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Preterm Birth and Developmental Coordination Disorder: What Do We Know and Not Know?

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Abstract

Purpose of Review Despite increasing research on the association between preterm birth and DCD, some critical questions remain unanswered. This review therefore aims to examine the current state of knowledge and identify areas that require further research.

Recent Findings Recent findings indicate that preterm birth is associated with a greater risk of DCD, with increasing severity of impairment observed with decreasing gestational age before 40 weeks. Numerous studies have examined risk factors for preterm DCD, but few have investigated the mechanisms separately for preterm and term-born DCD, which makes it challenging to determine if they share similar etiological factors. Evidence suggests that the developmental trajectory between preterm and term-born DCD may differ, but more details is required. Additionally, research has also been limited by inconsistent definitions of preterm populations in terms of the degree of prematurity and the use of gestational age and/or birth weight.

Summary Further research is needed to fully comprehend the association between preterm birth and DCD and to develop effective prevention and intervention strategies.

Keywords Developmental coordination disorder · Motor skill disorder · Preterm · Gestational age · Birth weight · Small-for-gestational age · Developmental trajectory · Risk factors

Introduction

Developmental coordination disorder (DCD) is a neurodevelopmental disorder with marked impairment in the development of motor coordination that significantly interferes with academic achievement or activities of daily living [1]. Numerous studies have demonstrated the negative impact of DCD on children, including causing difficulties with fine and gross motor skills, making it challenging to perform activities such as dressing, eating, playing, and participating in sports, which can lead to frustration, low self-esteem, academic struggles, and social isolation of affected children [2]. Although the exact cause of DCD is not yet known, research indicates that both genetic and non-genetic factors during critical periods of neurodevelopment may play a role in its development [3]. Several reviews have consistently demonstrated a higher occurrence of DCD or motor impairment in preterm children [4–6]. A meta-analysis [4] of motor outcomes in school-aged children born preterm showed that the rate of mild-to-moderate motor impairment was 40.5% (95% CI: 32.1–48.9/100) and moderate motor impairment to be 19.0% (95% CI: 14.2–23.8/100). Moreover, the rates of motor impairment in children born very preterm or with very low birth weight (<1500 g) were six times higher than in term-born peers when using a cut-off of <5th percentile or eight times higher when using a cut-off of <16th percentile [5]. Notably, a significant increase in motor impairment over time was observed in children born extremely preterm (<28 weeks) and/or extremely low birth weight (<1000 g) in Australia [7].

There used to be a debate on whether being born preterm should preclude a diagnosis of DCD. The DSM-4's exclusive criterion for DCD stated that the motor impairment could not be explained by a "general medical condition," which

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led to a question on whether being born preterm should be considered a general medical condition and therefore preterm born should preclude a DCD diagnosis. However, the DSM-5 has since revised the diagnostic criteria for DCD, and now the disorder is defined by four criteria: (i) a significant delay in the acquisition and execution of coordinated motor skills, considering the opportunities for skill learning and the individual's age; (ii) motor skill difficulties that significantly interfere with daily life including academic, prevocational, vocational, leisure, and play activities; (iii) onset of symptoms during the early developmental period; and (iv) motor skill difficulties that cannot be better explained by intellectual disability, visual impairment, or other neurological conditions that impact movement [1]. While the exclusive criterion in DSM-5 (i.e., intellectual disability, visual impairment, or a neurological condition impacting movement such as cerebral palsy, muscular dystrophy, degenerative disorder) is more specific than the exclusive criterion in the previous diagnostic criteria (i.e., a general medical condition), and as a result of the more specific exclusive criterion in the DSM-5, researchers and professionals tend not to preclude preterm from a diagnosis of DCD. As a result, the prevailing literature on DCD now commonly incorporates children who were born preterm, provided they do not exhibit any concurrent clinical conditions, such as brain injuries stemming from Intraventricular Hemorrhage (IVH) in premature infants. However, despite increasing research on the association between preterm birth and DCD, some critical questions remain unanswered. Therefore, this review aims to address these gaps in the literature and to examine the current state of knowledge and identify areas where further research is needed.

Risk Factors for DCD Born Preterm and at Term

Several recent population cohort studies have reported on risk factors for DCD and identified a range of prenatal, perinatal, neonatal, and environmental factors (see [6] for a detailed review). However, there is still a need for further evidence to elucidate whether the underlying causes of DCD differ between preterm and term-born individuals. This knowledge is not only imperative for achieving a more comprehensive understanding of DCD, but also critical for the development of effective strategies for early identification and intervention. While altered brain development is associated with DCD [8], what causes this change in brain development is unknown. In the case of preterm birth, various causal pathways have been explored to explain the increased risk of motor impairment in preterm born children. The late second and early third trimester of pregnancy are critical periods for the development of the brain, and preterm birth with premature exposure to the extra-uterine environment can disrupt the genetically programmed pattern of brain genesis, leading to structural and functional abnormalities in the brain [9, 10]. Additionally, preterm birth is associated with a range of irreversible adverse factors, such as hypoxic–ischemic injury, inflammation during pregnancy [11], and intraventricular hemorrhage [12], which can all impact motor function. Insufficient physical growth due to reduced weight and height [13], smaller muscle size [14], impaired bone health [15], and further alterations in brain maturation can also affect the motor development of preterm children. Furthermore, exposure to pain, infection [16], and medications such as morphine and postnatal steroids [17, 18] can also influence brain development. Environmental factors, such as neonatal intensive care unit (NICU) [19, 20]' may alter musculoskeletal and nervous system development, thereby altering the trajectory of motor development of preterm children. Lastly, parental factors related to preterm childcaring, such as increased parental concern, may contribute to reduced participation in physical activities, ultimately exacerbating the negative impact on motor outcomes for preterm children beyond infancy [21]. Another plausible explanation for the relationship between preterm birth and DCD could be the existence of shared underlying mechanisms. For example, recent research conducted on a large population sample of 109,731 children aged 3–5 years old revealed that exposure to high levels of air pollution during pregnancy was significantly associated with an increased risk of DCD [22]. Air pollution exposure is a complex factor that may contribute to an elevated risk of preterm birth through mechanisms that involve inflammation and oxidative stress [23]. It is possible that environmental or genetic factors that predispose individuals to preterm birth or low birth weight may also contribute to DCD.

On the other hand, children with DCD born at term may or may not share similar etiological factors as those with preterm DCD; however, direct comparative evidence between preterm and term DCD is limited. With a large sample of 33,354 children from the Danish National Birth Cohort, and using the DCDQ as a measurement of motor impairment, Faebo Larsen et al. [24] analyzed the risk factors separately for those born preterm and at term. The results indicated that being small-for-gestational age and delayed walking attainment were risk factors shared by both preterm and term children. However, younger maternal age (<25 years) and smoking during pregnancy were identified as risk factors specifically for children born at term. Notably, no statistically significant interactions were observed in this study, suggesting that the different risk factors in preterm and term groups may be due to random variation. Unfortunately, this study did not include perinatal or neonatal factors, which could have contributed more valuable insights to the literature.

In the general population, encompassing children born across a full range of gestational ages, Hua et al. [25] employed DSM-4 diagnostic criteria for DCD and a 15% cut-off in the Movement Assessment Battery for Children Second Edition (MABC-2) to define motor impairment. They identified several significant independent risk factors for DCD through multilevel logistic regression analysis, including preterm birth, maternal age older than 35, threatened abortion during the prenatal period, fetal distress, chronic lung disease, and newborn pathological jaundice (n=4001). In a more recent study by Du et al. [26], applying the DSM-5 criteria and utilizing a 5% cut-off in MABC-2 for defining motor impairment, placenta previa, placental abruption, and preterm birth were identified as independent risk factors for DCD in a general population sample (n=2185). Additionally, environmental factors including family socioeconomic status (SES) and sibling status were also found to be independently associated with DCD in the latter study. Unfortunately, although both studies by Hua et al. and Du et al. included a large number of term-born participants with DCD, they did not separately consider risk factors for term DCD. Conversely, numerous studies have reported on the risk factors for preterm DCD, yet clear causal pathways have not been identified. For example, in studies focusing on preterm children, one analysis involving 226 children born before 27 gestational weeks in the Swedish national cohort [27] identified risk factors for DCD at 6.5 years old, including retinopathy of prematurity (ROP), the receipt of postnatal steroids, increasing maternal age, pre-eclampsia, administration of postnatal steroids, and mechanical ventilation. Conversely, another study involving 629 Italian children born before 32 gestational weeks [28] identified risk factors for DCD at 8–11 years old as male sex, intrauterine growth restriction, ROP, and increasing maternal age at delivery. These results suggested a multifactorial etiology that may vary among individuals. Consequently, what remains to be examined is the extent to which the same risk factors can explain motor impairment in term-born individuals with DCD.

It is noteworthy that both male sex and preterm birth consistently emerge as significant and universally recognized risk factors for DCD within general populations [18, 28, 29]. Moreover, research has revealed an association between male sex and preterm birth, with pregnancies carrying male fetuses demonstrating a higher propensity for preterm birth compared to those carrying female fetuses [30, 31]. This male vulnerability to preterm birth holds further implications for developmental outcomes, as preterm boys frequently exhibit lower scores in developmental assessments and manifest more adverse patterns of brain development in contrast to preterm girls [32–34]. However, it is worth highlighting a scoping review that provides a synthesized overview of 36 studies involving children aged 5 to 13 years [6]. This review revealed the absence of a sex-specific effect in children born preterm, suggesting that the biological risk associated with preterm birth may outweigh the influence of male sex in this context. To gain a comprehensive understanding of these findings within the existing literature, further research is warranted to help us learn more about the interplay between male sex, preterm birth, and the manifestation of DCD. Such investigations will contribute significantly to advancing our knowledge of the underlying biological and sociocultural mechanisms at play in this multifaceted relationship.

The Developmental Trajectory

Furthermore, it is not always clear whether the motor development trajectories are different between preterm and term DCD. It is well-established that preterm infants have a different motor development trajectory compared to full-term infants [35]; nevertheless, only a limited number of studies have focused on longitudinal follow-up to examine the stability of DCD born preterm and full-term throughout childhood. A recent longitudinal study conducted by Spittle et al. [36] assessed 180 very preterm (<30 weeks of gestation OR <1250 g birth weight) and 73 term-born children (≥37 weeks AND ≥2500 g) at 5, 7, and/or 13 corrected years of age using the MABC. Children with scores ≤16th percentile with MABC were defined as DCD, and children with cerebral palsy or an IQ of <80 were excluded. This study confirms that the rate of DCD is higher in children born very preterm compared to controls from 5 to 13 years of age. Notably, the rate of DCD in the preterm group decreased from 48% at 5 years to 28% at 13 years. Furthermore, 22% of the children born very preterm transitioned from being classified with DCD at 5 years of age to typical motor development at 13 years of age. In contrast, children born at term demonstrated consistently low and stable rates of DCD over time, with no instances of persistent DCD classification observed among this group. It appears that children born very preterm might exhibit improved motor function over time. Spittle et al. [36] also found that moderate-to-severe white matter injury was the only variable associated with persisting DCD at all ages compared to persisting typical motor development at any age in children born very preterm.

Existing literature suggests that the likelihood of children overcoming motor delays may be related to the severity of their motor difficulties [37, 38] and their distinct cognitive and motor functional profiles [39, 40]. For instance, there are suggestions that recovery from serious motor challenges is less common than catching up from milder ones [37, 38]. However, it's important to note that neither of these studies specifically focused on children born preterm, and none of them has provided comprehensive evidence regarding the developmental trajectories of preterm children with motor

impairments over time. Although Spittle et al.'s study [36] provided important initial data suggesting a reduction in the disparity in motor delay between very preterm and term-born children as they grow older, the sample size of the study was small, which resulted in a very small number of term-born children with remitted DCD (n=4). It is also essential to highlight that this study did not assess medical treatment or developmental interventions, which complicates the interpretation of the results.

To gain a more thorough understanding of the developmental trajectories among children with DCD born preterm and at term, future research should rigorously control for interventions and involve larger sample sizes, particularly including more term-born children with persistent and remitted motor difficulties. Information is needed to determine whether catch-up growth occurs more likely in preterm children, the different rates and ages, the range of their motor impairments, and the mechanisms underlying persistent and remitted motor impairment. Other factors such as family SES, participation in physical activity, and diet should also be taken into consideration in a detailed comparison.

The Degree of Preterm

It should also be noted that, the degree of preterm birth, in terms of the cut-off value for gestational age, varies across studies in the literature. Generally, a consistent finding is that decreasing gestational age is associated with an increased risk of DCD in comparison to children born at term. Specifically, children born very preterm (<32 weeks) are consistently reported to have a significantly higher risk of DCD than those born at term, while reports are mixed for children born moderately preterm (32–33 weeks) and late preterm (34–36 weeks) [6]. Recently, a large cohort study [41] of 152,433 Chinese children was conducted to investigate the association between gestational age at birth and functional motor outcomes at ages 3 to 5 years. Adjusting for a wide range of child personal, maternal, and family characteristics, the study confirms the association of DCD with preterm birth in all degrees (very preterm, moderately preterm, and late preterm). Furthermore, the study suggests that early-term (37–38 weeks) and post-term (>41 weeks) gestational age are also factors associated with an increased risk of DCD, using multilevel regression. Another study [34] using the same Chinese population sample and the Ages & Stages Questionnaires-Third Edition (ASQ-3) as the measurement of neurodevelopmental functions reported similar results. Moreover, a non-linear relationship between gestational weeks and scores of gross motor skill and fine motor skill was also observed. In both studies, motor function scores increased with increasing gestational weeks before 40 weeks and decreased with decreasing gestational weeks after 40 weeks, with children born at 39–40 weeks gestation performing the best. Moreover, a unique association between post-term birth and DCD was reported in these studies, and the increased risk of DCD in post-term born children may reflect obstetric or neonatal complications associated with late-preterm birth, which could involve a different mechanisms than the association between preterm birth and DCD. The Chinese studies, with their large sample size, had greater power to detect subtle differences compared to other studies that did not find differences between some subgroups of gestational age [42]. However, it should be noted that the age of the children in the Chinese studies was relatively young (3–5 years old), and there is a possibility that some children with motor impairment may catch up, and the reported differences may disappear at a later stage. Additionally, because of the detailed exploration of the association between motor function and gestational age in a full range, the benchmark used in the Chinese studies was the motor performance of children born at completely full-term (39–40 weeks), excluding children born early term (37–38 weeks) or late term (41 weeks), who present the best motor performance as suggested in the study. This may inform future research on which subgroups of gestation should be considered as the benchmark.

Gestational Age and/or Birth Weight

Research on the relationship between preterm birth and DCD has also been limited by inconsistent definitions of preterm populations. Previous studies have used gestational age, birth weight, or a combination of to define preterm status. While gestational age and birth weight are related, they have different underlying causes and represent distinct etiologies. Birth weight can be influenced by two major factors: gestational age and intrauterine growth rate [43]. Therefore, low birth weight can be caused by either a short gestation age, retarded intrauterine growth, or a combination of both. To address this limitation, some studies [24, 28, 44–46] have removed the influence of gestational age on birth weight by looking at small-for-gestational age (SGA) infants. The term "SGA" is used to describe newborns with a weight below expected levels for their gestational age which can therefore indicate intrauterine growth restriction (IUGR) [47]. Results suggest that SGA is an independent risk factor for DCD, which indicated that both IUGR and preterm are associated to DCD. It is noteworthy that this association between SGA and DCD is significant in both preterm and term infants, as suggested in Faebo Larsen et al.'s study [24]. However, as mentioned earlier, this study considered only a limited number of confounding factors, and future studies with more careful designs should be conducted to explore a possible gestational age-dependent relationship between SGA and DCD.

Conclusion

In conclusion, preterm birth is a significant risk factor for DCD, and the severity of impairment increases with decreasing gestational age. The identification and assessment of motor function in preterm infants should be a key component of routine care, and early intervention programs should be implemented to minimize the long-term impact of DCD on the child's functioning and quality of life [48]. However, the literature on this topic has several gaps that need to be addressed. There is a lack of consensus on the definition of preterm populations, and the existing studies have used varying criteria to define preterm birth. Moreover, the relationship between gestational age, birth weight, and DCD remains unclear, and further research is needed to disentangle the complex interactions between fetal, maternal, and environmental factors that influence fetal growth. Additionally, the literature on the long-term outcomes and development trajectories of DCD in preterm populations is limited, and more research is needed to understand the developmental trajectories of these children over time. In conclusion, further research is needed to fully understand the relationship between preterm birth and DCD and to develop effective prevention and intervention strategies for this vulnerable population.

Declarations

Conflict of Interest The authors declare no competing interests.

Human and Animal Rights and Informed Consent This article does not contain any studies with human or animal subjects performed by any of the authors.

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