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Does the Movement Assessment Battery for Children-2 at 3 years of age predict developmental coordination disorder at 4.5 years of age in children born very preterm?



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ABSTRACT

Background: Very preterm children (VPT) are at high risk for developmental coordination disorder (DCD). The Movement Assessment Battery for Children-2 (MABC-2) Test is commonly used to identify children with DCD, but little is known about the predictive validity of this assessment in this population.

Aims: The aims of this study were to determine if MABC-2 scores at 3 years can predict DCD at 4.5 years and if DCD can be reliably identified in VPT children at 3 years.

Methods and procedures: In a retrospective sample of 165 VPT children, logistic regression was used to determine if the MABC-2 score at 3 years is predictive of DCD at 4.5 years. Cross-tabulations were used to determine the relationship between scores at 3 years and DCD at 4.5 years. **Outcomes and results:** MABC-2 scores at age 3 were a significant predictor (OR = 0.82, $p = 0.001$) of DCD diagnosis at 4.5 years. The MABC-2 has excellent sensitivity (90%), moderate specificity (69%), small to moderate positive predictive value (38%) and high negative predictive value (97%).

Conclusions and implications: The MABC-2 is highly sensitive in identifying VPT children with DCD, but also has many false positives. MABC-2 scores can reliably predict VPT children who are not at risk of DCD.

What this paper adds?

This paper adds to the research literature examining the use of the Movement Assessment Battery for Children-2 (MABC-2) Test in identifying DCD in early childhood. This is the first study to assess the predictive validity of the MABC-2 in the very preterm population at age 3 years. This study shows that the MABC-2 is highly sensitive but not very specific. A high negative predictive value shows that the MABC-2 is excellent at predicting which VPT children at 3 years are not at risk of DCD. This study also contributes to the limited literature on using the MABC-2 for early identification of DCD in a high-risk population.

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1. Introduction

Developmental coordination disorder (DCD) is an impairment in coordinated motor skills that significantly interferes with a child's performance in their everyday activities, such as self-care, school tasks, leisure activities, prevocational and vocational activities, and play (American Psychiatric Association, 2013). Difficulties with coordination and learning motor skills characteristic of DCD are present in early childhood and are not better explained by a neurological condition, intellectual disability, or visual impairment (American Psychiatric Association, 2013). While DCD may manifest in the early developmental period, the condition is often not identified until school-age (Missiuna, Moll, King, King, & Law, 2007). Children with DCD have poorer academic outcomes and may participate in fewer group activities than their typically developing peers (Cantell, Smyth, & Ahonen, 2003). As such, they are at risk for lower quality of life than their peers in physical, psychological and social functioning domains (Zwicker, Harris, & Klassen, 2013). These negative effects arising from DCD extend beyond childhood and into adulthood (Cousins & Smyth, 2003).

The prevalence of DCD in children aged 5–11 years is estimated at 5–6% (American Psychiatric Association, 2013), equating to approximately 450,000 Canadian children (Statistics Canada, 2017) and over 1,400,000 American children being affected (U.S. Census Bureau, 2010); however, children born very preterm (VPT: ≤ 32 weeks of gestational age) are at six to eight times higher risk for the disorder (Edwards et al., 2011). Studies have shown that 30–42% of VPT children are affected by DCD (Edwards et al., 2011; Foulder-Hughes & Cooke, 2003; Goyen & Lui, 2009). Zhu, Olsen, and Oleson (2012) showed that each week prior to 39 weeks gestation was associated with increased risk for DCD. In addition to lower gestational age, other perinatal variables that are associated with DCD include male sex, low birth weight, prolonged rupture of membranes, retinopathy of prematurity, and postnatal steroid exposure (Davis, Ford, Anderson, & Doyle, 2007; Goyen & Lui, 2009; Zhu et al., 2012; Zwicker, Yoon et al., 2013). VPT children score significantly lower on motor tests than their typically developing or full-term peers and are found to experience motor deficits in coordination, balance skills, ball skills, gross and fine motor control, and visual motor integration (De Kieviet, Piek, Aarnoudse-Noens, & Oosterlaan, 2009).

The Movement Assessment Battery for Children, 2nd edition (MABC-2) Test is the most commonly used and recommended assessment to identify children with DCD (Blank, Smits-Engelsman, Polatajko, & Wilson, 2012); this standardized motor assessment provides information to support diagnostic criterion A by determining if the acquisition and execution of coordinated motor skills is substantially below that expected given the individual's chronological age (American Psychiatric Association, 2013; Harris, Mickelson, & Zwicker, 2015). Scores from the MABC-2 indicate if a child falls within the normal range for his age, if the child is "at risk" of having motor difficulties, or if the child has significant movement impairments. The age limit has been lowered from 4 years of age in the original version of the MABC to 3 years of age in the MABC-2 (Henderson, Sugden, & Barnett, 2007). With this lowered age limit, there now lies the possibility of using the MABC-2 to identify children who are at risk of DCD at an earlier age.

Several studies have confirmed that the MABC-2 is a reliable and valid tool to assess for movement disorders in the first age band (ages 3–6 years) (Henderson et al., 2007; Ellinoudis et al., 2011). Smits-Engelsman, Niemeijer, and van Waelvelde (2011) confirmed that the MABC-2 has good to excellent test-retest reliability in typically developing three-year-old children. However, there is limited information about the predictive validity of the MABC-2 in the VPT population in this age group. Earlier identification of DCD can allow for VPT children who are at high risk for DCD to receive appropriate interventions earlier to support their daily occupations and reduce the consequences of DCD on quality of life.

The aims of this study were to assess if the MABC-2 Test at 3 years of age can predict DCD at 4.5 years of age in VPT children and to determine if DCD can be reliably identified at age 3 with this measure in this high-risk population. We hypothesized that MABC-2 scores at age 3 years will be predictive of DCD in VPT populations and that the MABC-2 has moderate specificity and sensitivity to identify DCD at 4.5 years.

2. Material and methods

2.1. Participants

Very preterm children born at 24–32 weeks gestational age and seen in the Neonatal Follow-Up Program (NFUP) at the BC Women's Hospital in Vancouver, Canada at their 3-year and 4.5-year follow-up visits between January 2010 and July 2015 were eligible to participate in this study ($n = 280$). In the NFUP, children are assessed by a multidisciplinary team, including a neonatologist or developmental pediatrician, nurse, physical or occupational therapist, speech language pathologist, and psychologist. The recruitment criteria for the NFUP include birthweight ≤ 800 g, gestational age ≤ 25 completed weeks, grade 4 intraventricular hemorrhage, cystic periventricular leukomalacia, severe retinopathy of prematurity (\geq stage 3 or requiring laser treatment), home oxygen therapy, and/or participants in funded research studies.

Children were excluded if: (1) they had a medical diagnosis that would impact their performance on the MABC-2 and/or preclude a diagnosis of DCD (e.g., cerebral palsy, global developmental delay, intellectual impairment, or significant visual or hearing impairments); (2) the MABC-2 was not administered at age 3 years or age 4.5 years; or (3) the child refused to complete the MABC-2. This study was approved by the University of British Columbia and Children's and Women's Health Centre of British Columbia Research Ethics Board. Parents or legal guardians of participants provided written informed consent to the use of NFUP data for research purposes.

2.2. Assessment

The MABC-2 is a motor performance test which assesses a child's fine and gross motor abilities on eight test items in each of the three age bands (3–6 years; 7–10 years; and 11–16 years). The items are categorized into three components: manual dexterity, aiming and catching, and static and dynamic balance. For some test items, two attempts are allowed, with the child's best attempt used as the score for the test item. Children are scored an F for failure if they attempt an item but are unable to complete it or an R for refusal if they refuse to attempt a task. A failure (F) is assigned a standard score of 1. Children who have a physical or sensory disability impacting their performance score an I for inappropriate on the item. According to the MABC-2 manual, no component score or total test score can be calculated for the child if one or more items are recorded as an R or I. In these cases, the examiner should assess the child's motor performance qualitatively (Henderson et al., 2007).

Raw item scores are converted into age-adjusted item standard scores and component standard scores for each age between 3 and 16 years. The total standard score can be transformed into an age-adjusted percentile rank. The norms for each age band are provided in the manual. In the absence of Canadian norms for this test, the UK norms were used as it was thought that cultural norms for motor skills would be similar between the two nations. For all ages, the MABC-2 manual suggests that children who score ≤ 5 th percentile have a significant movement difficulty, while those who score in the 6th–15th percentile are “at risk” of having a movement difficulty and require monitoring. Children who score ≥ 16 th percentile do not have a motor impairment. Clinically, a cut-off score of ≤ 15 th percentile to diagnose children with DCD is recommended, while a stricter cut-off score of ≤ 5 th percentile is recommended for children ages 3–5 years (Blank et al., 2012).

2.3. Design & procedure

Children were individually assessed at the NFUP at the BC Women's Hospital by a multidisciplinary team. Physical therapists and occupational therapists administered the MABC-2 to children at age 3 and 4.5 years following a standard test protocol. All examiners had experience in administering the MABC-2 in clinical settings. At the 4.5 year assessment, a child was diagnosed with DCD if the physician and therapist determined that the diagnostic criteria for DCD had been met (American Psychiatric Association, 2013).

Consistent with the recommendations from the European Academy of Childhood Disability guidelines (Blank et al., 2012), children who scored ≤ 5 th percentile were classified as “DCD”. In this study, children were scored according to their chronological age. Children who scored ≥ 16 th percentile on the MABC-2 were classified as “non-DCD”; children who scored in the “at risk” category (within the 6th and 15th percentiles) were also classified as “non-DCD”. Children who refused to complete the assessment were assigned an R and a reason for their refusal by the examiner using his or her clinical judgment.

We extracted the following variables from the NFUP database: gender, gestational age (weeks), birth weight (grams), days on ventilation, Apgar scores at 5 min, and MABC-2 scores at ages 3 and 4.5 years.

2.4. Data analysis

IBM SPSS Statistics V.23 (IBM, New York, USA) was used for statistical analysis of the collected data. We first examined differences between risk factors in the DCD group and the non-DCD group at 4.5 years using Fisher's exact test for categorical variables and Kruskal-Wallis equality-of-populations rank test for continuous variables. Then, to test our first hypothesis, statistically significant variables from these analyses were entered into a logistic regression model to determine the relationship of confounding variables with DCD diagnosis at 4.5 years and to identify variables independently associated with DCD diagnosis at 4.5 years of age. To test our second hypothesis, cross tabulations were conducted to determine the relationship between MABC-2 scores at age 3 years and diagnosis of DCD at age 4.5 years and to calculate the specificity, sensitivity, positive predictive value, and negative predictive value of the MABC-2 at age 3 in this population. A p value of < 0.05 was used to denote statistical significance.

3. Results

Of the 280 children seen at the NFUP between January 2010 to July 2015, 50 children were excluded because of other diagnoses, such as cerebral palsy ($n = 31$), global developmental delay ($n = 8$), or significant medical issues ($n = 11$). Twenty-two (9.6%) children were excluded because the MABC-2 was not completed at either age 3 or age 4.5 years because they did not return for their follow-up appointment(s). Of the remaining 208 children, an additional 43 (20.7%) children were excluded if the test could not be completed because they refused to complete one or more items on the assessment due to immature or delayed motor skills ($n = 19$), poor attention or focus ($n = 4$), or uncooperative or other behavioral issues ($n = 20$). The final sample consisted of 165 children (median age 26 weeks, IQR 25–28 weeks), with 88 (53%) males and with 29 (17.6%) being diagnosed with DCD at 4.5 years (Fig. 1).

Characteristics for the DCD group and non-DCD group are shown in Table 1. Children with DCD had significantly lower gestational age, lower birth weight, longer days on ventilation, lower Apgar scores at 5 min, and lower MABC-2 percentile ranks at age 3 and 4.5 years. There was no significant difference in sex distribution between the two groups.

3.1. MABC-2 scores at age 3 years predict DCD at 4.5 years

Significant group differences were entered into the logistic regression analysis. Diagnosis of DCD was entered as the dependent measure. Given the high correlation between gestational age and birth weight ($r = 0.80$), only gestational age was entered into the

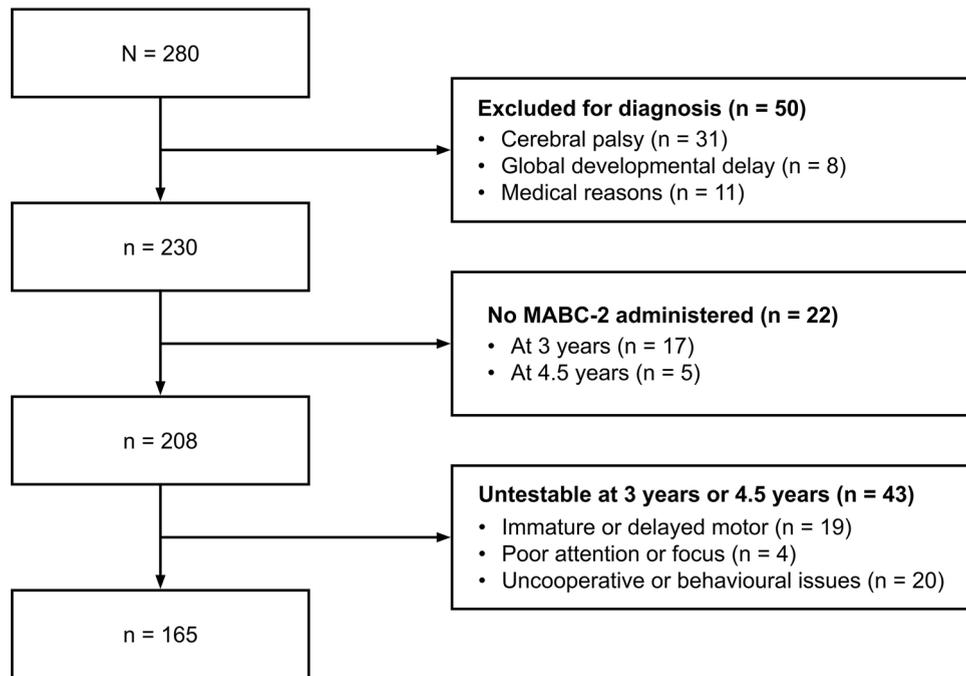


Fig. 1. Participant inclusion flowchart.

Table 1
Differences in DCD risk factors between children with and without DCD at 4.5 years.

Variable	DCD (n = 29)	Non-DCD (n = 136)	p value
Perinatal variables			
Male	18 (62)	70 (52)	0.31
Gestational age (weeks)	25 (24–26)	27 (25–29)	< 0.001
Birth weight (grams)	730 (670–790)	885 (717–1127)	< 0.001
Neonatal variables			
Ventilation duration (days)	45 (27–65)	23 (5–52)	0.004
5 min Apgar score	6 (5–7)	8 (6–9)	0.003
MABC-2 (percentile)			
Age 3 years	1 (1–5)	16 (5–25)	< 0.001
Age 4.5 years	1 (1–5)	50 (25–75)	< 0.001

Data are presented as a number (%) for dichotomous variables and median (IQR) for continuous or categorical variables. MABC-2, Movement Assessment Battery for Children – 2nd edition.

Table 2
Logistic regression model for predicting diagnosis of DCD at 4.5 years.

Variable	B	SE	OR	95% CI	p value
MABC-2 score at 3 years	−0.199	0.062	0.82	0.73–0.93	0.001
Gestational age (weeks)	−0.309	0.194	0.73	0.50–1.08	0.11
Apgar (5 min)	0.001	0.158	1.00	0.73–1.36	0.99
Ventilation duration (days)	0.005	0.011	0.67	0.98–1.03	0.67

CI, confidence interval; MABC-2, Movement Assessment Battery for Children-2; OR, odds ratio.

model as an indicator of physiological maturity. The results from the analysis are summarized in Table 2. The logistic regression model was significant ($\chi^2 = 41.53$, $df = 4$, $p < 0.001$). MABC-2 score at age 3 years were highly correlated (odds ratio = 0.82) and was the only significant individual predictor related to diagnosis of DCD at 4.5 years ($p = 0.001$).

3.2. Predictive validity of MABC-2

Cross-tabulations showed that there is a significant association between MABC-2 percentile rank at 3 years and diagnosis of DCD

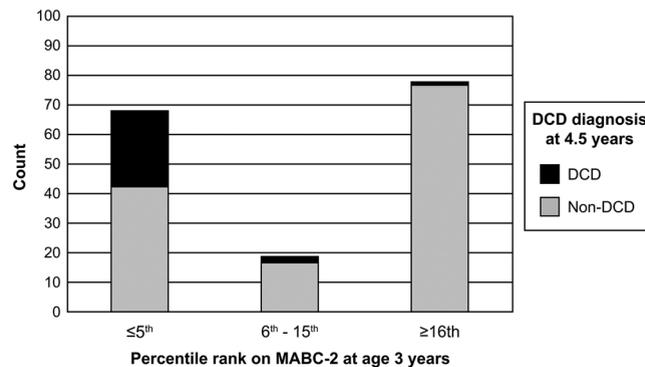


Fig. 2. Number of children within each percentile range at age 3 years and DCD diagnosis at 4.5 years.

at 4.5 years ($\chi^2 = 34.98, df = 2, p < 0.001$). The total number of children with and without DCD classified in each category can be found in Fig. 2. Only 1 (1.3%) child who scored ≥ 16 th percentile and only 2 (10.5%) children who scored in the “at risk” (6th to 15th percentile) ranges on the MABC-2 at age 3 years were diagnosed with DCD at 4.5 years. Forty-two children (61.8%) who scored in the ≤ 5 th percentile at age 3 years did not have DCD at 4.5 years.

MABC-2 scores at age 3 years were then compared with DCD diagnosis at age 4.5 years as shown in Table 3 to obtain the specificity, sensitivity, and positive and negative predictive values ($\chi^2 = 34.08, df = 1, p < 0.001$). The MABC-2 has excellent sensitivity (89.7%) and moderate specificity (69.1%) in identifying DCD at age 4.5 years. The MABC-2 also yielded a small to moderate positive predictive value (38.2%) and a very high negative predictive value (96.9%).

4. Discussion

The first aim of this study was to determine if DCD can be predicted at age 3 years in VPT children using the MABC-2. Our findings show that MABC-2 scores at age 3 years was the only significant variable contributing to DCD diagnosis at 4.5 years, after adjustment for gestational age, Apgar scores, and days of ventilation. The odds ratio suggests that children with DCD at 4.5 years are 1.22 times more likely to have a MABC-2 score of ≤ 5 th percentile at age 3 years. Perinatal and neonatal variables associated with DCD, such as gestational age or days of ventilation, differed significantly between children with and without DCD; however, these variables were not predictive of DCD in the regression model when MABC-2 scores at 3 years were included. The significantly different characteristics identified between our DCD and non-DCD groups are consistent with existing research findings with the exception of sex. Male sex has previously been identified as an independent predictor of DCD (Davis et al., 2007; Zwicker, Yoon et al., 2013); however, in our study, male sex was not significantly different between the two groups. This finding is similar to a recent study exploring the predictive validity of the MABC-2, where male sex was not associated with MABC-2 scores at 4 years and was only weakly associated with MABC-2 scores at age 8 years (Griffiths et al., 2017).

The second aim was to determine if the MABC-2 can be used to reliably identify DCD at age 3 years in this population. This study found that the MABC-2 was highly sensitive (89.7%) to 3-year-old VPT children with DCD. However, the positive predictive value (38.2%) indicates that there are many false positives in our high risk VPT population. Therefore, children whose MABC-2 scores at age 3 years may indicate they are at risk of DCD (≤ 5 th percentile) should not be diagnosed with DCD until at least age 4.5 years. The high negative predictive value (96.9%) reveals that children who score ≥ 16 th percentile on the MABC-2 at age 3 years are very likely to not have DCD at age 4.5 years.

In our study, 20% ($n = 43$) of our VPT children were excluded because they were not able to complete the assessment due to attention issues, behavioral issues, or immature or delayed motor skills; thus, total MABC-2 scores or percentile ranks could not be derived. As per our clinic protocol, children in this study were assessed with the MABC-2 by the NFUP clinicians at their corrected age but scored according to their chronological age. Because clinicians do not correct for prematurity when scoring for this assessment at age 3 years, children who were assessed may not have been ready to perform some of the MABC-2 tasks as they are developmentally younger than their at-term peers who are in the same age band.

Table 3
2 × 2 table comparing MABC-2 scores at 3 years and DCD diagnosis at 4.5 years.

At risk of DCD at 3 years	DCD diagnosis at 4.5 years		Total
	DCD	Non-DCD	
MABC-2 scores ≤ 5 th percentile	26	42	68
MABC-2 scores > 5 th percentile	3	94	97
Total	29	136	165

$\chi^2 = 34.08, df = 1, p < 0.001$; MABC-2, Movement Assessment Battery for Children-2.

Attention and behavioral issues are present in typically-developing 3–4 year olds, who may get bored easily, may not be able to sit attentively, and are not concerned with pleasing examiners (Payne & Isaacs, 1998). Smits-Engelsman et al. (2011) found that approximately 90% of their three-year-old children were willing and able to perform more than half the tasks on the MABC-2. However, their study was conducted with typically-developing, term-born children. VPT children under 4 years of age have been shown to have lower cognition, behavioral problems (Clark, Woodward, Horwood, & Moor, 2008), emotional problems (Woodward et al., 2009), and poor executive function (Edgin et al., 2008) in comparison with their at-term peers. Preterm children also have an increased risk of hyperactivity and attention deficit disorders (Delobel-Ayoub et al., 2006). Because the MABC-2 is an assessment that requires attention and cooperation for each test item, VPT children who are at higher risk for impairments in multiple domains compared to their term-born peers will very likely experience more difficulty completing the assessment. Our study was consistent with this existing research in that about 12% of the VPT children in our study were not able to complete the full assessment due to behavioral or attentional difficulties.

Because of the high sensitivity of the MABC-2 at age 3 years, VPT children who score \leq 5th percentile in the MABC-2 at age 3 years are at high risk for DCD and thus should be routinely followed until at least school-age by clinicians. However, the high negative predictive value of the MABC-2 suggests that if a VPT child scores \geq 16th percentile at age 3 years, then they are very likely to have good motor outcomes at 4.5 years. In these cases, surveillance rather than routine screening with standardized testing for motor outcomes is likely adequate as the majority of these children will not have a motor impairment at age 4.5 years. Ongoing surveillance of motor development of children born preterm is recommended as DCD may emerge later in childhood in this high-risk population (Edwards et al., 2011).

There are several limitations to this study. Due to the restrictive inclusion criteria of our tertiary care NFUP, our results may not be generalizable to other cohorts of very preterm infants. We were limited to data available in our participants' medical charts due to our study's retrospective design; a further limitation of this design is that therapists were not blinded to previous assessments as they were conducted as part of clinical care. Data on therapeutic interventions between age 3 years and age 4.5 years were not systematically collected. Therapeutic interventions or implementation of recommendations from the NFUP clinicians may have improved a child's motor performance on the MABC-2 at age 4.5 years and may have impacted the specificity of the MABC-2 in this study. Sensitivity and specificity of the MABC-2 may differ if the child is assessed at an older age; however, a recent study showed that the MABC-2 administered at 4 years yielded similar results, with high sensitivity (79%) and specificity (93%) for predicting motor impairment at age 8 years in a cohort of infants born preterm (Griffiths et al., 2017). To further clarify the ability of the MABC-2 to predict DCD, further research is needed with standardized measures other than the MABC-2 used to classify DCD.

5. Conclusion

In conclusion, MABC-2 scores at age 3 years is a significant predictor for DCD outcome at age 4.5 years in very preterm children. The MABC-2 at the \leq 5th percentile cut-off is highly sensitive to be able to identify VPT children at age 3 years who will develop DCD, but the high number of false positives at this age reduces the positive predictive value. However, clinicians can have greater confidence in the MABC-2 in identifying who is not at risk of DCD at age 3 years, which can help to inform which children require only surveillance and which children can be discharged from standardized motor screening. While the MABC-2 is a useful measure to identify which 3-year-old VPT children may or may not be at risk of DCD, one in five children at this age may not be able to complete the assessment.

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