMA extension for scoping reviews flow diagram for article selection by Tricco et al. (2018).

The reviewed articles included reports of several adverse neurodevelopmental outcomes and occupational participation restrictions in preterm children during school age, such as 1) cognitive impairment (Erdei et al., 2020; Kim et al., 2021; Koca; Huri, 2022), 2) executive function deficits (Schnider et al., 2020; Kim et al., 2021; Sawyer et al., 2021), 3) sensory processing difficulties (Bröring et al., 2018), 4) emotional and behavioral problems (Lejeune et al., 2016; Bröring et al., 2018; Ritchie et al., 2018; Schnider et al., 2020; Kim et al., 2021; Sawyer et al., 2021), 5) language deficits (Nguyen et al., 2018), 6) visual perception deficits (Perez-Roche et al., 2016) 7) academic challenges (Twilhaar et al., 2018; Sawyer et al., 2021), 8) feeding problems (Koca; Huri, 2022), 9) peer relationship problems (Lejeune et al., 2016; Ritchie et al., 2018; Schnider et al., 2020), as well as 10) adaptive behavior deficits (Fjørtoft et al., 2015).

Table 2. Findings of included studies.

Author, Date, location	Objective	Study population	Study design	Study Methods	Study findings
Bröring et al., (2018). Netherlands	To investigate sensory processing difficulties	VPT n = 57 at mean gestation age of 30.2 weeks FT n = 56 Assessed at mean age of 9.2 years	Regional cohort study design	Sensory Integration and Praxis Test (SIPT), Multisensory Integration Test (MSIT), Sensory Profile (SP)	VPT children show sensory processing difficulties regarding somatosensory registration and sensory modulation, and preserved multisensory (audio-visual) integration
Bröring et al., (2018). Netherlands	To investigate prevalence, pervasiveness and co-occurrence of symptoms of attention deficit hyperactivity disorder (ADHD) and autism spectrum disorder (ASD) in VPT school-age children	VPT n = 57 at mean gestational age of 30.2 weeks FT n = 57 Assessed at mean age 9.2	Regional cohort study design	DSM-ADHD scale, CBCL (Attention Problems scale), Teacher Report Form (TRF), Parent and Teacher form of Disruptive Behavior Disorders rating scale (Inattention and Hyperactivity/Impulsivity scale), Social Responsiveness Scale (SRS), Parent and Teacher report of Children's Communication Checklist (CCC-2), Social Communication Questionnaire (SCQ), WISC-III	VP-children showed higher levels of parent and teacher reported attention problems, social impairment and compromised communication skills Fair to strong agreement was found between parent and teacher reported ADHD and ASD symptoms, indicating pervasiveness of observed difficulties Co-occurrence of ADHD and ASD symptoms in VP-children was found
Erdei et al., (2020). New Zealand	To examine the predictive accuracy of assessments at 2, 4, 6, and 9 years in identifying preterm children with cognitive impairment by 12 years	VPT n = 103 at ≤ 32 weeks of gestation FT = 109 Assessed at the age of 2, and again at the age of 4,6,9 and 12 years	Prospective regional cohort study design	Bayley Scales of Infant Development, Second Edition (age 2), WPPSI-Revised WISC-IV (ages 9 and 12)	By 12 years, very preterm children were more likely to have severe cognitive impairment compared with children born term. Cognitive risk prediction improves with age. Assessments at 6 years offer optimal diagnostic accuracy.

Fjørtoft et al., (2015). Norway	To examine and compare adaptive behavior in VPT children to their FT peers	PT with CP n = 28 PT non CP n = 10 Both at mean gestational age of 26.4-26.8 weeks FT n = 31 Assessed at 10-11 years of age	Regional cohort study design	Vineland adaptive behavior assessment scale-II (Vineland-II), WISC-III, MABC-2, General Movements Assessment, Assessment of Motor Repertoire	Adaptive Behavior Composite scores were significantly lower in the two PT groups than in the control group The difference was still significant after adjustment for sex, SES, WISC-III and MABC-2
Kim et al., (2021). Korea	To evaluate cognitive and behavioral outcomes of EPT children	EPT n = 71 at 23-32 weeks of gestation FT n = 40 Assessed at 7-8 years of age	Regional cohort study design	Korean WISC-IV, Advanced Test of Attention (ATA), Stroop Color-Word Test, Children's Color Trails Test (CCTT), Wisconsin Card Sorting Test (WCST), Korean CBCL, Korean ADHD Rating Scale (K-ARS)	Mean full-scale intelligence quotient (FSIQ) score in the EPT group was significantly lower than that of the FT control group EPT children group showed significantly worse executive function test results Except for the higher social immaturity subscore in the EPT group, behavior scores were not different between the two groups
Koca & Huri, (2022). Turkey	To investigate feeding problems and cognitive functions of PT and FT children and examine the relationship between them	VPT n = 30 at 30-36 weeks of gestation (mean gestational age of 33 weeks) FT n = 30 Assessed at 6-10 years of age	Regional cohort study design	Screening Tool of Feeding Problems, Dynamic Occupational Therapy Cognitive Assessment,	Feeding problems of PT children are statistically higher than those born at term PT's cognitive functions were statistically weaker It was found that feeding problems and cognitive functions were statistically related in premature children

Lejeune et al., (2016). France	To investigate social understanding and social reasoning abilities in PT children in comparison to their FT peers	VPT n = 102 at mean gestational age of 28.4 weeks FT n = 88 Assessed at 5-7 years of age	Regional cohort study design	Social Resolution Task (SRT), Visual attention subtest of Neuropsychological Assessment (NEPSY), Kaufman Assessment Battery for Children (K-ABC), French adaptation of Peabody Picture Vocabulary Test-Revised (standardized adaptation)	Compared with their full-term born peers, preterm children exhibited difficulties to understand and reason about inappropriate social behavior, particularly for situations related to the transgression of conventional rules. They used more irrelevant information and exhibited less social awareness when reasoning about the transgression of social rules. Variance of the social reasoning tasks could be explained by the general cognitive abilities that were relatively small.
Nguyen et al., (2018). Australia	To investigate language trajectories of VPT children and FT children and examine predictors for the identified trajectories	VPT n = 224 at mean gestational age of 27.5 weeks FT n = 77 Assessed at the age of 2, and again at the age of 5,7 and 13 years	Prospective regional cohort study design	Parent reported-Communication and Symbolic Behavior Scales- development Profile (Social and Speech scales), Kaufman Survey and Early Academic and Language Skills, Clinical Evaluation of Language Fundamentals-4 th Ed. (Core language Index)	The VPT group was 8 times more likely to have a language trajectory that represented poorer language development compared with FT controls Greater social risk and use of allied health services were associated with poorer language development
Perez-Roche et al., (2016). Spain	To evaluate visual cognitive skills in PT children and school performance	PT n = 40 at mean gestational age of 30.8 weeks Assessed at mean age of 8.7 years FT n = 40 Assessed at mean age of 8.9 years	Prospective regional cohort study design	Test of Visual Perceptual Skills (TVPS-3), Test of Visual Analysis Skills (TVAS), parent report questionnaire of school performance	Preterm birth is associated with diminished visual motor integration and figure-ground ability

Ritchie, Bora & Woodward, (2018). New Zealand	To investigate the nature of children's close friendships, peer relations, and bullying experiences	Extremely preterm (EPT) n = 44 at 23-27 weeks of gestation Very preterm (VPT) n = 69 at 28-32 weeks of gestation Full term (FT) n = 109 Prospectively to 12 years of age	Prospective regional cohort study design	40-item Friendship Quality Strengths and Difficulties Questionnaire, 16- item Multidimensional Peer Victimization Scale, Wechsler Intelligence Scale for Children, 4 th Edition- WISC 4, Movement Assessment Battery for Children, 2nd Ed., MABC-2	EPT showed more peer social difficulties than VPT and FT. EPT were 3 times more likely to be rated from parents and students as experiencing problems related to peers. Emotional problems, inattention/hyperactivity, and motor deficits were associated with an increased risk of peer relationship problems.
Sawyer et al., (2021). USA	To examine early executive function (EF) differences in PT children, how a measure of behavioral self-regulation correlates with other measures of EF in children born preterm and how this measure relates to academic outcomes in preterm children	PT n = 33 at 25-32 weeks of gestation FT n = 14 Assessed at the age of 5, and again at the age of 6 and 7 years	Longitudinal cohort study design	Head Toes Knees Shoulders task, Child Behavior Checklist-CBCL, MABC-2, Cambridge Neuropsychological Test Automated Battery (CANTAB) Stop Signal Task and Spatial Working Memory task, Wechsler Preschool and Primary Scale of Intelligence, 4 th Ed. WPSI-IV and the WISC-V.	PT children performed worse in executive function tasks, self-regulation and academic performance measures and exhibited worse motor ability over time

Schnider et al., (2020). Switzerland	To investigate whether executive functions deficits contribute to behavioral problems in VPT children at school-age	VPT n = 38 at 25-32 weeks of gestation FT n = 41 Assessed at 12.9 ± 1.8 years of age		German WISC-IV, CANTAB (Stockings of Cambridge task, Spatial Working Memory task, Intra-/Extradimensional Shift task), German SDQ,	Executive function abilities were poorer in the very preterm compared to the term-born group Parents of VPT children reported more behavioral problems on the SDQ Total Difficulties Score. Increase in behavioral symptoms in VPT group at school-age compared to FT peers may partly be explained by their executive function deficits
Twilhaar et al., (2018). Netherlands	To evaluate the developmental trajectories of arithmetic, reading comprehension and spelling abilities of VPT children and FT children in primary school	VPT n = 52, at <32 weeks of gestation or very low birth weight (<1500 g) FT n = 58 Assessed twice a year in grade 1–5 (halfway, end) and once in grade 6 (halfway or end) of primary school	Longitudinal cohort study design	Academic performance standardized tests by National Institute for Educational Measurement	VP birth was associated with impaired arithmetic, reading comprehension and spelling performance. Deficits apparent in the first grades of primary school did not improve or worsen with progression through later grades. VPT children show academic growth to the same extent as full-term born children, suggesting intact learning abilities. VPT children in general were not able to reach similar performance levels as FT children.
		Total PT n = 958			
		Total FT n = 750			

Note: PT= preterm, VPT = very preterm, EPT = extremely preterm, FT = full-term, CP = cerebral palsy, ASD = Autism Spectrum Disorder, ADHD = Attention Deficit Hyperactivity Disorder. Source: Authors, 2023.

3.1 Adverse neurodevelopmental outcomes

3.1.1. Cognitive impairment

Kim et al. (2021) investigated the cognitive ability of 71 preterm infants born before 30 weeks gestation or <1000 g at birth, compared to a control group of full-term born peers. Using the Korean Wechsler Intelligence Scale (Kwak et al., 2011) for Children-Fourth Edition, it was found that the mean full-scale intelligence quotient (FSIQ) score in the preterm group was significantly lower than the full-term control group (89.1 ± 18.3 SD vs. 107.1 ± 12.7 SD; $p < 0.001$). Additionally, in the preterm group, 26 (37%) children had an FSIQ score below 85, compared to only one child (3%) in the control group.

Regarding specific domains of cognitive ability, Koca & Huri (2022) compared 30 preterm children (mean gestational age 33,47 weeks), aged 6-10, with full-term born peers using the DOTCA-Ch assessment to evaluate cognitive domains, such as orientation, spatial perception, praxis, visuomotor construction and thinking processes. Consequently, preterm children were found to be weaker in all assessed cognitive domains compared to full-term born peers ($p < 0.001$).

Based on the high risk of cognitive impairment in very preterm children, Erdei et al. (2020) examined the predictive accuracy of assessments at 2, 4, 6, and 9 years in identifying preterm children with cognitive impairment by 12 years. For this study, a regional cohort of 103 very preterm children (VPT ≤ 32 weeks' gestation) and 109 full-term born children was conducted. By using age-appropriate, cognitive functioning standardized measures like Bayley Scales of Infant Development, Second Edition (age 2) (Bayley, 1993), Wechsler Preschool and Primary Scale of Intelligence (ages 4 and 6) (Wechsler, 1989) and Wechsler Intelligence Scale for Children, Fourth Edition (ages 9 and 12) (Wechsler, 2003), it was observed that by 12 years, very preterm children were more likely to have severe or any cognitive impairment compared with full-term born children. This study highlighted that cognitive risk prediction improves with age, while assessments at 6 years offer optimal diagnostic accuracy.

3.1.2. Executive functions deficits

In order to examine executive functions in preterm children at school age, Sawyer et al. (2021) compared the performances of 33 preterm children, born in the 25-32 week gestational age range with the performances of full-term born peers. Each assessment included age appropriate executive function tasks, standardized tests and parent-reported questionnaires of executive function, along with behavior problems and academic performance measures, which were given to both groups before starting kindergarten at the age of 5 and again at the age of 6 and 7 years.

According to the study findings, preterm children performed worse on all executive function measures, as well as on all measures about self-regulation, academic outcomes, and motor ability across time. Moreover, the measures between executive function, behavior and academic performance had weak to strong correlations. This study also highlights the predictive value of early EF measures on functional academic outcomes and their potential as targets of effective interventions in this high-risk population.

Kim et al. (2021) examined executive functioning by administering Advanced Test of Attention (ATA) in preterm children and their full-term born peers to measure sustained attention, selective attention and impulsivity. Subsequently, Stroop Color-Word Test was administered to measure the inhibitory control of prepotent behavior, Children's Color Trails Test (CCTT) to measure alternating and sustained visual attention, sequencing, psychomotor speed, cognitive flexibility, planning, and inhibition-disinhibition, as well as Wisconsin Card Sorting Test (WCST) to measure cognitive flexibility. Based on the study findings, the preterm group showed significantly worse in the majority of the executive function test results (ATA, Stroop test, CCTT, WCST). Overall, study findings indicated deficits in inhibition control, sequencing, psychomotor speed, and cognitive flexibility among preterm children.

Schnider et al. (2020), on the other hand, investigated whether executive function deficits contribute to behavioral problems in preterm children and adolescents at school-age. In their study, 38 children and adolescents born very preterm and 41 age-matched full-term born peers were assessed at a mean age of 12.9 years with a comprehensive battery of executive function tests, including working memory, planning, cognitive flexibility, and verbal fluency. At the same time, a Strengths and Difficulties Questionnaire (SDQ) (Goodman, 2001) was given to the parents to report the behavioral problems of their children.

The study findings indicated that executive function abilities were poorer in the very preterm compared to the full-term born group ($p = .005$). Furthermore, from mediation analysis it was shown that the effect of birth status on behavioral problems was significantly mediated by executive function abilities while adjusting for age at assessment, sex, and socioeconomic status. Consequently, the increase in behavioral symptoms in very preterm children at school-age compared to full-term born peers may partly be explained by their executive function deficits.

3.1.3. Sensory processing deficits

Based on the hypothesis about white matter abnormalities in preterm children, Bröring et al. (2018) studied sensory processing skills in school-age preterm children, compared to their full-term born peers. To investigate somatosensory registration, sensory modulation and multisensory integration, 57 very preterm school-age children (mean age = 9.2 years, mean gestational age = 30.2 weeks) were assessed, using a fixed battery of experimental and validated tasks for somatosensory registration (tactile perception, kinesthesia, and graphesthesia), multisensory integration (MultiSensory Integration Test; MSIT), and sensory modulation (Sensory Profile).

Focusing on the somatosensory registration, the very preterm group performed significantly worse on Registration of Light Touch, Position Sense of finger joints and Graphesthesia subtests compared to the control group, while Sensory Discrimination of Touch subtest showed no difference between the two groups. As far as sensory modulation is concerned, the very preterm group obtained lower scores than the full-term born group on the total test score, indicating that very preterm children overall had more sensory modulation difficulties. Study findings point out that more difficulties were found in regulating the individual sensory systems and behavioral responses to sensory input and not in regulating competing sensory inputs in combination with movement and activity level. Moreover, in multisensory integration tasks, it was found that the very preterm group did not significantly differ from the term control group in general task performance of audio-visual integration.

3.1.4. Emotional and behavioral problems

Schnider et al. (2020) focused on examining the behavioral and emotional problems of very preterm children at school age, through the mediating role of executive functions. Along with the comprehensive battery of executive function tests, a Strengths and Difficulties Questionnaire (SDQ) was administered to the parents of both the preterm and control group. In the very preterm group, on average, the Total Difficulties Score was 2.9 points higher than in the full-term born group. On subscale level, more difficulties were observed in the Hyperactivity/Inattention and Emotional Problems domains in the very preterm compared to the full-term born group. No group differences were apparent for the Conduct Problems, Peer Problems, and Prosocial Behavior domains. Overall, study findings indicated the contribution of executive functions to behavior and emotional problems of preterm children at school age.

Bröring et al. (2018) investigated the behavioral problems of the very preterm children as a part of attention deficit hyperactivity disorder (ADHD) and autism spectrum disorder traits. Using questionnaire and diagnostic interview data, parent and teacher-reported symptoms of ADHD and ASD of 57 very preterm children (mean age = 9.2 years, mean gestation age = 30.2 weeks) were compared with 57 gender and age matched full-term born children. Very preterm children showed higher levels of parent and teacher-reported attention problems, social impairment and compromised communication skills. Fair to strong agreement was found between parent and teacher reported ADHD and ASD symptoms, indicating pervasiveness of observed difficulties. Co-occurrence of ADHD and ASD symptoms in very preterm children was found. Lower gestational age was associated with higher ADHD and ASD symptom levels, male sex with higher ADHD symptom levels and lower socioeconomic status with higher ASD symptom levels.

In the study of Kim et al. (2021) about cognitive and behavioral outcomes of school-aged preterm children, on the other hand, the scores of the Korean Child Behavior Checklist (K-CBCL), except for the social problem domain, and the Korean ADHD Rating Scale (K-ARS) were not different between the two groups. Therefore, study findings indicated that, except for social immaturity, the behavioral problems were not different in children.

Lejeune et al. (2016) studied the social understanding and social reasoning abilities in preterm children, as a risk factor of behavioral problems manifestation. A total group of 102 preterm children (mean gestational age = 28.4 weeks) and 88 full-term born children between 5 and 7 years old were assessed, using a social resolution task (SRT) to assess abilities to judge, identify and reason about others' behavior in relation to conventional and moral rules knowledge. According to study findings, very preterm children exhibited difficulties to understand and reason about inappropriate social behavior, particularly for situations related to the transgression of conventional rules, when compared with their full-term born peers. They used more irrelevant information and exhibited less social awareness when reasoning about the transgression of social rules. However, the part of the variance of the social resolution task that could be explained by the general cognitive abilities of preterm children was relatively small.

3.1.5. Language difficulties

About the language functioning of preterm children, Nguyen et al. (2018) attempted to examine its developmental trajectory from 2 to 13 years of age in very preterm children compared with full-term controls. For this reason, two hundred and twenty-four very preterm children (< 30 weeks' gestation) and 77 full-term controls were assessed in language skill domains, such as verbal memory, grammar, semantics, and pragmatic skills. Language functioning was assessed as part of a larger neuropsychological test battery at each follow-up, including early functional communication skills, school readiness, verbal memory, grammar, semantics, expressive vocabulary and pragmatic skills. At each follow-up age, the very preterm group displayed poorer language functioning than the term controls, with the groups exhibiting similar developmental trajectories ($p = .55$). After analysis, preterm children seemed to have no evidence of developmental "catch-up" at the age of 13.

3.1.6. Visual perception difficulties

Perez-Roche et al. (2016) suggested that visual perceptual and visual motor skills seem to be among the most affected cognitive domains in these children. In their prospective cohort study, 80 preterm children (age range = 5 to 13, gestational age = < 37 weeks) and full-term born control group were assessed through full ophthalmologic assessment and standardized testing of visual cognitive abilities (Test of Visual Perceptual Skills and Test of Visual Analysis Skills). On the other hand, parents completed a questionnaire on school performance in children. Based on the study findings, figure-ground skill and visual motor integration were significantly decreased in the preterm group, compared with full-term born control subjects (figure-ground: 45.7 vs 66.5, $p = 0.012$; visual motor integration, TVAS: (9.9 vs 11.8, $p = 0.018$). Moreover, visual cognitive difficulties corresponded with worse performance in mathematics ($r = 0.414$, $p = 0.004$) and reading ($r = 0.343$, $p = 0.018$).

3.2. Occupational participation restrictions

3.2.1. Adaptive behavior deficits

Due to the consequences of prematurity for everyday practical and social skills in childhood, recent research is being addressed in adaptive behavior, which is the behavior necessary for an individual to function safely and appropriately in daily life, both at a personal and a social level. On this account, Fjørtoft et al. (2015) conducted a hospital-based follow-up study from two Middle Norwegian counties, in which twenty-eight very low birth weight (VLBW) children without cerebral palsy (CP) (gestational age = 26.8 weeks, mean birth weight = 884 g), 10 VLBW children with CP (gestational age = 26.4, mean birth weight = 819) and 31 term born control children were examined at 10-11 years.

Adaptive behavior was assessed using the Vineland adaptive behavior assessment Scale-II (Vineland-II) parent/caregiver rating form, in the domains of communication, daily living skills and socialization. In this study, a significant difference occurred between the adaptive behavior of VLBW children with and without CP at 10-11 years of age and that of the control group. Specifically, the VLBW children without CP had lower adaptive functioning in terms of daily living skills and socialization.

The findings were still significant for the group of VLBW children without CP after adjustment for sex, socioeconomic status, cognitive and motor function, whereas the lower adaptive functioning in VLBW children with CP was mainly due to low cognitive function. Additionally, an increased maladaptive behavior was found in VLBW children with and without CP compared with the controls. Overall, study findings indicated that preterm and VLBW children with and without CP have to meet greater adaptation challenges than their peers born at term.

3.2.2. Feeding problems

Koca & Huri (2022) suggested that the cognitive deficits preterm children exhibit have an impact on their ability for independent feeding. For this reason, an association between cognitive deficits and feeding problems of 60 preterm children was investigated, compared with a control group. Besides cognitive function, children's feeding problems were evaluated with the STEP- "Screening Tool of Feeding Problems" questionnaire. The subtests of STEP are (a) risk of aspiration, (b) food selectivity, (c) feeding skills deficits, (d) food refusal and associated behavioral problems, and (e) nutrition-related behavior problems. After analysis, food selectivity, feeding behavior problems and total feeding problems were found to be significantly higher in children born preterm than in the control group ($p < 0.001$).

Moreover, the total score of feeding problems and food selectivity problems of preterm children were found to be negatively related to all evaluated cognitive functions (spatial perception, praxis, visuomotor construction, thinking processes) except orientation skills ($p < 0.05$). A relationship was found to be negatively related to food

refusal and related behavioral problems and praxis and total cognitive score ($p < 0.05$). In summary, study findings point out that feeding problems seen in preterm children may be related to their weaker cognitive functions compared to their peers.

3.2.3. Academic challenges

School performance is one of the major childhood occupations children enable daily. To characterize the developmental trajectories of very preterm children in academic domains during primary school, Twilhaar et al. (2019) conducted the first longitudinal study to evaluate the arithmetic, reading comprehension and spelling abilities of very preterm and full-term born children during primary school. A Dutch cohort was performed and 52 very preterm children (< 32 weeks' gestation and/or very low birth weight < 1500 g) born between 2001–2003 and 58 full-term born controls participated.

Using a pupil monitoring system, with 11 measurements of arithmetic and spelling performance and 7 measurements of reading comprehension, it was found that very preterm children scored on average 0.53 SD lower on arithmetic ($p < 0.001$), 0.31 SD on reading comprehension ($p < 0.001$) and 0.21 SD on spelling ($p = 0.01$) compared with full-term born peers. Furthermore, arithmetic, reading comprehension and spelling scores increased with respectively 0.27, 0.41 and 0.27 SD over time ($p < 0.001$). Notably, although the preterm group performed worse than the control group in all academic domains, longitudinal study findings indicate that their progression was similar to full-term born peers, suggesting intact learning abilities.

Similarly, Sawyer et al. (2021) attempted to examine the correlation between executive functions and academic performance in the preterm population and their controls, aged 5 to 7 years old, during school age. After executive functioning evaluation, academic skills were assessed using the Woodcock-Johnson Tests of Achievement, 3rd Edition (WJ-III). The Letter-Word Identification subtest requires subjects to read letters and words and was used as a measure of early reading skills.

The Applied Problems subtest assesses math skills required to solve practical problems presented orally (picture quantities, questions about time and money, word problems) and was used as a measure of early math skills. Generally, scores in all domains were worse for preterm versus full-term born children, while higher executive function scores tended to be associated with higher scores on the academic measures. Effects of executive function measures (a) on Letter-Word ID were moderate within ages 6 and 7 and for the mean values and (b) on Applied Problems were strong within age 5, from age 5 to 7, and for the mean values. Consequently, this study suggests that executive functions are correlated with academic performance and highlights the predictive value of early executive function measures on functional academic outcomes and their potential as targets of effective interventions in this high-risk population.

3.2.4. Peer relationship problems

Being included in peer activities is essential for social development, as it is important for a child's self-confidence and well-being. Based on this knowledge, Ritchie et al. (2018) focused on assessing preterm children's close friendships, peer relations, and bullying experiences at school age. Through a regional cohort study, 44 extremely preterm (gestational age at birth = 26 weeks), 60 very preterm (gestational age at birth = 29 weeks), and 109 full-term born children were evaluated prospectively to 12 years of age.

Across all measures, extremely preterm children had more peer social difficulties than very preterm and full-term born children. They were more likely to report no close friendships (5-14% extremely preterm vs 0%-3% very preterm/full-term born), dissatisfaction with their peer network (16% vs 1-2%), and less time interacting face-to-face with friends (16-23% vs 5-8%). They were also 3 times more likely to be rated by their parents and teachers as experiencing problems relating to peers ($p \leq .001$).

In contrast, rates of chronic bullying (≥ 2 times/week) were similar for extremely preterm and very preterm children (12-14% vs 4% full-term born). Emotional problems, inattention/hyperactivity, and motor deficits were associated with an increased risk of peer relationship problems, whereas higher body mass index, delayed pubertal development, vision problems, and inattention/hyperactivity problems were associated with frequent bullying. Therefore, except for bullying, risks of peer social difficulties were greatest among extremely preterm children.

4. Discussion

4.1. Summary of evidence

In this scoping review, 13 articles were identified examining the neurodevelopmental outcomes and occupational

participation of preterm children at school age. These studies investigated adverse neurodevelopmental outcomes, including cognitive impairment, executive function deficits, sensory processing deficits, behavioral and emotional problems, language and visual perception difficulties. Additionally, occupational participation restrictions focusing on adaptive behavior deficits, feeding problems, academic challenges and peer relationship problems were explored.

The findings suggest that preterm children manifested a broad range of adverse neurodevelopmental outcomes in skill domains such as cognitive-perceptual deficits, behavior and emotional problems, when compared to full-term born peers. These outcomes seemed to affect their daily functioning in occupational participation areas at school age. In particular, cognitive deficits tended to be associated with feeding problems in school-aged preterm children (Koca; Huri, 2022), while executive function difficulties and visual perception deficits were strongly correlated with behavioral problems and academic challenges (Perez-Roche et al., 2016; Twilhaar et al., 2018; Sawyer et al., 2021). Emotional and behavioral problems were also related to peer relationship problems and restrictions from peer activities, as reported from both the parents and teachers of the preterm population (Lejeune et al., 2016; Ritchie et al., 2018).

Out of the 13 studies, 5 conducted a longitudinal study design, exploring the predictive accuracy of neurodevelopmental outcome assessments through school age (Nguyen et al., 2018; Ritchie et al., 2018; Twilhaar et al., 2018; Erdei et al., 2020; Sawyer et al., 2021). These studies suggest that severe deficits in skill domains persisted over the years. However, Twilhaar et al. (2018) indicated that, although very preterm children in general were not able to reach similar performance levels as full-term born peers, they showed academic growth to the same extent, suggesting intact learning abilities.

Early literature has primarily explored the association between prematurity and cognitive impairment (Bhutta et al., 2002; Baron; Rey-Cassery, 2010). In this scoping review, 5 out of the 13 studies delve into cognitive and executive deficits in preterm school-age children (Erdei et al., 2020; Schnider et al., 2020; Kim et al., 2021; Sawyer et al., 2021; Koca; Huri, 2022). Additionally, the review includes articles investigating skill domains and occupational participation areas that have not been thoroughly studied before. For instance, the study on visual perception skills by Perez-Roche et al. (2016), as well as the study on adaptive behavior by Fjørtoft et al. (2015), yield novel findings that enhance the overall understanding of the functioning of the preterm children during school age.

According to Koca & Huri (2022) and Lejeune et al. (2016), occupational participation restrictions and relative skill domain deficits could be explained by general cognitive ability. Specifically, feeding problems and social reasoning task difficulties were associated with cognitive impairment in school-aged preterm children. Fjørtoft et al. (2015), on the other hand, demonstrated that adaptive behavior skills, such as daily living and communication skills, were still affected after adjusting for cognitive ability in preterm children, suggesting that restrictions in occupational participation areas also occurred because of prematurity, regardless of cognitive deficits.

5. Limitations and Strengths

There are several limitations and strengths in this scoping review. Specifically, the included studies in the current scoping review, varied based on different countries and settings. This generated diverse sample sizes and characteristics based on the number of preterm children assessed in school age. Notably, the mean gestational age of the assessed children differed among the preterm groups in all reviewed studies.

For instance, Koca and Huri (2022) included a preterm group sample with mean gestational age of 33 weeks for assessing the cognitive deficits and the feeding problems of preterm children, while Fjørtoft et al. (2015) and Nguyen et al. (2018) had a preterm group with mean gestational age group of < 28 weeks for assessing adaptive behavior and language trajectories, consecutively. This variation in gestational age among the preterm groups underscores the heterogeneity of the study samples and emphasizes the importance of considering this factor in the interpretation of the research findings.

On the other hand, studies investigating cognitive ability, executive functioning, social and peer relationship problems, behavior and emotional problems utilized the same assessment measures to extrapolate conclusions on each corresponding skill domain. Kim et al. (2021) and Bröring et al. (2018) administered the CBCL assessment measure to report behavioral problems. Furthermore, Sawyer et al. (2021) and Schnider et al. (2020) utilized the CANTAB measure to report executive functioning deficits, while Erdei et al. (2020) and Kim et al. (2021) administered the WISC-IV assessment measure to report cognitive deficits in preterm children.

Another strength of this study is that each domain examined has matching findings regarding specific deficits

that provide a comprehensive view of the challenges faced by preterm school-age children. This consistency enhances the reliability and validity of the study outcomes, offering a nuanced understanding of the interconnected nature of challenges within this population.

6. Implications for Future Research

Prematurity is associated with adverse neurodevelopmental outcomes in regard to functioning and occupational participation during school-age. While there are studies with agreeing and consistent findings that explore the potential deficits in the aforementioned domains, there is a gap in certain skill domains (e.g. visual perception, sensory processing) as well as occupational participation areas related to school-age, such as play and leisure time, daily living activities and rest, that could be the focus of future research.

Regarding the possible gestational age differences between preterm group samples, future research could inquire into a more detailed stratification of gestational age within preterm groups. This could be achieved by categorizing children into narrower gestational age ranges in order to explore potential differences or patterns in neurodevelopmental outcomes and occupational participation.

7. Conclusions

Study findings suggest that neurodevelopmental deficits and occupational participation restrictions in preterm children not only exist in early childhood but persist during school age. Future research should focus on exploring in depth potential differences or patterns in neurodevelopmental outcomes and occupational participation between preterm groups with different gestational age ranges.

8. Authors' Contributions

Symeon Dimitrios Daskalou conceived the study and reviewed literature, collected data, synthesized and wrote the first draft of the manuscript. *Christina Ouzouni* synthesized and reviewed the first draft of the manuscript. *Nikolaos Gerosideris* collected data, synthesized and wrote the first draft of the manuscript. *Vilemini Karagianni* synthesized and reviewed the first draft of the manuscript. *Ioanna Giannoula Katsouri* conceived the study, reviewed literature, collected data, synthesized and reviewed the first draft of the manuscript. All authors reviewed and edited the manuscript and approved the final version of the manuscript.

9. Conflicts of Interest

The Authors confirm that there is no conflict of interest.

10. Ethics Approval

Not applicable.

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