Motor Impairment Trends in Extremely Preterm Children: 1991–2005

Alicia J. Spittle, PhD,[a,b,c] Kate Cameron, DPT,[a,c] Lex W. Doyle, MD,[b,c,d,e] Jeanie L. Cheong, MD,[b,c,d] for the Victorian Infant Collaborative Study Group

abstract

BACKGROUND: There are increasing numbers of surviving children who were born extremely preterm (EP; gestational age <28 weeks) or extremely low birth weight (ELBW; birth weight <1000 g). Our objective in this study was to compare the rates of motor impairment at 8 years of age between 3 cohorts of EP and/or ELBW and term-born children to establish if motor impairment rates are changing over time.

METHODS: All children born EP and/or ELBW in the calendar years of 1991–1992, 1997, and 2005 in Victoria, Australia, were recruited at birth. Randomly selected normal birth weight (>2499 g) and term-born controls were matched for expected date of birth, sex, and sociodemographic status. At 8 years' corrected age, motor impairment was defined as cerebral palsy (CP) or a score less than the fifth centile on the Movement Assessment Battery for Children for the 1991–1992 and 1997 cohorts and less than or equal to the fifth centile on the Movement Assessment Battery for Children–Second Edition for the 2005 cohort.

RESULTS: Motor impairment was more likely in children born EP and/or ELBW compared with children born at term for all epochs. There was a significant increase in motor impairment in EP and/or ELBW children over the 3 eras, from 23% in 1991–1992 and 26% in 1997 to 37% in 2005 (χ^2_{trend} = 10.2; P = .001). This was due to an increase in non-CP motor impairment (13% in 1991 to 1992; 15% in 1997; 26% in 2005; χ^2_{trend} = 12.5; P < .001), not CP (11% in 1991 to 1992; 11% in 1997; 12% in 2005).

CONCLUSIONS: The rate of motor impairment in EP and/or ELBW children assessed at 8 years of age increased between eras, an increase caused by non-CP motor impairment.

[a]*Department of Physiotherapy, Melbourne School of Health Sciences, and Departments of* [d]*Obstetrics and Gynaecology and* [e]*Paediatrics, Melbourne Medical School, University of Melbourne, Melbourne, Australia;* [b]*Neonatal Services, The Royal Women's Hospital, Melbourne, Australia; and* [c]*Victorian Infant Brain Studies, Murdoch Children's Research Institute, Melbourne, Australia*

Dr Spittle conceptualized and designed the study, drafted the initial manuscript, and reviewed and revised the manuscript; Dr Cameron conceptualized and designed the study, conducted the initial analyses, and reviewed and revised the manuscript; Dr Doyle conceptualized and designed the study, designed the data collection and study protocol, coordinated and supervised data collection, contributed to data analyses, and critically reviewed the manuscript; Dr Cheong conceptualized and designed the study, designed the data collection and study protocol, coordinated and supervised data collection, and critically reviewed the manuscript; and all authors approved the final manuscript as submitted and agree to be accountable for all aspects of the work.

DOI: https://doi.org/10.1542/peds.2017-3410

Accepted for publication Jan 9, 2018

Address correspondence to Alicia J. Spittle, PhD, Department of Physiotherapy, University of Melbourne, 7th Floor Alan Gilbert Building, 161 Barry St, Parkville, VIC 3052, Australia. E-mail: aspittle@unimelb.edu.au

WHAT'S KNOWN ON THIS SUBJECT: Preterm children have worse motor outcomes at school compared with peers born at term. However, it is unknown if there have been changes in motor outcomes with advances in neonatal care.

WHAT THIS STUDY ADDS: There are increased rates of motor impairment at 8 years' corrected age in extremely preterm and/or extremely low birth weight children over 3 eras, with rates of motor impairment increasing from 23% in 1991–1992 and 36% in 1997 to 37% in 2005.

To cite: Spittle AJ, Cameron K, Doyle LW, et al. Motor Impairment Trends in Extremely Preterm Children: 1991–2005. *Pediatrics*. 2018;141(4):e20173410

Over the past 3 decades, there have been significant increases in survival rates of infants born extremely preterm (EP; <28 weeks' gestation) and/or extremely low birth weight (ELBW; <1000 g birth weight) because of improvements in neonatal intensive care[1,2] alongside a greater willingness to provide intensive care to more EP and/or ELBW infants.[2,3] Advances in obstetric and neonatal care have included the introduction of antenatal corticosteroids and assisted ventilation in the 1970s and 1980s and the introduction of surfactant in 1991. Recent advances in perinatal care over the last few decades include caffeine for the treatment of apnea of prematurity,[4] increased use of noninvasive respiratory support,[5] and targeted use of postnatal corticosteroids.[6] Although some of these interventions show promise for improved neurodevelopment in early childhood, the effects of changes in neonatal practices on long-term motor outcomes at a population level is unknown.[7,8] Because more EP and/or ELBW infants are surviving, it is vital to understand the impact of these interventions on neurodevelopmental morbidity in later childhood.

Our population-based studies of EP and/or ELBW children from Victoria, Australia, have recently revealed that rates of major neurodevelopmental disability in 8-year-old children born over 3 time epochs, from 1991 to 1992, 1997, and 2005, have remained unchanged, despite advances in care.[9] Of more concern, academic performance for children born EP and/or ELBW was poorer in the most recent cohort born in 2005, compared with the earlier 2 epochs.[9]

Children who are born preterm are at an increased risk of a range of neurodevelopmental impairments, with motor impairments such as cerebral palsy (CP) and non-CP motor impairments such as developmental coordination disorder (DCD) being more prevalent in EP and/or ELBW survivors than term-born peers.[10,11] CP registers have improved our understanding of changes in rates of CP over time, with authors of a recent study in Australia reporting that CP rates in children born at <28 weeks peaked in the 1990s and early 2000s, but are now declining.[12] Comparatively, changes in rates of non-CP motor impairments in children born EP and/or ELBW over time are not well documented. Motor impairments, whether mild or severe, are associated with poorer academic outcomes, including reading, spelling, and arithmetic, and less participation in social leisure activities, hobbies, and sports compared with children without motor impairment.[13,14]

It is therefore important to understand how the rates of motor impairment in children born EP and/or ELBW are changing over time. Our aims in this study were (1) to examine how rates of motor impairment assessed at age 8 in EP and/or ELBW children born in Victoria, Australia, have changed over the 3 eras of 1991–1992, 1997, and 2005 compared with controls, and (2) to determine the perinatal predictors associated with motor impairment in EP and/or ELBW children.

METHODS

Three cohorts of children were recruited as part of the Victorian Infant Collaborative Study, a series of longitudinal, population-based studies of children born EP and/or ELBW in Victoria, Australia. All EP and/or ELBW children born in the 3 discrete cohorts of 1991–1992 (24 months), 1997, and 2005 (12 months, respectively) were included in the study. The infants were treated in a NICU at 1 of the 4 tertiary neonatal units in the state (The Royal Women's Hospital, Monash Medical Centre, Mercy Hospital for Women, or The Royal Children's Hospital). A control group of normal birth weight (>2499 g), term-born children were recruited from 1 of the 3 tertiary maternity hospitals and matched with an EP and/or ELBW survivor for expected date of delivery, sex, health insurance status (private insurance or not), and the mother's country of birth (English-speaking or non–English-speaking). General neurodevelopmental outcomes at 2[15] and 8[9] years of age for the cohorts have been reported.

Ethics

Ethical approval was given by the human research ethics committees of the 4 hospitals. Parents of participants gave written, informed consent for their child to participate in the 8-year follow-up assessment for the 2005 cohort; follow-up was considered routine clinical care for EP and/or ELBW children in the earlier cohorts.[9]

Perinatal Characteristics

Extensive perinatal data on the pregnancy and neonatal course were recorded by research nurses from medical records, and data at 2 years of age were obtained during follow-up assessments, as previously described.[9] A diagnosis of a patent ductus arteriosus (PDA) was recorded, as was necrotizing enterocolitis (NEC), defined as stage 2 or worse on Bell's criteria.[16] Estimated due date was based on obstetric ultrasound at 20 weeks' gestation when available (>90% cases) or by menstrual history when ultrasound was unavailable. Birth weight *z* scores were computed by using the British growth reference curves.[17]

Outcome Measures

Children were invited to attend a comprehensive developmental assessment at 8 years' corrected age at 1 of the 3 tertiary maternity hospitals. All children had a neurologic and motor assessment

conducted by a pediatrician who was unaware of the child's medical history, including gestation or weight at birth. The assessment included the Movement Assessment Battery for Children (MABC)[18] for the 1991–1992 and 1997 cohorts, or the Movement Assessment Battery for Children–Second Edition (MABC-2)[19] for the 2005 cohort. The type and distribution of CP was classified by the pediatrician after a neurologic examination, which included an assessment of muscle tone, reflexes, and motor function. The Gross Motor Function Classification Scale (GMFCS)[20] was used to classify the severity of motor dysfunction for children with CP for the 1997 and 2005 cohorts, whereas a functional scale was used for the 1991–1992 cohort. To compare data across the 3 cohorts, CP was classified as mild (GMFCS I and/or able to ambulate independently), moderate (GMFCS II–III and/or requires assistance to ambulate) and severe (GMFCS IV–V and/or unable to ambulate).

The MABC and the MABC-2 are both reliable and valid means of identifying impairments in motor function in children both with and without motor impairment.[21,22] They include assessments of manual dexterity, balance, and aiming and catching, each of which is scored on a 6-point scale. Normative scores are based on data from the United Kingdom. The original MABC has a cutoff of less than the fifth centile for motor impairment, whereas the second edition has a cutoff of less than or equal to the fifth centile for motor impairment. Children with severe motor impairments who were unable to perform the MABC and/or MABC-2 were given a centile of 1. Motor impairment was defined as a diagnosis of CP and/or an MABC and/or MABC-2 score of less than the fifth centile for the 1991–1992 and 1997 cohorts and less than or equal to the fifth centile for the 2005 cohort. Any child with a MABC and/or MABC-2 score in the motor impairment range without CP was classified as having a non-CP motor impairment.

TABLE 1 Demographics and Perinatal Characteristics of EP, ELBW, and Term-Born Children Across 3 Cohorts

Variable	1991–1992	1997	2005
EP and/or ELBW cohort			
Live births free from lethal abnormalities, *n*	552	297	343
Survivors to 8 y, *n* (%)	298 (54)	201 (68)	219 (64)
Perinatal characteristics			
Outborn, *n* (%)	23 (8)	10 (5)	25 (11)
Antenatal corticosteroids, *n* (%)	217 (73)	176[a] (88)	193[b] (89)
Preeclampsia, *n* (%)	56 (19)	39[b] (19)	35[b] (16)
Cesarean delivery, *n* (%)	114 (38)	127 (63)	141 (64)
Multiple births, *n* (%)	91 (31)	44 (22)	50 (23)
Mean gestational age (SD), wk[c]	26.7 (1.9)	26.6 (2.0)	26.5 (1.9)
Mean birth wt (SD), g[c]	888 (161)	836 (165)	868 (179)
Mean birth wt SD score[c] (SD)	−0.73 (1.20)	−0.95 (1.08)	−0.73 (1.12)
Male, *n* (%)	138 (46)	105 (52)	102 (47)
PDA, *n* (%)	156 (52)	100 (50)	146 (67)
NEC, *n* (%)	26 (9)	11 (5)	18 (8)
IVH (grade 3 or 4), *n* (%)	18 (6)	7 (3)	17 (8)
Cystic PVL, *n* (%)	18 (6)	6 (3)	8 (4)
Postnatal corticosteroids, *n* (%)	98 (33)	73 (36)	42[b] (19)
Bronchopulmonary dysplasia,[d] *n* (%)	121 (41)	77[b] (38)	105 (48)
Surgery in newborn period, *n* (%)	77 (26)	65 (32)	54 (25)
Control cohort			
Recruited at birth, *n*	265	199	219
Survivors to 8 y, *n* (%)	262 (99)	199 (100)	218 (99.5)
Perinatal characteristics			
Multiple births, *n* (%)	8 (3)	1 (0.5)	2 (0.9)
Mean gestational age (SD), wk[c]	39.2 (1.4)	39.2 (1.2)	39.5 (1.3)
Mean birth wt (SD), g[c]	3381 (441)	3489 (472)	3575 (482)
Mean birth wt SD score[c] (SD)	−0.03 (0.89)	0.17 (0.96)	0.25 (0.90)
Male, *n* (%)	126 (48)	105 (53)	102 (47)

All data are represented as numbers and percentages except for variables with the footnote [c], which represent means and SDs.
[a] *n* = 2 missing data.
[b] *n* = 1 missing data.
[c] Data represent means and SDs.
[d] In oxygen at 36 wk.

Statistical Analysis

Data were analyzed by using Stata/IC, version 14.2 (StataCorp, College Station, TX) and SPSS for Windows, version 24 (IBM SPSS Statistics, IBM Corporation, Armonk, NY). χ^2 for trend was used to analyze systematic changes in rates of categorical outcomes over time, such as CP, non-CP motor impairment, and poor motor function. Predictors for dichotomous outcomes in EP and/or ELBW infants, including CP, non-CP motor impairment, and poor motor function, were analyzed by using multivariable logistic regression. In each case, logistic regression was fitted by using generalized estimating equations with robust (sandwich) estimation of SEs to allow for multiple births within a family. Results are presented as odds ratios (ORs) and 95% confidence intervals (CIs).

RESULTS

The demographic and perinatal characteristics of the groups are listed in Table 1. Survival rates improved from 54% in 1991–1992 to 68% in 1997 and stabilized in 2005 at 64%. Perinatal characteristics for the 3 epochs remained similar over time, except for rates of antenatal corticosteroid use and PDA, which rose over time, and postnatal corticosteroids, which fell over time.

All cohorts had high follow-up rates, with 92% in the 1991–1992 cohort, 94% in the 1997 cohort, and 87% in the 2005 cohort for children born EP and/or ELBW, and 86%, 87%, and 87%, respectively, for children in the control cohort (Table 2). Children born EP and/or ELBW in 2005 were significantly more likely to have motor impairment compared with their full-term peers, with 37% (71 out of 191) of EP and/or ELBW children having motor impairment, compared with 7% (13 out of 189) of children born at term (OR: 8.00; 95% CI: 4.33–15.2; $P < .001$). There was a significant increase in motor impairment over time for children born EP and/or ELBW, increasing from 23% in 1991–1992 and 26% in 1997 to 37% in 2005 (Table 2). Rates of CP in children born EP and/or ELBW remained relatively constant over time at 11% in 1991–1992, 11% in 1997, and 12% in 2005, whereas non-CP motor impairment increased over time from 13%, 15%, and 26%, respectively. The severity of CP in children born EP and/or ELBW was similar across eras (1991–1992: 52% mild, 21% moderate, 28% severe; 1997: 48% mild, 29% moderate, 19% severe; and 2005: 41% mild, 41% moderate, 18% severe). The rate of survival free of motor impairment was 38% for the 1991–1992 cohort, which rose to 47% for the 1997 cohort, but then fell to 35% for the 2005 cohort.

Children in the control group also showed a significant increase in motor impairment, although less pronounced than the EP and/or ELBW group, increasing from 2% in 1991–1992 to 8% in 1997 and then remaining stable at 7% in 2005, which is attributed largely to an increase in non-CP motor impairment (Table 2).

When examining predictors of motor impairment on univariable analyses (Table 3), children born EP and/or ELBW in 2005 were more likely to have poor motor function compared with those born in both the 1991–1992 and 1997 groups. Other predictors of poor motor impairment on a univariable analysis included being outborn, male sex, lower gestational age, having a PDA, grades 3 or 4 intraventricular hemorrhage (IVH), cystic periventricular leukomalacia (PVL), postnatal corticosteroids, bronchopulmonary dysplasia (receiving oxygen at 36 weeks' postmenstrual age), and surgery during the primary hospitalization. Differences in perinatal characteristics did not explain the worse motor function in 2005 compared with both earlier eras; adjustment for risk factors increased the ORs for both comparisons (Table 3). Other variables associated with increased rates of motor impairment on a multivariable analysis included poorer fetal growth, postnatal corticosteroids, grades 3 or 4 IVH, cystic PVL, and neonatal surgery.

TABLE 2 Trends in MABC Scores, CP, and Motor Impairment in EP and/or ELBW Children and Term Controls Assessed at 8 Years

	1991–1992	1997	2005	*P*
Children born EP and/or ELBW				
Survived to 8 y	298	201	219	—
Assessed at 8 y, *n* (% survivors)	275 (92)	189 (94)	191 (87)	—
MABC data,[a] *n* (% assessed)	263 (96)	169 (89)	176 (92)	—
Motor impairment,[b] *n* (% assessed)	64 (23)	50 (26)	71 (37)	.001
CP diagnosis, *n* (% assessed)	29 (11)	21[c] (11)	22 (12)	.74
Non-CP motor impairment, *n* (% assessed)	35 (13)	29 (15)	49 (26)	<.001
Children born at term				
Survived to 8 y	262	199	218	—
Assessed at 8 y, *n* (% survivors)	226 (86)	172 (86)	189 (87)	—
MABC data,[a] *n* (% assessed)	209 (92)	159 (92)	187 (99)	—
Motor impairment,[b] *n* (% assessed)	5 (2)	13 (8)	13 (7)	.029
CP diagnosis, *n* (% assessed)	1 (0.4)	0 (0)	2 (1)	.42
Non-CP motor impairment, *n* (% assessed)	4 (2)	13 (8)	11 (6)	.043

—, not applicable.
[a] Includes children with CP who could not complete the MABC and who were assigned a centile score of 1.
[b] Defined as a CP diagnosis and/or MABC score in the motor impairment range.
[c] There were 4 children with missing data.

TABLE 3 Associations With Any Motor Impairment at 8 Years of Age in EP and/or ELBW Children

Predictor	OR (95% CI)		*P*	
	Univariable	Multivariable	Univariable	Multivariable
Compared with 1991–1992 cohort	1.94 (1.28–2.95)	2.54 (1.55–6.45)	.002	<.001
Compared with 1997 cohort	1.62 (1.03–2.53)	1.96 (1.17–3.27)	.036	.01
Antenatal corticosteroids	0.78 (0.51–1.19)	0.76 (0.43–1.35)	.25	.35
Outborn[a]	2.30 (1.30–4.05)	1.81 (0.87–3.76)	.004	.12
Male sex	1.65 (1.17–2.32)	1.35 (0.92–1.97)	.004	.12
Gestational age per wk increase	0.89 (0.81–0.99)	0.93 (0.80–1.07)	.032	.29
Birth wt SD per 1 SD increase	0.92 (0.79–1.06)	0.69 (0.55–0.86)	.23	.001
PDA	1.93 (1.35–2.77)	1.39 (0.90–2.14)	<.001	.14
NEC	1.09 (0.57–2.08)	0.58 (0.24–1.39)	.80	.22
IVH grade 3 or 4	4.37 (2.26–8.46)	2.53 (1.25–5.09)	<.001	.01
Cystic PVL	6.69 (3.06–14.9)	6.00 (2.60–13.8)	<.001	<.001
Postnatal corticosteroids	2.75 (1.92–3.94)	1.87 (1.16–3.03)	<.001	.011
In oxygen at 36 wk	2.47 (1.76–3.48)	1.48 (0.97–2.24)	<.001	.07
Surgery	2.96 (2.06–4.26)	2.11 (1.36–3.28)	<.001	.001

Any motor impairment is defined as a CP diagnosis or motor impairment on the MABC.
[a] Not born in a perinatal center with a NICU.

DISCUSSION

Despite advances in neonatal care, children born EP and/or ELBW in 2005 were significantly more likely to have motor impairment at 8 years of age compared with children born at term. These motor impairments included higher rates of CP (EP and/or ELBW: 12%, versus term: 1%) and non-CP motor impairments (EP and/or ELBW: 26%, versus term: 6%). Of concern, and a unique finding of this current study, is that these motor impairments for children born EP and/or ELBW are increasing over time in the most recent cohort born in 2005 compared with both earlier cohorts, which is not explained by confounding perinatal variables. The increase in motor impairments in the EP and/or ELBW children is due to the increasing rates of non-CP motor impairment, rather than rates of CP, which have remained constant.

We have previously reported that motor skills were significantly worse in children born EP and/or ELBW in the 1991–1992 and 1997 cohorts compared with children born at term.[23] Thus, the higher rates of motor impairment in EP and/or ELBW children compared with controls for the 2005 were expected. Our findings are consistent with the wider literature; authors of recent systematic reviews in which DCD and CP were considered have reported that poor motor outcomes were more prevalent in children born at <1500 g birth weight or <32 weeks' gestation compared with children born at term.[11,24] However, with advances in neonatal care, we anticipated the magnitude of the difference between EP and/or ELBW and control groups would decrease rather than increase. Despite preterm birth being a significant risk factor for motor developmental deficits, there is a paucity of literature in which non-CP motor impairment trends in children born EP and/or ELBW were considered, and of these, most children were assessed during infancy and not into school age.[25–27] Non-CP motor impairment, such as DCD, merits further attention in this population. Not only do poor motor skills negatively affect a child's ability to participate in activities of daily living, but motor impairment is associated with poor academic performance, cognitive deficits, and emotional and behavioral problems.[28,29]

A single-center Canadian study revealed a significant increase in the proportion of children performing 2 SDs below the mean on motor assessment tools at 18 months of age in children who were born weighing <800 g between 1983 and 2003.[25] In contrast, the multicenter National Institute of Child Health and Human Development Neonatal Research Network reported a decrease in children performing 2 SDs below the mean on motor assessment tools at 18 months of age during 3 epochs (1993–1994, 1995–1996, and 1997–1998) for ELBW infants born at <32 weeks' gestation age.[26] However, when examining the outcomes of infants born at <25 weeks' gestation age separately, the number of children performing 2 SDs below the mean on motor assessment tools at 18 months of age was similar.[27]

There were consistent perinatal predictors of motor impairment across the 3 epochs on a multivariable analysis, including poorer fetal growth, brain injury (PVL and grades 3 or 4 IVH), surgery, and male sex. However, these perinatal variables did not explain the difference in outcomes between the 2005 and earlier cohorts, suggesting there are additional variables on the causal pathway to non-CP motor impairment for children born EP and/or ELBW. Authors of recent literature have emphasized that motor performance skills are learnt; they do not develop automatically over time.[30] Moreover, the process of learning motor performance skills is affected by multiple biological, social, and cultural variables.[31] For example, motor performance skills and physical activity levels have been shown to have a reciprocal relationship in school-aged children. Over the past decade, there have been increased rates of screen time and decreased physical activity in children.[32] It is possible that children born EP and/or ELBW are more susceptible to poorer motor function compared with term-born peers as a result of the way they spend their time. The poor motor function observed in our Victorian cohorts is likely to be multifactorial, and further research is needed to fully understand these causal relationships.[30]

A limitation of this study is the change of outcome measures over time from the MABC first edition in 1991–1992 and 1997 to the second edition in 2005. We changed to the newer edition of the MABC-2 when it was made available in 2007 to reflect current practice and normative data at that time. The criteria for motor impairment are different between the 2 tests, and although we could have chosen to use the same criterion for all 3 cohorts (eg, less than or equal to the fifth centile), we felt this was inappropriate because the normative data were different between tests, and it is not how the tests are used clinically. In addition, it has been noted by Brown and Lalor[22] that it is wrong to assume that the MABC-2 is the same outcome measure as the first edition, given changes in the age bracket, test structure, and normative data. Despite this, both the MABC and MABC-2 have been found to be reliable and valid outcome measures for assessing motor performance in children, including non-CP motor impairment.[21,22] It is important to note that the rate of non-CP motor impairments measured with the different versions of the MABC in the control groups did not change between the 1997 and 2005 cohorts, who were assessed on the different

measures. There was, however, an increase in motor impairment between the first 2 control cohorts (1991–1992 and 1997) when the same edition of the MABC was used.

There are several strengths of this study, including the recruitment of 3 cohorts born over a 14-year time period from the same geographical location, high follow-up rates, and a contemporaneous matched control group recruited at birth. An additional strength of the study was the range of perinatal variables that were collected prospectively, allowing the effects of changes in neonatal care on motor outcomes to be assessed. With further advances in neonatal care, such as the increased use of high-flow oxygen for respiratory support since the time of birth of the cohorts in this study, it is important to monitor future motor outcomes for children born today. In addition, factors influencing motor performance, such as screen time, physical activity, and sedentary behavior beyond the perinatal period, in both EP and/or ELBW children and term controls, warrant further study.

CONCLUSIONS

Rates of motor impairment, including CP and non-CP motor impairment, continue to be more prevalent in EP and/or ELBW children compared with term controls at 8 years of age. Despite advances in neonatal care from the early 1990s to 2005, the rates of non-CP motor impairment in EP and/or ELBW children increased over time. Other perinatal variables are associated with an increased risk of motor impairment in EP and/or ELBW children, but do not explain the increase in rates of motor impairment over time. Further research is needed to understand the variables that influence motor outcomes of children born EP and/or ELBW, and whether there are differential effects of environmental and social factors between EP and/or ELBW and term-born children in relation to motor performance.

VICTORIAN INFANT COLLABORATIVE STUDY GROUP

Peter Anderson,[2,4,5] Alice Burnett,[2,4,5,6] Catherine Callanan,[3,4] Elizabeth Carse,[7] Margaret P. Charlton,[7] Noni Davis,[1] Julianne Duff,[1,4] Esther Hutchinson,[4,6] Marie Hayes,[7] Elaine Kelly,[4,8] Marion McDonald,[4] Gillian Opie,[8] Gehan Roberts,[2,4,5,9] and Amanda Williamson.[8]

[1] Newborn Research, Royal Women's Hospital, Melbourne, Australia;

[2] Victorian Infant Brain Studies, Murdoch Children's Research Institute, Melbourne, Australia;

[3] Department of Obstetrics & Gynaecology, University of Melbourne, Melbourne, Australia;

[4] Premature Infant Follow-up Program, Royal Women's Hospital, Melbourne, Australia;

[5] Department of Paediatrics, University of Melbourne, Melbourne, Australia;

[6] Department of Neonatal Medicine, Royal Children's Hospital, Melbourne, Australia;

[7] Newborn Services, Monash Medical Centre, Melbourne, Australia;

[8] Department of Paediatrics, Mercy Hospital for Women, Melbourne, Australia; and

[9] Centre for Community Child Health, Royal Children's Hospital, Melbourne, Australia.

ABBREVIATIONS

CI: confidence interval
CP: cerebral palsy
DCD: developmental coordination disorder
ELBW: extremely low birth weight
EP: extremely preterm
GMFCS: Gross Motor Function Classification Scale
IVH: intraventricular hemorrhage
MABC: Movement Assessment Battery for Children
MABC-2: Movement Assessment Battery for Children–Second Edition
NEC: necrotizing enterocolitis
OR: odds ratio
PDA: patent ductus arteriosus
PVL: periventricular leukomalacia

PEDIATRICS (ISSN Numbers: Print, 0031-4005; Online, 1098-4275).

FINANCIAL DISCLOSURE: The authors have indicated they have no financial relationships relevant to this article to disclose.

FUNDING: Funded by grants from the National Health and Medical Council (project grant ID 284512; Career Development Fellowship ID 1108714; Centre of Research Excellence ID 1060733) and the Victorian Government's Operational Infrastructure Support Program.

POTENTIAL CONFLICT OF INTEREST: The authors have indicated they have no potential conflicts of interest to disclose.

REFERENCES

1. EXPRESS Group, Fellman V, Hellström-Westas L, et al. One-year survival of extremely preterm infants after active perinatal care in Sweden. *JAMA*. 2009;301(21):2225–2233

2. Saigal S, Doyle LW. An overview of mortality and sequelae of preterm birth from infancy to

adulthood. *Lancet*. 2008;371(9608):261–269

3. Gultom E, Doyle LW, Davis P, Dharmalingam A, Bowman E. Changes over time in attitudes to treatment and survival rates for extremely preterm infants (23-27 weeks' gestational age). *Aust N Z J Obstet Gynaecol*. 1997;37(1):56–58
4. Schmidt B, Roberts RS, Davis P, et al; Caffeine for Apnea of Prematurity Trial Group. Caffeine therapy for apnea of prematurity. *N Engl J Med*. 2006;354(20):2112–2121
5. Owen LS, Manley BJ, Davis PG, Doyle LW. The evolution of modern respiratory care for preterm infants. *Lancet*. 2017;389(10079):1649–1659
6. Doyle LW, Cheong JLY. Postnatal corticosteroids to prevent or treat bronchopulmonary dysplasia–who might benefit? *Semin Fetal Neonatal Med*. 2017;22(5):290–295
7. Schmidt B, Roberts RS, Anderson PJ, et al; Caffeine for Apnea of Prematurity (CAP) Trial Group. Academic performance, motor function, and behavior 11 years after neonatal caffeine citrate therapy for apnea of prematurity: an 11-year follow-up of the CAP randomized clinical trial. *JAMA Pediatr*. 2017;171(6):564–572
8. Doyle LW, Crowther CA, Middleton P, Marret S, Rouse D. Magnesium sulphate for women at risk of preterm birth for neuroprotection of the fetus. *Cochrane Database Syst Rev*. 2009;(1):CD004661
9. Cheong JLY, Anderson PJ, Burnett AC, et al; Victorian Infant Collaborative Study Group. Changing neurodevelopment at 8 years in children born extremely preterm since the 1990s. *Pediatrics*. 2017;139(6):e20164086
10. Spittle AJ, Orton J. Cerebral palsy and developmental coordination disorder in children born preterm. *Semin Fetal Neonatal Med*. 2014;19(2):84–89
11. Edwards J, Berube M, Erlandson K, et al. Developmental coordination disorder in school-aged children born very preterm and/or at very low birth weight: a systematic review. *J Dev Behav Pediatr*. 2011;32(9):678–687
12. Reid SM, Meehan E, McIntyre S, Goldsmith S, Badawi N, Reddihough DS; Australian Cerebral Palsy Register Group. Temporal trends in cerebral palsy by impairment severity and birth gestation. *Dev Med Child Neurol*. 2016;58(suppl 2):25–35
13. Davis NM, Ford GW, Anderson PJ, Doyle LW; Victorian Infant Collaborative Study Group. Developmental coordination disorder at 8 years of age in a regional cohort of extremely-low-birthweight or very preterm infants. *Dev Med Child Neurol*. 2007;49(5):325–330
14. Dahan-Oliel N, Mazer B, Maltais DB, Riley P, Nadeau L, Majnemer A. Child and environmental factors associated with leisure participation in adolescents born extremely preterm. *Early Hum Dev*. 2014;90(10):665–672
15. Doyle LW, Roberts G, Anderson PJ; Victorian Infant Collaborative Study Group. Outcomes at age 2 years of infants < 28 weeks' gestational age born in Victoria in 2005. *J Pediatr*. 2010;156(1):49–53.e1
16. Bell MJ, Ternberg JL, Feigin RD, et al. Neonatal necrotizing enterocolitis. Therapeutic decisions based upon clinical staging. *Ann Surg*. 1978;187(1):1–7
17. Cole TJ. Growth monitoring with the British 1990 growth reference. *Arch Dis Child*. 1997;76(1):47–49
18. Henderson SE, Sugden DA. *Movement Assessment Battery for Children*. Kent, United Kingdom: The Psychological Corporation/Harcourt Brace Jovanovich; 1988
19. Henderson SE, Sugden DA, Barnett AL. *Movement Assessment Battery for Children–2nd Edition (MABC-2)*. 2nd ed. Kent, United Kingdom: The Psychological Corporation/Harcourt Brace Jovanovic; 2007
20. Palisano R, Rosenbaum P, Walter S, Russell D, Wood E, Galuppi B. Development and reliability of a system to classify gross motor function in children with cerebral palsy. *Dev Med Child Neurol*. 1997;39(4):214–223
21. Schoemaker MM, Niemeijer AS, Flapper BC, Smits-Engelsman BC. Validity and reliability of the Movement Assessment Battery for Children–2 Checklist for children with and without motor impairments. *Dev Med Child Neurol*. 2012;54(4):368–375
22. Brown T, Lalor A. The Movement Assessment Battery for Children–Second Edition (MABC-2): a review and critique. *Phys Occup Ther Pediatr*. 2009;29(1):86–103
23. Roberts G, Anderson PJ, Davis N, De Luca C, Cheong J, Doyle LW; Victorian Infant Collaborative Study Group. Developmental coordination disorder in geographic cohorts of 8-year-old children born extremely preterm or extremely low birthweight in the 1990s. *Dev Med Child Neurol*. 2011;53(1):55–60
24. Williams J, Lee KJ, Anderson PJ. Prevalence of motor-skill impairment in preterm children who do not develop cerebral palsy: a systematic review. *Dev Med Child Neurol*. 2010;52(3):232–237
25. Synnes AR, Anson S, Arkesteijn A, et al. School entry age outcomes for infants with birth weight ≤ 800 grams. *J Pediatr*. 2010;157(6):989–994.e1
26. Vohr BR, Wright LL, Poole WK, McDonald SA. Neurodevelopmental outcomes of extremely low birth weight infants <32 weeks' gestation between 1993 and 1998. *Pediatrics*. 2005;116(3):635–643
27. Hintz SR, Kendrick DE, Vohr BR, Poole WK, Higgins RD; National Institute of Child Health and Human Development Neonatal Research Network. Changes in neurodevelopmental outcomes at 18 to 22 months' corrected age among infants of less than 25 weeks' gestational age born in 1993-1999. *Pediatrics*. 2005;115(6):1645–1651
28. Van Hus JW, Potharst ES, Jeukens-Visser M, Kok JH, Van Wassenaer-Leemhuis AG. Motor impairment in very preterm-born children: links with other developmental deficits at 5 years of age. *Dev Med Child Neurol*. 2014;56(6):587–594
29. Oudgenoeg-Paz O, Mulder H, Jongmans MJ, van der Ham IJM, Van der Stigchel S. The link between motor and cognitive development in children born preterm and/or with low birth weight: a review of current evidence. *Neurosci Biobehav Rev*. 2017;80:382–393
30. Robinson LE, Stodden DF, Barnett LM, et al. Motor competence and its effect on positive developmental

trajectories of health. *Sports Med*. 2015;45(9):1273–1284

31. Barnett LM, Hardy LL, Lubans DR, et al; Physical Activity and Sedentary Behaviour Stream of the Australasian Child and Adolescent Obesity Research Network. Australian children lack the basic movement skills to be active and healthy. *Health Promot J Austr*. 2013;24(2):82–84
32. Lubans DR, Morgan PJ, Cliff DP, Barnett LM, Okely AD. Fundamental movement skills in children and adolescents: review of associated health benefits. *Sports Med*. 2010;40(12):1019–1035

Motor Impairment Trends in Extremely Preterm Children: 1991–2005

Alicia J. Spittle, Kate Cameron, Lex W. Doyle, Jeanie L. Cheong and for the Victorian Infant Collaborative Study Group

Pediatrics 2018;141;
DOI: 10.1542/peds.2017-3410 originally published online March 22, 2018;

PEDIATRICS®
OFFICIAL JOURNAL OF THE AMERICAN ACADEMY OF PEDIATRICS

Motor Impairment Trends in Extremely Preterm Children: 1991–2005

Alicia J. Spittle, Kate Cameron, Lex W. Doyle, Jeanie L. Cheong and for the Victorian Infant Collaborative Study Group

Pediatrics 2018;141;
DOI: 10.1542/peds.2017-3410 originally published online March 22, 2018;