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Predicting physical activity in a national cohort of children born extremely preterm

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ABSTRACT

Predicting physical activity in a national cohort of children born extremely preterm.

Objectives: To compare physical activity among school-aged children born extremely preterm or with extremely low birthweight (EP/ELBW) to term-born children, and to identify early predictors for physical inactivity in the EP/ELBW-children.

Methods: A national cohort born during 1999–2000 at gestational age < 28 weeks or birthweight <1000 g and term-born controls were assessed. EP/ELBW-children without neurodevelopmental disabilities were labeled "healthy". At five years, we examined the EP/ELBW-children's motor, mental and intellectual functioning using the *Movement Assessment Battery for Children* (MABC), *The Strength and Difficulties Questionnaire* (SDQ) and *The Wechsler Preschool and Primary Scale of Intelligence-revised*. At 11 years, the parents reported their children's physical activity (PA) in questionnaires.

Results: Information was obtained from 231/372 EP/ELBW and 57/61 term-born children. At 11 years, EP/ELBW-children had fewer exercise events per week, were less engaged in team sports, had lower endurance, lower sports proficiency, and were less vigorous during PA than term-born children ($p < 0.05$). Low sports proficiency in the healthy EP/ELBW-children at 11 years was predicted (odds ratio; 95% confidence interval) by abnormal MABC-score (3.0; 1.0 to 8.7), and abnormal SDQ-score (4.0; 1.6 to 10.0) at 5 years. Lower endurance at PA was predicted by abnormal MABC-score (2.6; 1.0 to 6.6), abnormal SDQ-score (3.0; 1.4 to 6.5), and borderline intellectual functioning (4.2; 1.8 to 10.1).

Conclusions: Eleven-year-old EP/ELBW-children were less physically active than term-born. In healthy EP/ELBW-children, impaired motor coordination, borderline intellectual functioning and behavioral problems at 5 years of age predicted unfavorable PA habits at 11 years.

1. Introduction

Over the past decades, advances in neonatal medicine have improved survival rates of extremely preterm (EP) (<28 weeks of gestation) and extremely low birthweight (ELBW) (<1000 g) infants [1]. These children are at risk of major sequelae, such as cerebral palsy (CP), severe cognitive impairment, blindness and deafness [2]. Such disabilities are often recognized at an early age, with supportive services usually established before school age. However, children born at this early stage are also challenged by more subtle problems, such as motor

Abbreviations: CI, confidence interval; DCD, developmental coordination disorder; EP/ELBW, extremely preterm/extremely low birthweight; FIQ, full-scale intelligence quotient; FIQ70–84, full-scale intelligence quotient of 70–84; MABC, *Movement Assessment Battery for Children*; MABC5, *Movement Assessment Battery for Children*-score under the 5th percentile; NDD, neurodevelopmental disability; PA, physical activity; SD, standard deviation; SDQ, *Strength and Difficulties Questionnaire*; TDS, Total Difficulties Score; TDS90, TDS ≥ the 90th percentile of reference children; WPPSI-R, *Wechsler Preschool and Primary Scale of Intelligence-revised*

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coordination problems [3,4], minor cognitive impairment, inattention, hyperactivity and difficulties in social interactions [5]. Such disabilities can pass unnoticed, and influence school performances [6] as well as skills and motivation needed to participate in leisure time physical activity (PA), play and sports [7].

Population studies have shown that PA is associated with numerous health benefits and that PA prevents development of diseases like cardiometabolic and psychiatric disorders [8], conditions increasingly recognized as overrepresented in preterm-born adults [9]. Some studies find children born preterm to be less physically active than term born children, [10,11] while other studies find them to be similarly active [12,13]. Moreover, habits of PA tend to track from childhood to adulthood [14]. If habits are to be altered, early interventions are clearly preferable [15]. We therefore need more information on the PA habits of EP/ELBW-born children and we should search for early predictors of later childhood inactivity.

In this study, we aimed to compare PA in a national cohort of 11-year-old EP/ELBW schoolchildren with those of term-born children. Moreover, we investigated if structured data on motor, cognitive and mental function obtained at 5 years of age could predict habits of PA at 11 years of age in the EP/ELBW children who were considered to be healthy.

2. Methods

2.1. Participants and study design

This was a national prospective observational study of all infants born in Norway during 1999–2000, with gestational age (GA) < 28 weeks and/or birthweight (BW) < 1000 g. The inclusion of the preterm born children, data collection and outcome at discharge from the neonatal intensive care unit and at two, five and 11 years of age, have been described in previous communications [2,16–18].

At five years of age the EP/ELBW children's motor- and intellectual functioning were assessed, and their parents completed questionnaires regarding sociodemographic measures, mental health and behavioral characteristics, general health issues, and use of medication.

At 11 years of age, term-born children were recruited as controls for a regional subsample of the EP/ELBW children who had been born within the Western Norway Regional Health Authority. The term-born children were identified from birth protocols at the maternity ward [18] and were invited as the next-born child of the same gender as the EP/ELBW child, with GA > 37 weeks and BW > 3000 g, corresponding to the Norwegian 10-centile [19]. Information on PA was provided by standardized questionnaires filled in by the parents at 11 years of age (Fig. 1).

Skromme et al. previously described early characteristics of the EP/ELBW children who participated vs. those who did not participate at 11 years of age [18]. The children who did not participate (140/372) were overall more vulnerable, with a higher rate of CP, blindness or deafness at five years of age.

2.2. At five years of age; questionnaires, tests and classifications

2.2.1. The Movement Assessment Battery for Children (MABC)

Physiotherapists assessed the EP/ELBW children's motor function using the MABC test. [20] Total age-specific motor impairment scores range from 0 to 40, increasing with poorer function. The MABC manual defines age specific abnormal total scores, presented as scores below the 5th percentile (MABC5), indicating motor coordination problems [21]. Validity and reliability of the MABC is high [22]. The test is commonly used to identify children with developmental coordination disorder (DCD), defined as a marked impairment in the development of motor coordination that is not explained by mental retardation and that is not due to a known physical disorder [23].

2.2.2. Gross motor function classification system (GMFCS)

Pediatricians classified the EP/ELBW children with CP according to the GMFCS. This is a 5-level classification system describing the gross motor function of children and youth with CP based on their self-initiated movements. Level 1 indicates walking abilities without restrictions whereas level 5 indicate very limited mobility abilities even with the use of assistive technology [24].

2.2.3. Wechsler Preschool and Primary Scale of Intelligence-revised (WPPSI-R)

Psychologists examined the EP/ELBW children's intellectual function with the WPPSI-R. The test provides a full-scale intelligence quotient score (FIQ) with a mean values of 100 and standard deviation (SD) of 15 point, that represents the child's general intellectual ability [25]. The correlation between the WPPSI-R and other comparable tests is strong, and the WPPSI-R has a high inter-rater agreement and test-retest stability [25,26]. In this study a borderline IQ is defined as a FIQ between 70 and 84 points (FIQ70–84).

3. The Strength and Difficulties Questionnaire (SDQ)

Parent-reported SDQ is a behavioral screening questionnaire for 4–17-year-old children with good psychometric properties [27]. The SDQ is frequently used when investigating mental health in EP/ELBW children [5,28,29]. The questionnaire consists of 20 items distributed into four subscales; emotional problems, hyperactivity/inattention, conduct problems, and peer problems. The four subscales compute a Total Difficulties Score (TDS) ranging from 0 to 40. TDS ≥ the 90th percentile (TDS90) of the reference children was considered as a risk of having a mental health problem as recommended by Goodman [30,31].

3.1.1. Neurodevelopmental disability (NDD)

Visual function and hearing were determined from the clinical examination or previous examination at the public health care clinics.

For the purpose of this study neurodevelopmental disability (NDD) were defined as one or more of the following: CP classes 1 to 5 on the GMFCS, FIQ more than 2 standard deviations (SD) below the reference mean value of 100 (<70 on the WPPSI-R), severe visual impairment or legal blindness, or complete deafness or need of hearing aid.

A healthy-EP/ELBW child was defined as an EP/ELBW child with no NDD or minor sensory disability at five years of age (i.e. no CP, FIQ ≥ 70, strabismus or refractive error, or mild hearing loss). Further details regarding data collection on NDD are provided in Appendix A.

3.2. At 11 years of age; the questionnaires mapping physical activity

We collected information on participation in sports clubs, team sports or other physical activities. The parents graded the children's proficiency or clumsiness and how vigorous and enduring the child was, compared to their peers in sports and play. In addition, a validated question from *the World Health Organization health behavior in school-children survey* served to determine the frequency of leisure time physical activity: *Apart from at school, how often do you usually exercise so much that you get out of breath or sweat?* [32].

3.3. Ethics

The Regional Committee on Medical Research Ethics granted ethical approval of the protocol, and the mothers gave written, informed consent.

3.4. Statistics

Summary statistics are presented as means and standard deviations

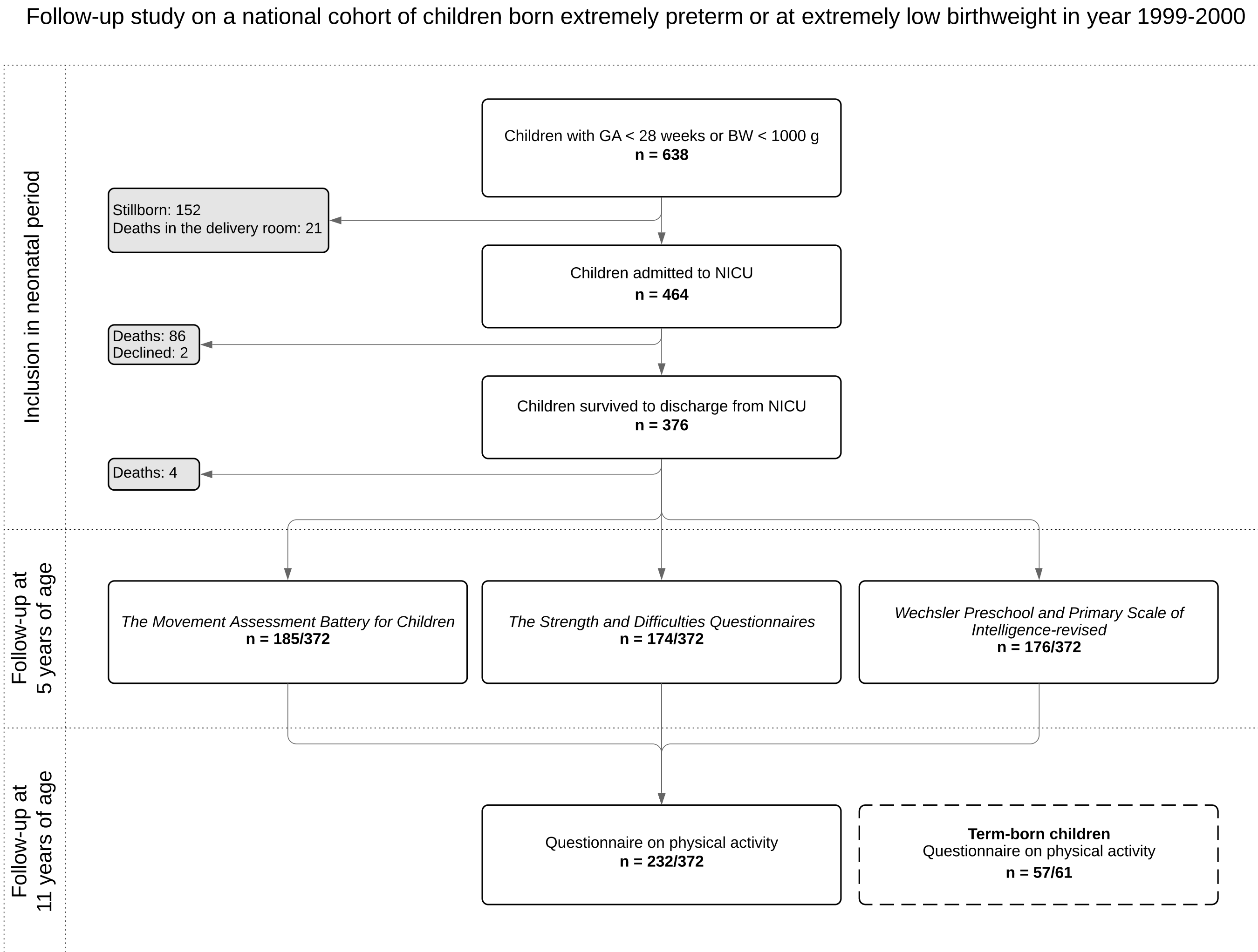

Fig. 1. The recruitment of subjects participating in a follow-up study of a national cohort of children born extremely preterm or at extremely low birthweight in year 1999–2000.
Abbreviations: BW: birthweight; GA: gestational age; NICU: neonatal intensive care unit.

(SD) or medians with interquartile ranges. Group comparisons were performed with the χ^2-exact test and the Mann-Whitney *U* test. Results on PA were adjusted for socioeconomic status (single parenthood and low maternal education level defined as less than years of college education). Small for gestational age (SGA) was defined as under the 10th percentile for gestational age (GA) [19]. Bronchopulmonary dysplasia (BPD) was defined as oxygen dependency at 36 weeks postmenstrual age.

Test results from the MABC-, the SDQ- and the WPPSI-R-test were dichotomized into normal and abnormal test results defined by MABC5, TDS90 and FIQ70–84, respectively.

Multiple logistic regression analyses were used to identify if abnormal motor coordination (MABC5), behavioral problems (TDS90) or borderline intellectual functioning (FIQ70–84) at five years of age could predict outcome regarding PA at 11 years of age for the healthy-EP/ELBW children. The dependent variables on PA used in the analyses were obtained from the questionnaire and dichotomized into "leisure time PA $\leq$ 1 day/week or $>$1 day/week", "participating/not participating in organized sports activities", "equal/lower endurance", "more or equal/less vigorous", "average or high/poor proficiency in sports activities", "equal or better/clumsy manual dexterity" and "equal or better/clumsy gross motor function". Prediction of the dependent variables "poor proficiency in sports activities", "clumsy manual dexterity" and "clumsy gross motor function" were adjusted for both borderline intellectual functioning (FIQ70–84) and abnormal motor coordination (MABC5) [33]. Additionally, we adjusted for low maternal education, use of asthma medication at five years of age, BPD and SGA if significant differences were found between the comparing groups (Appendix Table 1). The results are expressed as odds ratios (OR) with 95% confidence intervals (CI).

The study was conducted as part of a long-term follow-up of EP/ELBW children, and statistical power analysis was not conducted with respect to PA, as the number of participants was given by the size of the cohort. $p \leq 0.05$ was considered statistically significant. All analyses were performed using IBM SPSS statistics version 25.

4. Results

4.1. Study population

Data on physical activity at 11 years of age were available for 232 out of 372 eligible EP/ELBW children (115 boys) at mean age (SD) 10.8 (0.4) years and 57 out of 61 eligible term-born (31 boys) controls at the mean (SD) age of 11.7 (0.7) years (Table 1). After excluding the one participant with unknown NDD status (Appendix A), 208/231 children were classified into the healthy-EP/ELBW group and 23/231 children were classified into the disabled-group with NDD.

Table 1
Assessment of 232 surviving extremely preterm/extremely low birthweight (EP/ELBW) children and 57 term-born children participating a nationwide cohort born in Norway during 1999–2000.

Variables	EP/ELBW-born		Term-born		p
	n = 232		n = 57		
Male gender, n (%)	115	(49.6)	31	(54.3)	0.516
Birthweight g, mean (IQR)	865	(230)	3687	(685)	<0.001
Bronchopulmonary dysplasia, n (%)	113	(48.7)			
Small for gestational age, n (%)	46	(19.8)			
Patent ductus arteriosus, surgical closure, n (%)	38	(16.4)			
Assessment at 5 years of age					
MABC test assessment, n (%)	185	(79.7)			
MABC score < 5th percentile, n	29				
Full scale IQ assessment (FIQ), n (%)	176	(75.8)			
FIQ < 85 points, n	35				
FIQ < 70 points, n	10				
SDQ assessment, n (%)	174	(75.0)			
TDS ≥ the 90th percentile, n	60				
NDD assessment, n (%)	197	(84.9)			
NDD moderate or severe, n	22				
Asthma medication assessment, n (%)	198	(85.3)			
None, n	156				
Daily use, n	12				
Intermittent use, n	30				
Assessment at 11 years of age					
Mother higher education[a], n (%)	124	(53.4)	35	(61.4)	0.512
Single parenthood, n (%)	31	(13.3)	2	(3.5)	0.036
Speech therapist (current), n (%)	7	(3.0)	1	(1.8)	1.000
Physiotherapist (current), n (%)	22	(9.4)	1	(1.8)	0.056
Habilitations services (current), n (%)	10	(4.3)	0	(0)	0.219
Reduced mobility at 11 y, n (%)	8	(3.4)	0	(0)	0.363
Current visual impairment, n (%)	53	(22.8)	5	(8.8)	0.016
Blind on eye, n	3		1		
Binoculars, n	54		4		
Current hearing impairment, n (%)	24	(10.3)	2	(3.5)	0.188
Cochlea implant, n	2		1		
Hearing devices, n	8		0		
Hearing and visual impairment, n	6		0		
Asthma at 11 years, n (%)	36	(15.5)	4	(7.0)	0.132
Inhaled corticosteroids, n (%)	21	(9.1)	3	(5.3)	0.433

Abbreviations: IQR: interquartile range; MABC: The Movement Assessment Battery for Children: NDD: neurodevelopmental disability; SDQ: Strength and Difficulties Questionnaires; TDS: total difficulty score; *p*: from χ^2-exact test except independent *t*-test for birthweight.

[a] At least three-year college education or a university degree.

4.2. Physical activity at 11 years of age

Among all EP/ELBW children, 31% exercised ≤1 day/week in their leisure time compared to 14% of term-born children (Table 2). The difference between the groups remained significant after adjusting for socioeconomic status, OR (95% CI) 2.8 (1.2 to 6.5), $p = 0.02$ (Fig. 2).

Healthy-EP/ELBW children were less physically active than term-born (28% vs. 14% exercised ≤1 day/week), were more often reported to have lower physical endurance (36% vs. 2%) and to be less vigorous (22% vs. 7%). Healthy-EP/ELBW children were also more often rated to be clumsier (32% vs. 5%) and to have poorer proficiency (23% vs. 5%) in sports and play, and fewer participated in team sports (48% vs. 72%). The difference in team sport participation was explained by the high rate of participating term-born boys compared to healthy-EP/ELBW boys (80% vs. 50%, $p = 0.003$). All these results remained significant after adjusting for socioeconomic status.

We compared the healthy-EP/ELBW children with those with NDD. In all questions on PA, except questions regarding participation in sports and other activities, more disabled EP/ELBW than healthy-EP/ELBW children reported unfavorable characteristics (Table 2). The results remained significant after adjusting for socioeconomic status.

4.3. Early predictors of physical activity among healthy EP/ELBW children

4.3.1. Motor problems

In the healthy-EP/ELBW group, an abnormal MABC score (MABC5) at five years of age was associated with poorer proficiency at sports, lower endurance, less vigorous PA and clumsiness at 11 years of age. After adjustment for confounders, the result remained significant for poorer proficiency and less vigorous PA (Table 3).

4.3.2. Behavioral problems

An abnormal TDS (TDS90) at five years of age was associated with poorer proficiency at sports, lower endurance, less vigorous PA, and gross motor clumsiness at 11 years of age. A TDS90 was also associated with less participation in organized sports activities outside school. After adjustment for confounders, the result remained significant for poorer proficiency, lower endurance and less vigorous PA (Table 3).

4.3.3. Intellectual function

A borderline intellectual functioning (FIQ70–84) at five years of age was associated with lower endurance, less vigorous PA and poor manual dexterity at 11 years of age. After adjustment for confounders, the result remained significant (Table 3).

5. Discussion

In this national birth cohort, healthy-EP/ELBW schoolchildren were less physically active, had lower endurance and were less vigorous in PA than their term-born peers. They were also more likely to be rated clumsy and to have poorer proficiency at sports. Disabled EP/ELBW children reported even poorer outcome. In healthy EP-born children, impaired motor coordination, borderline intellectual functioning and behavioral problems at 5 years of age predicted unfavorable habits of physical activity at 11 years of age.

5.1. Physical activity

Our results are comparable with other studies that report less PA among unimpaired children born with very low BW or ELBW [10,11,34,35]. However, a study measuring PA by accelerometers did not find differences when comparing schoolchildren born earlier than 25 weeks of gestation and term-born controls [12]. Diverging results may be explained by differences in methodology. Moreover, differences in PA may become more apparent if control groups are recruited from societies where children in general are more physically active [34,36,37].

EP/ELBW children were reported to have lower endurance and to be less vigorous when physically active. Several studies have found EP/ELBW born children and young adults to have a reduced exercise capacity compared to age-matched controls [12,38–41]. Although chronic lung disease and altered breathing patterns during exercise have been described in EP-born populations [12,39,42], impaired lung function and airflow limitation are not considered to be a major contributor to these findings, and several other mechanisms have been highlighted. Head circumference was a significant covariate in a study by Welsh et al., suggesting that reduced exercise capacity may be influenced by neuromuscular impairment [12]. This is supported by Burns et al. who found that motor coordination was the principal determinant of cardiovascular endurance in the ELBW children [40]. Also, a reduced muscle mass in EP-born children may contribute to an earlier onset of metabolic acidosis and lower workload achievements [12]. Given the

Table 2
Comparing questionnaire reported data on physical activity for the extremely preterm/extremely low birthweight born (EP/ELBW) with neurodevelopmental disability (n = 23), the EP/ELBW born without neurodevelopmental disability (n = 208) and term-born controls (n = 57) in the national cohort of Norway in 1999–2000.

Questions on physical activity	EP/ELBW-NDD		EP/ELBW			Term-born		
	N = 23 m = 13, f = 10		N = 208 m = 102, f = 106		*p*[a)]	N = 57 m = 31, f = 26		*p*[b)]
	n (m/f)		n (m/f)[a)]			n (m/f)		
Apart from at school, how often does your child usually exercise so much that it gets out of breath or sweats?					0.024			< 0.001
4–7 times/week	2	(1/1)	40	(25/15)		25	(15/10)	
2–3 times/week	7	(5/2)	106	(48/58)		24	(13/11)	
≤1 time/week	12	(6/6)	58	(27/31)		8	(3/5)	
Total	21		204			57		
At play and sports: *How is the child's endurance compared to its average peers?*					0.001			0.006
Equal	6	(3/3)	132	(60/72)		48	(25/23)	
Lower	16	(9/7)	74	(40/34)		9	(6/3)	
Total	22		206			57		
At play and sports: *How vigorous is the child compared to its average peers?*					0.003			0.012
More or equal	11	(8/3)	162	(76/86)		53	(28/25)	
Less	12	(5/7)	45	(25/20)		4	(3/1)	
Total	23		207			57		
How will you rate your child's proficiency in sports activities?					< 0.001			< 0.001
High	2	(2/0)	45	(19/26)		37	(23/14)	
Average	3	(2/1)	111	(57/54)		16	(6/10)	
Low	16	(8/8)	46	(23/23)		3	(2/1)	
Total	21		202			56		
How will you describe your child's manual dexterity compared to peers?					< 0.001			0.001
Equal or better	7	(5/2)	157	(71/86)		55	(29/26)	
Clumsier	13	(7/6)	47	(29/18)		2	(2/0)	
Total	20		204			57		
How will you describe your child's gross motor function compared to peers?					< 0.001			< 0.001
Equal or better	5	(3/2)	142	(64/78)		54	(28/26)	
Clumsier	17	(10/7)	66	(38/28)		3	(3/0)	
Total	22		208			57		
Does your child participate in								
Team sports	8	(8/0)	100	(52/48)	0.225	41	(25/16)	0.002
Sports club activities other than team sports	4	(2/2)	68	(31/37)	0.133	16	(10/6)	0.506
Other organized activity	7	(5/2)	82	(32/50)	0.400	22	(10/12)	1.00

[a] Comparing EP/ELBW with or without neurodevelopmental disability (NDD).
[b] Comparing EP/ELBW without NDD and term born. χ^2-exact test.

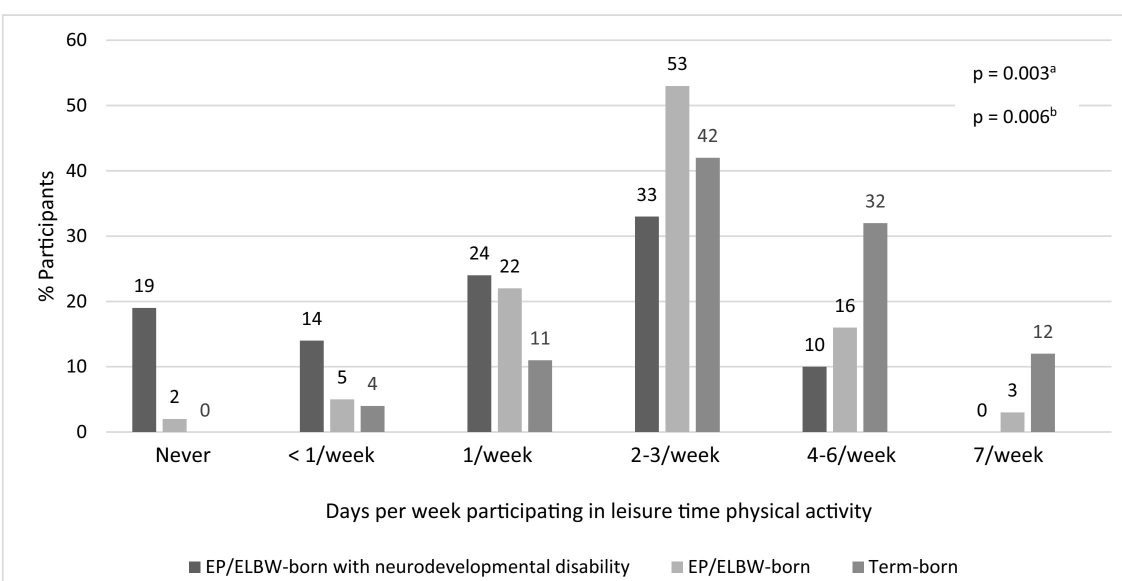

Fig. 2. Leisure time physical activity reported for the national cohort of children born extremely preterm/extremely low birthweight (EP/ELBW) with neurodevelopmental disability (n = 23), without neurodevelopmental disability (n = 208) and term-born controls (n = 57) born in Norway during 1999–2000.
p[a])Differences between the EP/ELBW children with and without neurodevelopmental disability. Exact chi-square test.
p[b])Differences between the EP/ELBW children without neurodevelopmental disability and the term-born children. Exact chi-square test.

Table 3
Prediction of reported reduced physical activity (PA) and clumsiness among 208 healthy children at 11 years of age born extremely preterm or with extremely low birthweight, by *the Movement Assessment Battery for Children*, *the Strength and Difficulties Questionnaire* reported as Total difficulty score and *The Wechsler Preschool and Primary Scale of Intelligence-Revised* assessment at the age of 5 years, using binary logistic regression.

Outcome at 11 years	Predictor: motor coordination problem at 5 years of age					
	Crude MABC5 (n = 21/170)			MABC5 adjusted		
	OR	95% CI	p	OR	95% CI	p
Leisure time PA ≤ 1 day/week	1.72	(0.64, 4.66)	0.283	1.33	(0.45, 3.90)	0.601[a]
Organized sports activities: not participating	1.97	(0.78, 4.97)	0.149	1.66	(0.61, 4.50)	0.320[a]
Lower endurance	2.66	(1.05, 6.72)	0.039	2.56	(1.00, 6.56)	0.051[b]
Less vigorous	5.41	(2.08, 14.11)	0.001	5.27	(2.00, 13.84)	0.001[b]
Poor proficiency in in sports activities	3.36	(1.23, 9.17)	0.018	2.95	(1.01, 8.67)	0.049[c+d]
Clumsy: manual dexterity	2.83	(1.06, 7.59)	0.038	1.21	(0.37, 3.94)	0.755[d+e]
Clumsy: gross motor function	3.40	(1.33, 8.65)	0.010	2.34	(0.85, 6.45)	0.101[d]

Outcome at 11 years	Predictor: behavioral problem at 5 years of age					
	Crude TDS90 (n = 46/153)			TDS90 adjusted		
	OR	95% CI	p	OR	95% CI	p
Leisure time PA ≤ 1 day/week	1.19	(0.54, 2.65)	0.668	1.09	(0.45, 2.14)	0.852[a]
Organized sports activities: not participating	2.35	(1.15, 4.81)	0.019	2.12	(0.97, 4.64)	0.060[a]
Lower endurance	2.57	(1.25, 5.30)	0.010	3.02	(1.41, 6.47)	0.004[b]
Less vigorous	3.21	(1.45, 7.12)	0.004	3.65	(1.60, 8.36)	0.002[b]
Poor proficiency in sports activities	3.90	(1.71, 8.90)	0.001	4.03	(1.62, 10.06)	0.003[c+d]
Clumsy: manual dexterity	2.19	(0.99, 4.83)	0.052	1.56	(0.624, 3.93)	0.339[d+e]
Clumsy: gross motor function	2.17	(1.05, 4.48)	0.036	1.18	(0.82, 4.16)	0.142[d]

Outcome at 11 years	Predictor: borderline intellectual functioning at 5 years of age					
	Crude FIQ 70–84 (n = 29/157)			FIQ 70–84 adjusted		
	OR	95% CI	p	OR	95% CI	p
Leisure time PA ≤ 1 day/week	1.44	(0.59, 3.50)	0.420	1.32	(0.51, 3.44)	0.570[a]
Organized sports activities: not participating	1.16	(0.49, 2.72)	0.736	0.98	(0.38, 2.49)	0.964[a]
Lower endurance	4.06	(1.73, 9.53)	0.001	4.19	(1.75, 10.05)	0.001[b]
Less vigorous	3.61	(1.50, 8.70)	0.004	3.60	(1.48, 8.75)	0.005[b]
Poor proficiency in in sports activities	2.11	(0.85, 5.24)	0.109	1.48	(0.55, 3.98)	0.434[c+f]
Clumsy: manual dexterity	3.06	(1.26, 7.40)	0.013	3.22	(1.22, 8.52)	0.019[e+f]
Clumsy: gross motor function	2.00	(0.88, 4.56	0.100	1.66	(0.70, 3.96)	0.253[f]

Abbreviations: FIQ: full-scale intelligence quotient according to The *Wechsler Preschool and Primary Scale of Intelligence-revised;* MABC: *Movement Assessment Battery for Children;* MABC5: MABC < the 5th percentile for age; TDS: Total difficulty score. TDS90: TDS ≥ the 90th percentile of the reference children.
Adjustments: a) low maternal education; b) use of asthma medication at 5 years of age; c) bronchopulmonary disease (oxygen dependency at 36 weeks postmenstrual age); d) borderline intellectual function (FIQ70–84); e) Small for gestational age; f) MABC5.

possible important impact of neuromuscular limitations on exercise capacity, studies exploring EP/ELBW children's trainability using custom made exercise programs could be useful.

5.2. Early predictors of physical activity among healthy EP/ELBW children

To our knowledge, this is the first study to investigate the predictive value of preschool minor motor-, behavioral- and intellectual deficits to estimate later physical activity among healthy-EP/ELBW school-children.

In our study, an abnormal MABC score at five years of age predicted poorer proficiency in sports activities and less vigorous PA at 11 years of age. This is in accordance with previous research, finding motor problems to persist and to become more apparent with increasingly demanding motor tasks as the child grows older [43,44]. Studies have shown that children with DCD have lower physical fitness, not solely explained by activity deficits [45,46], but possibly because they experience earlier fatigue than children who are more well-coordinated. However, the pathway linking DCD to reduced PA is not fully described, and psychosocial aspects may be significant. Children with DCD perceived themselves as less capable of exercise than their peers, and coping mechanisms may result in both withdrawing from arenas of PA and increased sedentary behavior [44,47,48].

EP/ELBW children have increased risk of behavioral problems and reduced cognitive function; features that are associated with motor coordination problems [49]. In the present study, an abnormal TDS (indicating behavioral problems) at five years of age predicted reduced endurance, less vigorous PA and poorer proficiency at sports activities at 11 years of age. Play and PA in childhood are demanding social activities requiring the ability to interact with peers and to interpret and adjust to feedback. Low self-esteem and reduced self-concept as well as inattention and hyperactivity all represent barriers to PA [44].

Reduced cognitive function has been linked to reduced level of aerobic and muscular fitness in children and adults [50,51]. We found that borderline intellectual functioning at five years of age predicted poorer manual dexterity, as well as lower endurance and less vigorous PA at 11 years of age. This may be explained by lack of motivation and opportunities for participation in PA as well as by DCD, which is known to be associated with lower intellectual functioning [33,51]. Improved exercise capacity has been associated with increased cognitive function [52]. How PA affects cognition is not fully explained, but research have shown that exercise may recruit use-dependent plasticity mechanisms that prepare the brain to encode meaningful information from the environment and activate mechanisms that protect the brain from damage [53]. Thus, improving PA in EP/ELBW children might influence the individuals in ways that go beyond the physical effects.

Motor coordination, mental health and cognition all influence the preterm born child's ability to perform and participate in play and sports. In order to settle life-long healthy lifestyle habits, these children should actively be encouraged to take part in PA. The present study underlines the vulnerability of EP/ELBW schoolchildren with apparently mild problems. Preschool tests for motor coordination difficulties, behaviour problems or intellectual deficits could help direct parents and school personnel to facilitate PA during childhood in these children.

5.3. Strengths and limitations

The strengths of this study are the large population-based prospective design and the relatively high follow-up rate. However, several limitations need to be considered when interpreting the results. Firstly, we collected questionnaire-based data on physical activity rather than objective measurements like accelerometry (questions provided in Table 2). In addition, the behavioral problem assessment, the SDQ, relies solely on parental response, and no diagnostic tool were performed. The physiotherapists received formal training before study startup if they were not familiar with the MABC test, and experienced psychologists performed the WPPSI-R test. However, we did not perform a formal inter-rater agreement test specific for this study, and the test-personnel were not blinded for information on perinatal data.

The EP/ELBW children were recruited on the basis of either a GA of less that <28 weeks or BW of less than 1000 g irrespective of GA. Therefore, the results cannot be generalized to EP-born individuals in general. Also, the EP/ELBW children included at 11 years of age were probably healthier than the non-responding children, which influence the generalizability of our comparison between the term-born, healthy-EP/ELBW and the disabled EP/ELBW group. The term-born control-group was small, however based on the "next-born subject principle" for a subsample of the EP/ELBW cohort, reducing the risk of selection bias.

6. Conclusions

EP/ELBW schoolchildren had less favorable habits of physical activity than term-born children. In healthy-EP/ELBW children, subtle findings at five years of age regarding motor-, behavioral- and intellectual dysfunction, predicted lower proficiency and endurance and less vigorous physical activity at 11 years of age. This study suggests that information available at a very early age in these children can be used to design focused interventions to improve their habits of physical activity.

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Data sharing statement

In accordance with the approvals granted for this study by The Regional Committee on Medical Research Ethics and The Norwegian Data Inspectorate, the data files are stored securely and in accordance with the Norwegian Law of Privacy Protection. The data file cannot be made publicly available as this might compromise the respondents' privacy. Some of the participating centres are small and the number of extremely preterm births limited with a risk of identifying anonymous participants. To prepare future research papers other researchers in our group currently use the data file. A subset of the data file with anonymized data can be made available to interested researchers upon reasonable request to Thomas Halvorsen (thomas.halvorsen@helse-bergen.no), providing Norwegian privacy legislation and GDPR are respected, and that permission is granted from The Norwegian Data Inspectorate and the data protection officer at Haukeland University Hospital.

CRediT authorship contribution statement

Mette Engan: Conceptualization, Methodology, Formal analysis, Writing - original draft, Writing - review & editing, Validation. **Merete Salveson Engeseth:** Conceptualization, Methodology, Formal analysis, Writing - original draft, Writing - review & editing, Validation. **Silje Fevang:** Conceptualization, Methodology, Formal analysis, Writing - original draft, Writing - review & editing, Validation. **Maria Vollsæter:** Methodology, Investigation, Data curation, Writing - original draft, Writing - review & editing, Validation. **Geir Egil Eide:** Supervision, Formal analysis, Data curation, Writing - review & editing, Validation. **Ola Drange Røksund:** Funding acquisition, Methodology, Investigation, Writing - review & editing, Validation. **Thomas Halvorsen:** Funding acquisition, Methodology, Investigation, Writing - review & editing, Validation. **Hege Clemm:** Resources, Conceptualization, Methodology, Writing - original draft, Writing - review & editing, Validation.

Declaration of competing interest

The authors have no conflicts of interest relevant to this article to disclose.

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