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NARRATIVE REVIEW

Preterm Birth and Childhood Gross Motor Competence

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Abstract

The high rates of preterm birth in countries such as Canada are a concern, as evidence suggests that children born preterm are at risk for a number of complications, including delays in motor development. Such delays may be due to immaturity and/or damage to the nervous system at birth, as the central nervous system plays an integral role in motor proficiency. In particular, children born early preterm consistently demonstrate lower gross motor proficiency in childhood. While some children may exhibit motor milestone delays early in development, research suggests that motor deficits may not emerge in some preterm children until the years of school entry or beyond. Increased awareness of potential motor issues, referral networks to qualified movement specialists, and the accurate identification of motor delays is critical for early and timely intervention. Therefore, the purpose of this article is to discuss the research related to gross motor proficiency of preterm children, highlighting the critical role of movement specialists and the importance of movement-based monitoring and instruction in the preterm population. **Health and Fitness Journal of Canada 2018;11(1):3-14.**

Keywords: Preterm Birth, Childhood gross motor competence, preterm gross motor development

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Introduction

Although global rates of serious neonatal morbidity, stillbirth, and perinatal mortality have decreased dramatically in recent decades, rates of preterm birth are increasing worldwide

which is a major health concern even in high income countries, including Canada (see Figure 1 for examples of global rates of preterm birth; Blencowe et al., 2013; British Columbia Perinatal Health Program, 2008). In large part, this is due to the increased trends of older maternal age, higher maternal weight status prior to pregnancy, and the use of technology-assisted reproduction in high income countries (British Columbia Perinatal Health Program, 2008).

In Canada, approximately 8.0% of infants are born preterm, wherein a 'preterm' birth refers to the live birth of an infant before 259 days or 37 completed weeks of gestation (Public Health Agency of Canada [PHAC], 2013). Additional categories are used to further classify preterm birth according to gestational age. Early preterm birth refers to infants born at less than 32 weeks gestational age, and can be split into very preterm and extremely early preterm (Blencowe et al., 2013; PHAC, 2013). A moderate to late preterm birth refers to children who are born between 32 but less than 37 weeks gestational age, which includes both moderate and late preterm (Blencowe et al., 2013). Figure 2 provides a visual representation of preterm birth classifications in accordance with gestational age. Moderate to late preterm births account for the greatest proportion of preterm births, representing 6.4-7.0% of all live births in Canada, as compared to

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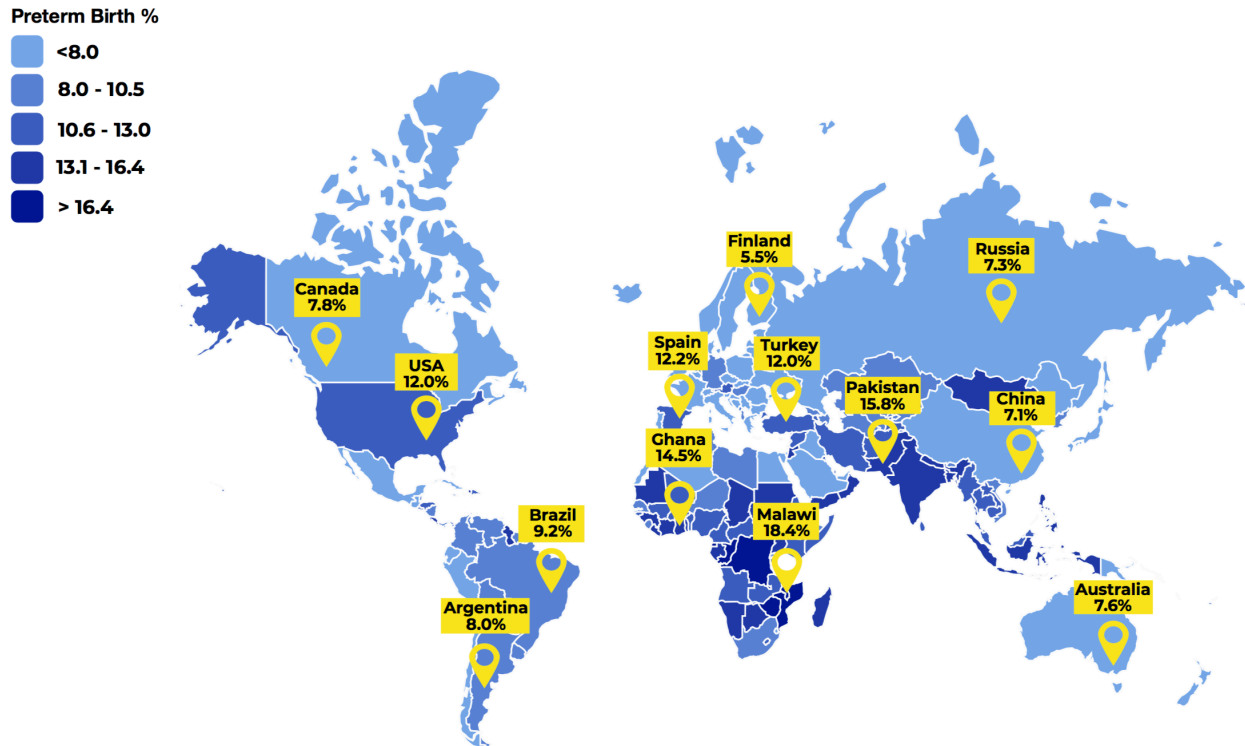


Figure 1: Global preterm birth rate estimates, 2010. Adapted with permission from *Born Too Soon: The Global Action Report on Preterm Birth* (March of Dimes et al., 2012)

early preterm births which account for only 1.1-1.2% of Canadian live births (Canadian Institute for Health Information, 2009; PHAC, 2013).

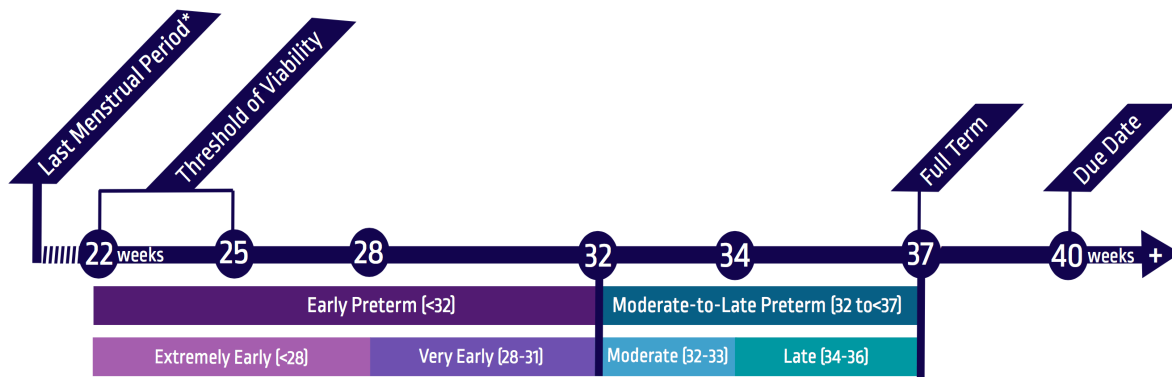
Research has shown consistently a number of developmental concerns associated with premature birth, which can be burdensome and have an impact across the lifespan (Blencowe et al., 2013). Children born preterm may demonstrate a variety of deficits across multiple domains (such as sensory, behavioural, cognitive, and/or motor-based difficulties) in relation to development, including motor development (March of Dimes et al., 2012; Van Hus et al., 2014). In particular, the gross motor competence of children born preterm is of interest in early childhood, as gross motor skill acquisition in the early childhood years is required for life-long movement opportunities and can affect outcomes related to health and

well-being (Pang and Fong, 2009). The purpose of this commentary is to present research examining gross motor proficiency of children born preterm. The goal is to highlight the critical role of movement specialists (such as qualified exercise professionals) for children born preterm and the importance of movement-based monitoring and instruction.

Importance of Gross Motor Competence

An important progression in the development of the motor system is the acquisition of gross motor competence, which requires movement proficiency across a number of fundamental motor skills (Barnett et al., 2016). Fundamental motor skills require the use of the large muscle groups of two or more body parts to achieve an essential movement consisting of stability, object control,

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*Gestational age is calculated based upon the first day of the mother's last menstrual cycle

Figure 2: Preterm categorization based upon completed weeks gestational age at birth

* Gestational age is calculated based upon the first day of the mother's last menstrual cycle

and/or locomotion (Barnett et al., 2016). Fundamental motor skills are often considered to be the movement vocabulary of the human body comparable to the ABC's of the English language (Stodden et al., 2012). Early childhood provides an opportunity for children to develop gross motor competence, which is critical for establishing a foundation for later physical activity and sport participation, as well as for engaging in tasks of daily living across the lifespan (Barnett et al., 2016). Research has shown a relationship between competence in the gross motor domain with positive health outcomes (Barnett et al., 2016). For example, higher levels of fundamental movement skill competence is associated with better cardio-respiratory fitness and higher levels of physical activity (Lubans et al., 2010). A negative association has been shown between higher competence in fundamental movement skills and weight status (Lubans et al., 2010). In contrast, poor motor competence can influence an individual at school and at home, affecting one's development in areas such as self-concept, social

inclusion, and motivation for physical activity (Barnett et al., 2016; Lin and Yang, 2015; Ulrich, 2000; Yoon et al., 2006). There is also a consensus that the social and emotional wellbeing of a child can be negatively impacted by deficits in motor coordination, which contributes to motor competence (Piek et al., 2016). Particularly, opportunities for developing physical fitness decrease when a child's motor competence is poor, as their capability for activity participation is limited (Rivlis et al., 2011) due to motor-based constraints. Decreased flexibility and lower explosive strength are examples of deficits that have been found in children with gross motor coordination difficulties (de Chaves et al., 2016).

In addition to minor motor difficulties, children born preterm (with no major disability) may also exhibit behavioural and learning difficulties when attending mainstream schools (Bracewell and Marlow, 2002; Foulder-Hughes and Cooke, 2003). Moreover, detection is usually delayed until a child enters school when formal academic and physical education begins (Goyen and Lui, 2002). For example, van Hus et al. (2014)

showed an association between non-cerebral palsy motor impairment in children born very preterm at age five with complex minor neurological dysfunction, cognitive impairment, slow processing speed, and poor visuomotor coordination. These findings demonstrate the broad context of the school setting in which motor difficulties may co-exist with other impairments, making the source of the constraint challenging to isolate.

Neurological Considerations: Motor Development and Preterm Birth

Gross motor skill development largely depends on the development of the nervous system and such processes as myelination (the insulation of axons with myelin to promote rapid transition of nerve impulse conduction; Tierney and Nelson, 2009). Myelinated axon bundles largely make up the white matter of the brain, allowing for optimal functioning of the cognitive, sensory, and motor systems (Fields, 2010). Areas of the central and peripheral nervous system responsible for the control of motor function begin the process of myelination prenatally, which continues after birth until approximately preschool age (Tierney and Nelson, 2009; van de Bor et al., 1990). In the prenatal period specifically, myelination and significant white matter development occurs between 24 and 32 weeks gestation, and there is also a sudden increase in white matter volume between 36 and 41 weeks gestation (Dubois et al., 2014). Therefore, the prenatal period represents an important time for motor-related brain development; however, this time is shortened when a child is born preterm. Although not completely understood, the connection between preterm birth and motor skill delay is postulated to originate from alterations to the neonatal

brain structure (specifically, damage to the white matter), a less mature central nervous system, and disruption (due to susceptibility to white matter injury) to the typical myelination process at the time of birth, resulting in myelination deficits (Back, 2017; Ferrari et al., 2012; Husby et al., 2013; Jongbloed-Pereboom et al., 2012; Van Hus et al., 2014; Williams et al., 2009). Further, brain injury is a common occurrence in infants born preterm, with an increasing prevalence at younger gestational ages (Jongbloed-Pereboom et al., 2012). General alterations to the white matter of children born preterm include reduced cortical folding and white matter volumes (Ferrari et al., 2012).

Gross Motor Proficiency and Preterm Birth

To date, research consistently indicates that during early development, the preterm population demonstrates motor impairment or atypical motor patterns (Bracewell and Marlow, 2002; de Kieviet, Piek, Cornelieke, and Oosterlaan, 2009), with a particular focus on children born early preterm as compared to full term peers in infancy and toddlerhood. For example, children under 18 months born preterm were found to exhibit lower gross motor proficiency scores and difficulty with anti-gravity movements when compared to full term peers (van Haastert et al., 2006). Toddlers born moderate to late preterm have scored below full-term children in gross motor skills, demonstrating higher gross motor developmental delays (de Jong et al., 2012). Delayed gross motor milestones in the preterm population can include motor skills like walking, which has been found to be delayed in 18 month old children born preterm with very low birth weight (Jeng et al., 2000).

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In the early years of development, children born early preterm show both quantitative and qualitative differences in early gross motor development. For example, Hemgren and Persson (2004) showed that early preterm children at three years exhibited greater hyperextension of the head, knees, and trunk (and a lack of rotation of the trunk) during locomotion, walking on tiptoes, and retention of outward rotation and plantar flexion of the feet from infancy when compared to both moderate preterm and full term children. Such qualitative indicators may be useful for healthcare professionals to target in early intervention strategies if they are affecting movement quality.

Research has also shown that difficulties in motor functioning do not dissipate with age, as evidence of poor motor proficiency throughout childhood has been reported. For example, a cohort of children born extremely preterm and less than 1000 g were assessed at 1.5 years and then again at age three and five years. Results showed a decrease in gross motor skill proficiency at three years compared to 16 months, which declined even further by age five, when 81.1% of the cohort scored below the accepted range of typical values (Goyen and Lui, 2002). Similarly, Prins and colleagues (2010a) examined children born moderate preterm at three months, nine months, and at four years of age. While results showed no correlation between motor development at three months, nine months and four years, one fifth of the children demonstrated atypical motor outcomes at four years of age (Prins et al., 2010).

These findings suggest that gross motor proficiency should be monitored throughout early childhood for all children born preterm, irrespective of

gestational age. While some children may exhibit poor motor skills throughout early childhood, minor motor problems may not be detected in other children until the age of school entry at approximately age five (Goyen and Lui, 2002). Reports of motor difficulties in five year old children born very preterm have been cited to range from 30-40% (Van Hus et al., 2014). In a Dutch study of five year old children formerly admitted to a neonatal intensive care unit born early preterm or less than 1500 g (but without severe handicaps), below age-expected scores were present on at least one of three motor assessments (De Kleine et al., 2006). Jongmans and colleagues (1998) have also shown that children born less than 35 weeks gestational age (and admitted to neonatal intensive care in infancy) demonstrated lower overall scores on motor assessments at six years of age, with 44% of the children scoring within a motor impairment range (Jongmans et al., 1998). This research provides support for examining motor proficiency at the age of school entry in children born preterm.

Research suggests that low movement skill proficiency in children born preterm continues to persist into later school grades across gestational ages (e.g., early preterm, see Folder-Hughes and Cooke, 2003a; moderate to late preterm, see Odd et al., 2013) and even adolescence into adulthood (Husby et al., 2013). For example, in a UK study of seven- to eight-year-old children born early preterm in mainstream schooling, 30.7% of children born preterm scored below the 5th percentile on a movement battery as compared to 6.7% of children born at term who scored within the same range (Folder-Hughes and Cooke, 2003). Similarly, in a different group of infants born less than 30 weeks gestational age (who had spent time in an intensive care

unit), 31.3% of the children showed motor impairment when assessed at eight years of age. Of the children who were identified as having a motor impairment, 51.5% were further classified as having a severe motor impairment (Wocadlo and Rieger, 2008). Qualitative analysis of eight year old children born before 35 weeks gestation has shown more compensatory movements through their arms and trunks when compared to full term participants on a balance task (Forslund, 1992). Further, Husby and colleagues (2013) has shown poor gross motor skills into adolescence and adulthood for individuals born preterm and very low birth weight as compared to matched controls at age 14 and 23 years. This finding demonstrates the potential for lifelong impact on one's movement behavior.

While there is some evidence for developmental delays across gestational age, a limitation of the research to date is that it has focused largely on early preterm birth, with participant eligibility often restricted to children born less than 32 weeks gestation, or born at a very low birth weight (even though this cohort typically accounts for only one fifth of the preterm population; Pitcher et al., 2012). Yet, when motor proficiency of the preterm population is discussed, it is often described as a homogenous group, which is not representative of the range of preterm gestational ages. Further research examining motor proficiency and children born moderate and late-preterm is critical for knowledge generation and warrants attention.

Assessing Gross Motor Proficiency

Although rates for major conditions influencing motor capabilities (e.g., cerebral palsy) have decreased with advancing technologies in children born

very preterm, the prevalence of minor motor impairments and the impact of the impairment remains a prominent issue (Goyen and Lui, 2002). Currently there is no definitive definition for the term, 'minor gross motor impairment'. It would be of benefit to provide a more concrete framework around this term, as mild motor difficulties may in fact fall on the lower end of the disability spectrum (Bracewell and Marlow, 2002). Reporting of gross motor difficulties remains vague in the literature, as it often encompasses poor performance below a given percentile or score on a developmental assessment battery, which may test a range of items. For example, scores lower than the 15th percentile on the Movement Assessment Battery for Children (MABC) are often considered to represent mild motor impairment, with scores less than the 5th percentile indicating definite moderate to severe impairment that potentially may indicate Developmental Coordination Disorder (Foulder-Hughes and Cooke, 2003; Spittle et al., 2011). However, for the purposes of this commentary, an example of a minor gross motor impairment includes difficulties or delays with gross motor tasks (De Kleine et al., 2006). Skills that may be affected (quantitatively or qualitatively) can include those requiring coordination (for example bilateral coordination or upper limb coordination), object manipulation and ball skills (for example, catching, throwing, or kicking), postural control (such as dynamic and static balance), and/or locomotor movement (for example running or skipping; Carosino et al., 2014; Foulder-Hughes and Cooke, 2003; Piek et al., 2012; Rosenbaum et al., 2004).

To assess a child's motor proficiency, appropriate test batteries should be utilized, taking care that the outcomes

provided from the assessment offer relevant information for the motor tasks of interest (i.e., gross motor-specific skills). However, a limitation of previous research examining motor capabilities in the preterm population is the use of motor items from global neurodevelopmental batteries rather than utilizing motor-specific assessment tools (Jongmans et al., 1998). As such, using gross-motor-specific tools should be considered in movement-related research and to better inform the development of individualized intervention strategies at the practical level. If a gross motor delay is suspected using a more general assessment battery, a more specific gross motor skill tool should be implemented to better identify areas of movement difficulty.

Common assessment batteries used for the motor skill assessment of children in childhood include such assessments as the Bruininks-Oseretsky Test of Motor Proficiency-2nd Edition (BOT-2) (Bruininks and Bruininks, 2005; Zimmer and Volkamer, 1987), the Körperkoordinations Test für Kinder (KTK) (Kiphard and Schilling, 2007), the Movement Assessment Battery for Children-Second Edition (MABC-2) (Henderson et al., 2007), the Peabody Developmental Motor Scales-Second Edition (PDMS-2) (Folio and Fewell, 2000), and the Test of Gross Motor Development-Second Edition (TGMD-2) (Ulrich, 2000). Although each of these assessments has unique benefits and limitations for the assessment of gross motor proficiency, the TGMD-2 is a commonly used assessment in the research literature due to its usability and gross motor specificity.

Before the age of two, movement specialists should also consider (when appropriate) the use of adjusted age

versus chronological age when assessing for gross motor milestone acquisition. Commonly available milestone charts are based on typically developing children born full term, and do not adequately represent time to acquisition of children born preterm. Using adjusted age as it relates to motor milestone acquisition is recommended as a more appropriate measure of developmental status whenever using age-dependent tools (Allen and Alexander, 1990; D'Agostino, 2010). See infographic and commentary by Rizzardo and Bredin (2018).

Considerations for Intervention

There is a particular need to better understand the motor difficulties of preterm-born children to better inform screening and intervention strategies (Williams et al., 2009). However, investigations examining effective intervention protocols are currently limited. Further, much of the literature has focused on the infant and toddler years, with less work examining the school years and motor difficulties in the preterm population. Identifying specific areas of concern for the acquisition of fundamental motor skills is particularly salient from a practitioner's perspective. For example, Foulder-Hughes and Cooke (2003a) showed that seven- to eight-year-old children born preterm demonstrated a high incidence of motor impairment when compared to their full-term peers (matched for age), with significant differences found in ball skills and dynamic balance, which included tasks such as bouncing and catching, standing on one leg, and walking heel-to-toe. Examining the consistency of motor difficulties across preterm children and the underlying constraints on the emergence of fundamental movement patterns is an important area for research

and further translation to the applied setting.

It is also important that children born preterm are monitored throughout their childhood years for motor skill proficiency. Qualified professionals are vital in offering developmentally appropriate environments and opportunities for children to learn to be proficient movers, and to assist a child in overcoming physical limitations. It is recommended that children with suspected motor delays work with physical therapists, occupational therapists, and/or other movement specialists (e.g., qualified exercise professionals) as early intervention is critical when motor impairments emerge (Noritz and Murphy, 2013). As such, professionals specializing in movement play an important role in designing and implementing timely, individualized, and developmentally appropriate programming for children born preterm for overcoming motor development delays (Foulder-Hughes and Cooke, 2003). It is important that health professionals and movement specialists can assess and identify delays in the acquisition of gross motor milestones, and subsequently offer evidence-based and/or best practice treatment strategies to manage and mitigate the impact on a child's movement capabilities.

The qualified exercise professional plays a potentially important role in working with a preterm population given their scope of practice and expertise in exercise physiology. While research has shown an association between low health-related physical fitness and poor motor skill proficiency (Haga, 2008; Rivilis et al., 2011; Robinson et al., 2015), there are also physiological considerations specific to a preterm population. For example, lung function

and subsequent exercise capacity has been shown to be impaired in preadolescents born before 28 weeks (MacLean et al., 2016). Extremely preterm birth has also been reported to impact peak oxygen consumption with poor exercise capacity (Welsh et al., 2010). Such physiological factors should be considered when planning intervention strategies for children born preterm who exhibit motor difficulties. Activities may need to be tailored in consideration of these issues whilst promoting the child's motivation and participation in physical activities across the lifespan. Incorporating strategies to concurrently address components of health-related fitness and gross motor impairments, is important for developmentally-appropriate programming that comprehensively considers the health and wellness needs of the child.

Conclusion

As preterm birth continues to be a contemporary concern in developed countries such as Canada, the gross motor developmental implications of preterm birth are important to address. Research has shown that preterm children may exhibit minor gross motor impairments (such as coordination), and are likely due in part to neurological constraints on development. Moreover, emerging research also suggests that later movement proficiency may not be predicted from assessments during toddlerhood. Therefore, children born preterm at various gestational ages should be monitored for gross motor proficiency into the school years, when movement difficulties may emerge. Proficiency in gross motor skills is important for establishing a foundation and perceived competence for physically active behavior, engaging in tasks of daily

living, as well as for maintaining health-related physical fitness across the lifespan. Effective knowledge translation efforts to practitioners who may work with children born preterm is important to assist in early identification and in the design and implementation of developmentally appropriate programming for overcoming motor developmental delays in the preterm population.

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Authors' qualifications

The authors' qualifications are as follows: Beth Rizzardo, BKin; Shannon Bredin, MSc, PhD.

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