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Comparison of physical activity and body composition in a cohort of children born extremely preterm or with extremely low birth weight to matched term-born controls: a follow-up study

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ABSTRACT

Objectives To compare physical activity and body composition in a cohort of children born extremely preterm/extremely low birth weight (EP/ELBW) with term-born (TB) controls.

Methods A regional cohort of children born during 1999–2000 at gestational age <28 weeks or with birth weight <1000 g and their individually matched TB controls were examined in 2010–2011. Information on physical activity was obtained from parental questionnaires, and body composition was determined by anthropometry and dual X-ray absorptiometry.

Results Fifty-seven EP/ELBW and 57 TB controls were included at a mean age of 11.6 years. Compared with the TB children, the EP/ELBW-born children exercised less often (22% vs 44% exercised more than 3 days per week), had lower physical endurance and poorer proficiency in sports and play and were less vigorous during exercise ($p<0.05$). They also had lower values (mean; 95 % CI) for muscle mass (0.9; 0.3–1.5 kg), total bone mineral density z-score (0.30; 0.13–0.52 units) and fat mass ratio (0.14; 0.06–0.21 units). The association between physical activity and bone mineral and skeletal muscle mass accrual was significantly weaker for the EP/ELBW-born than the TB children.

Conclusions The EP/ELBW-born children were less physically active, had signs of an unfavourable body composition with less muscle mass and lower bone mineral density than the TB controls. The association between physical activity and the measures of body composition was weaker in the group of EP/ELBW-born children.

INTRODUCTION

Children born extremely preterm (EP; ie, before 28 weeks' gestation) or with extremely low birth weight (ELBW; ie, <1000 g) are considered to be at increased risk of cardiovascular disease and osteoporosis.[1] The reasons may be complex and probably include prenatal conditions like placental insufficiency and later exposures like infections, immobilisation and suboptimal nutrition.[2] Most of the skeletal muscle mass[3] and 80% of skeletal mineralization is normally acquired during the last trimester.[4] EP/ELBW-born individuals are deprived of these valuable intrauterine weeks, and they are usually shorter and lighter with lower lean body mass (LBM), lower bone mass and a higher percentage of total body fat (%BF) at term equivalent age than infants born at term.[5–7] It is uncertain to what extent these differences track into later life and how nutrition and physical activity (PA) modify the anthropometry and body composition in children born EP/ELBW.[8 9] However, suboptimal bone and muscle mass may persist and lead to compromised skeletal and muscle health.[10–12]

PA is associated with numerous health benefits including reduced risk of cardiovascular disease and osteoporosis through improved insulin sensitivity, reduced blood pressure, enhanced endothelial function and increased bone mineralisation.[13 14] There is inconsistent evidence on whether children and young adults born EP/ELBW differ from children born at term regarding PA.[15–18] Moreover, we do not know if PA has the same beneficial effects in individuals born EP/ELBW as in those born at term. Therefore, the purpose of this study was to compare exercise habits and body composition in schoolchildren born EP/ELBW with term-born children and to assess the association between PA and body composition in the two groups.

METHODS

Participants

This follow-up cohort study in a high-income country included 57 children born EP (gestational age (GA) <28 weeks) or with ELBW (<1000 g) in the Western Norway Regional Health Authority during 1999–2000 participating in the Project Extreme Prematurity, which is a part of the WestPaed Research Group. The EP/ELBW children were included at birth and later examined at 2 and 5 years of age before this study was performed in 2010–2011. Neonatal care had been provided at one of two regional neonatal intensive care units. Medical data were obtained from clinical examinations and hospital records. Using information from birth protocols at the maternity wards, the next born individuals of the same sex, born at term (TB, GA >37 weeks) with a birth weight (BW) above the lower 10th percentile of Norwegian children (>3.0 kg)[19] at the same maternity ward as the participating EP/ELBW-born index case were invited as controls in 2010. If the parent of the first invited term-born individual declined participation, the next was invited and so on until one TB control was recruited for each participating preterm born index child. One average 1.6 controls had to be invited to recruit a full 1:1 TB control group.

PA questionnaires

Exercise habits were reported on questionnaires by the parents. A validated question from the *WHO Health Behaviour in Schoolchildren Survey* was used to determine the frequency of leisure time PA: *apart from at school, how often do you usually exercise so much that you get out of breath or sweat?*[20]

Anthropometry

Height, weight, subscapular and triceps skinfolds and waist circumference were measured. Subscapular to triceps skinfold ratio (STR) and waist-to-height ratio (WHtR) were calculated as estimates of truncal fat mass (FM). Z-scores for BW and anthropometric measures were calculated with reference to Norwegian growth curves.[19 21 22] Small for gestational age (SGA) was defined as a BW <10th percentile for GA.[19]

Dual-energy X-ray absorptiometry (DXA)

DXA is a validated method to determine body composition.[23] The participants were examined at two different centres of rheumatology on a Lunar Prodigy and Lunar Prodigy Advanced DXA scan (GE Medical systems Lunar, Madison Wsconsin, USA). Daily calibration with a local phantom provided by the manufacturer was performed at the two DXA centres, and the preterm and their matched TB controls were examined at the same centre according to geographic affiliation.

Whole-body less head and regional body composition were measured, and bone mineral density (BMD) z-scores were calculated using sex and age specific paediatric reference standards provided by Lunar Prodigy enCORE2009 software version 13.20.033.[23]

Data on bone mineral content (BMC) (total BMD, lumbar spine BMD (lumbar vertebra 1–4) and left and right total hip BMD (BMDth)), fat compartments (total FM, %BF, FM ratio ((arms+legs FM)/truncal FM) and fat mass index (FMI: FM normalised for height^2)) and skeletal muscle mass (LBM, appendicular lean mass (ALM), ALM index (ALMI: ALM/height^2) and LBM index (LBMI: LBM/height^2) were collected.

Blood samples

Blood for analyses of vitamin D (25-hydroxy vitamin D), oestradiol, testosterone, luteinising hormone and follicle-stimulating hormone was drawn at the consultation.

Puberty

The questionnaire contained a five-level question on puberty development, where parents were asked to compare their offspring to peers (delayed, somewhat delayed, similar, somewhat ahead or ahead of peers).

Statistics

Data are presented as means with SD or medians with ranges, as appropriate, or as mean group differences with 95% CIs based on the t-distribution with the appropriate df. To compare findings between the EP/ELBW and TB groups, a mixed linear model and Wilcoxon's signed-rank test were used. Independent sample t-tests were used to compare the SGA and the non-SGA preterm individuals. Leisure time exercise were adjusted for socioeconomic status defined by the maternal education (high education defined by minimum 3 years of college or university degree) and single parenthood. A mixed linear regression model adjusted the estimate of the body components for body size (height z-score and weight z-score), parental reported puberty and PA (days per week with exercise). Vitamin D level did not change the effect of EP/ELBW birth and was not included in the model. An interaction term was constructed to test differences between the EP/ELBW and TB groups regarding association between PA and body composition. P values have not been formally adjusted for multiple comparisons due to the complexity of the analyses and should be interpreted with caution. Accordingly, as a rule of thumb, we consider only p values <0.01 as statistically significant in the interpretation of the results. Analyses were performed using IBM SPSS statistics V.14.

Ethics

The mothers gave written informed consent.

Patient and public involvement

Patient representatives were involved in the study design of this and several other studies as part of the national follow-up study on EP/ELBW children.

RESULTS

Participants

Of 108 premature EP/ELBW children, 19 had died and 57 (29 males) consented to participate in the follow-up study. The participants needed more ventilator treatment but did not differ from those who declined on

Table 1 Characteristics of the 89 surviving EP/ELBW-born children and the 57 term-born children in the regional cohort of Western Norway health region in 1999–2000

	EP/ELBW born				
Characteristics	**Assessed**	**Not assessed**	**P value***	**Term born**	**P value†**
Participants, n	57	32		57	
Female gender, n (%)	28 (49)	12 (38)	0.29	26 (46)	
Birth weight (g), mean (SD)	842 (175)	837 (142)	0.74	3700 (434)	
Gestational age (weeks), median (range)	27 (24–31)	27 (23-30)	0.68		
Small for gestational age, 0.10 percentile, n (%)	20 (35)	6 (19)	0.11		
Ventilator treatment, n (%)	51 (89)	21 (66)	0.01		
Days on ventilator, median (range)	5 (0–24)	2.5 (0–29)	0.01		
Bronchopulmonary dysplasia, n (%)	31 (54)	12 (38)	0.13		
Periventricular leucomalacia, n (%)	4 (7)	3 (9)	0.70		
Necrotising enterocolitis, n (%)	1 (2)	1 (3)	0.59		
Gastrostomy tube, n (%)	0 (0)	1 (3)	0.36		
Cerebral palsy at 5 years, n (%)	3 (5)	5 (16)	0.13		
Eating difficulties any time, n (%)	16 (28)	7 (22)	0.52		
Growth hormone treatment, n (%)	2 (4)	0 (0)	0.53		
Assessment at 11 years of age					
Reduced mobility, n (%)	2 (4)			0 (0)	0.16
Single parenthood, n (%)	13 (23)			6 (10)	0.052
Mother higher education‡, n (%)	31 (54)			35 (61)	0.85
Hearing impairment, n (%)	6 (11)			2 (4)	0.16
Visual impairment, n (%)	11 (19)			5 (9)	0.06
Inhaled corticosteroids, n (%)	3 (5)			3 (5)	0.66

The enrolled subjects were examined in 2010–2011.
*P value for differences between the participating extremely preterm/extremely low birth weight (EP/ELBW)-born children and the EP/ELBW-born children not participating. Independent sample t-test, Mann-Whitney test and χ^2 exact test as appropriate.
†P value for differences between the participation EP/ELBW-born and the TB control group. Wilcoxon signed-ranks test.
‡High education defined by minimum 3 years of college or university degree.
EP/ELBW, Extremely preterm/extremely low birth weight; TB, term born.

other characteristics (table 1). Seven of the EP/ELBW-born children declined DXA scanning, and three were excluded from the DXA analyses because they were of minority ethnicity. One of the included participants who underwent DXA scanning had mild cerebral palsy (CP) affecting one leg. One subject who was not scanned was excluded from analyses on PA because of deafness and hemiplegic CP. Among the TB controls, 57 (31 males) completed the questionnaires, 54 showed up for examinations and 49 underwent DXA scanning. Mean age (SD) at examination was 11.6 (0.7) years for both groups.

Exercise and participation in sports activities

Twenty-two per cent of the EP/ELBW-born and 44% of the TB children exercised more than 3 days/week, and the overall mean (95% CI) difference was 0.9 (0.2 to 1.6) days/week adjusted for socioeconomic status, p=0.009 There was no statistically significant gender difference.

More EP/ELBW-born than TB participants were reported to have lower physical endurance, poorer proficiency in sports and play and to be less vigorous during exercise, when compared with their peers (table 2).

Nearly 50% of the EP/ELBW and 72% of the TB participated in team sports. The difference was mainly explained by the EP/ELBW boys not participating at the same level as TB boys (52% vs 81%, p=0.005). The EP/ELBW-born children participated in PA together with family or friends more often than the TB children (75% vs 60%, p=0.050).

Body composition

The mean (95% CI) height was 4.6 (2.0 to 7.2) cm and the weight was 2.8 (0.3 to 5.8) kg lower in the EP/ELBW than the TB children. The z-score for height were lower in the EP/ELBW group but not statistically significant (p=0.04). The mean z-score for weight, BMI, waist circumference, subscapular skinfold, triceps skinfold and the z-scores for these measures did not differ significantly (table 3). The FM and %BF were similar, but the STR was 11% higher

Table 2 Comparing reported physical activity and participation in sports between the 56 EP/ELBW-born subjects and the 57 term-born age-matched and gender-matched controls in the Western Norway Health Region in 1999–2000 as part of the Project Extreme Prematurity

	EP/ELBW		Term born		
	N=56 M=28, F=28		N=57 M=31, F=26		
Physical activity	**N**	**(M/F)**	**N**	**(M/F)**	**P value***
Apart from at school, how often does your child usually exercise so much that it gets out of breath or sweats?					0.013
Daily	3	(2/1)	7	(6/1)	
4–6 times/week	9	(4/5)	18	(9/9)	
2–3 times/week	28	(15/13)	24	(13/11)	
1 time/week	9	(3/6)	6	(2/4)	
Less than one time/week	2	(1/1)	2	(1/1)	
Never	3	(2/1)	0		
Total	54		57		
At play and sports: how is the child's endurance compared with its average peers?					0.006
Similar	34	(17/17)	48	(25/23)	
Less	18	(9/9)	9	(6/3)	
Much less	3	(1/2)	0		
Total	55		57		
At play and sports: how vigorous is the child compared with its average peers?					0.001
More	6	(1/5)	16	(13/3)	
Similar	34	(20/14)	37	(15/22)	
Less	15	(6/9)	4	(3/1)	
Total	55		57		
How will you rate your child's proficiency in sports activities?					<0.001
Very high	6	(2/4)	11	(10/1)	
High	8	(2/6)	26	(13/13)	
Average	25	(15/10)	16	(6/10)	
Somewhat low	13	(7/6)	3	(2/1)	
Very low	2	(1/1)	0		
Total	54		56		
Does the child participate in					
Team sports	27	(14/13)	41	(25/16)	0.009
Sports club activities other than team sports	14	(6/8)	16	(10/6)	0.83
Physical activity alone or together with family/ friends	42	(21/21)	34	(18/16)	0.050

*Wilcoxon's signed-ranks test two tailed.
EP/ELBW, extremely preterm/extremely low birth weight; F, female; m, male.

(p=0.04) and the FM ratio was 11% lower (p=0.001) in the EP/ELBW than the TB children. After adjusting for size and reported puberty, the mean (95% CI) difference in STR was 0.09 (0.01 to 0.17) units (p=0.04), and the mean difference in FM ratio was 0.14 (0.06 to 0.21) units (p=0.001).

The EP/ELBW-born children had lower LBM, ALM, total BMD z-score and BMDth z-scores. The mean (95% CI) difference in ALM was 0.9 (0.3 to 1.5) kg (p=0.004), and the difference in total BMD z-score was 0.33 (0.13 to 0.52) units (p=0.001) after adjusting for size and puberty (table 4). The EP/ELBW children had close

Table 3 Comparing anthropometry and body composition between the 54 EP/ELBW children and their 54 age-matched and gender-matched term-born controls born year 1999–2000 in the Western Norway health region and examined in 2010–2011

	All					Female						Male					
	EP/ELBW (n=54) and TB (n=54)					EP/ELBW (n=26) and TB (n=25)						EP/ELBW (n=28) and TB (n=29)					
Variables, units	Mean	SD	Mean	SD	P value*	Mean	SD	Mean	SD	m	P value†	Mean	SD	Mean	SD	m	P value‡
Birth weight, g	842	175	3700	434	<0.001	842	168	3554	399	0	<0.001	840	184	3826	431	0	<0.001
Age at examination, years	11.4	0.6	11.7	0.7	<0.001	11.6	0.7	11.8	0.6	0	<0.001	11.5	0.7	11.7	0.7	0	0.005
Height, cm	146.7	8.0	151.5	8.4	0.001	146.6	7.2	149.5	8.7	0	0.19	146.9	8.7	153.3	7.9	0	<0.001
Height z-score	−0.41	1.06	0.01	1.11	0.04	−0.43	1.02	−0.30	1.28	0	0.68	−0.40	0.11	0.27	0.89	0	0.002
Weight, kg	38.5	8.3	41.3	8.6	0.07	37.5	7.2	41.1	9.58	0	0.17	39.4	9.3	41.3	7.85	0	0.28
Weight, z-score	−0.34	1.1	−0.13	1.1	0.32	−0.43	0.99	−0.19	1.20	0	0.47	−0.25	1.17	−0.08	0.96	0	0.53
BMI, kg/m^2	17.7	2.6	17.8	2.8	0.79	17.3	2.4	18.3	3.5	0	0.33	18.0	2.7	17.5	2.0	0	0.31
BMI, z-score	−0.19	1.06	−0.21	1.01	0.92	−0.38	1.09	−0.11	1.12	0	0.47	−0.02	1.01	−0.30	0.93	0	0.23
Waist circumference, mm	65.3	8.1	66.3	7.6	0.55	63.4	6.2	65.9	9.4	2	0.30	67.2	9.3	66.7	5.6	5	0.68
Waist circumference, z-score	0.23	1.02	0.29	1.04	0.74	−0.08	0.97	0.06	1.31	2	0.74	0.51	1.00	0.50	0.70	5	0.92
Subscapular fold, mm	8.7	4.0	8.6	4.3	0.87	8.0	3.1	9.5	4.9	5	0.23	9.3	4.5	7.7	3.5	5	0.13
Subscapular fold, z-score	0.12	1.18	0.01	1.20	0.53	0.00	1.24	0.30	1.06	5	0.39	0.23	1.15	−0.25	1.27	5	0.09
Triceps fold, mm	11.3	4.1	12.3	4.1	0.23	11.0	3.6	13.5	4.3	3	0.04	11.6	4.6	11.3	3.7	5	0.06
Triceps fold, z-score	−0.08	0.92	0.17	0.88	0.20	−0.12	0.82	0.40	0.81	3	0.03	−0.06	0.99	−0.03	0.91	5	0.95
WHtR	0.45	0.05	0.44	0.04	0.39	0.43	0.04	0.44	0.06	2	0.67	0.46	0.05	0.44	0.03	5	0.08
WHtR, z-score	0.48	0.92	0.34	0.97	0.42	0.13	0.87	0.22	1.24	2	0.87	0.81	0.85	0.44	0.66	5	0.10
STR	0.78	0.24	0.70	0.21	0.04	0.75	0.18	0.71	0.21	5	0.45	0.81	0.27	0.69	0.21	5	0.050
Fat mass, kg	9.2	5.0	10.2	5.7	0.39	8.8	4.4	12.2	6.6	9	0.09	9.5	5.4	8.6	4.3	3	0.46
Total body fat, %	26.0	9.0	26.2	9.8	0.94	26.4	9.3	30.5	9.2	9	0.16	25.8	8.9	22.6	8.9	3	0.20
Fat mass index, kg/m^2	4.2	2.1	4.4	2.4	0.70	4.1	2.0	5.3	2.8	9	0.13	4.3	2.2	3.6	1.7	3	0.23
Fat mass ratio	1.11	0.20	1.25	0.21	0.001	1.10	0.19	1.21	0.25	10	0.07	1.13	0.20	1.28	0.16	4	0.004
Lean body mass, kg	24.6	4.4	26.9	4.8	0.003	23.3	3.3	25.7	4.2	9	0.052	25.6	5.0	27.9	5.2	3	0.014
LBMI, kg/m^2	11.3	1.1	11.6	1.2	0.20	10.9	0.9	11.3	1.0	9	0.16	11.7	1.1	11.8	1.2	3	0.51
ALM, kg	12.0	2.3	13.4	2.5	0.001	11.4	1.7	12.8	2.2	12	0.052	12.4	2.7	13.9	2.6	6	0.004
ALMI, kg/m^2	5.5	0.6	5.8	0.6	0.02	5.3	0.5	5.6	0.6	12	0.07	5.6	0.6	5.9	0.7	6	0.08
BMC, g	1095	259	1259	299	0.001	1064	235	1239	332	9	0.06	1116	277	1274	274	3	0.002
BMD, g/cm^2	0.809	0.068	0.863	0.077	<0.001	0.810	0.060	0.862	0.089	9	0.03	0.808	0.074	0.864	0.067	3	<0.001
BMD, z-score	−0.06	0.65	0.43	0.80	0.001	−0.25	0.54	0.19	0.83	9	0.07	0.07	0.70	0.63	0.73	3	0.002
BMDth left, g/cm^2	0.838	0.086	0.904	0.108	0.001	0.802	0.069	0.858	0.114	9	0.06	0.865	0.089	0.941	0.090	3	0.003
BMDth left, z-score	−0.06	0.73	0.44	1.03	0.004	−0.51	0.46	−0.10	0.97	9	0.11	0.26	0.73	0.88	0.86	3	0.013
BMDth right, g/cm^2	0.833	0.082	0.902	0.105	<0.001	0.801	0.072	0.861	0.105	9	0.04	0.857	0.081	0.936	0.094	3	0.002
BMDth right, z-score	−0.11	0.71	0.39	1.00	0.004	−0.52	0.52	−0.12	0.92	9	0.10	0.20	0.68	0.80	0.88	3	0.012

Continued

Table 3 Continued

Variables, units	All					Female						Male					
	EP/ELBW (n=54) and TB (n=54)					EP/ELBW (n=26) and TB (n=25)						EP/ELBW (n=28) and TB (n=29)					
	Mean	SD	Mean	SD	P value*	Mean	SD	Mean	SD	m	P value†	Mean	SD	Mean	SD	m	P value‡
BMD spine, g/cm^2	0.822	0.101	0.836	0.100	0.45	0.852	0.101	0.859	0.124	9	0.85	0.799	0.097	0.817	0.073	3	0.39
BMD spine, z-score	−0.06	0.69	−0.13	0.88	0.70	−0.24	0.71	−0.35	1.04	9	0.69	−0.07	0.66	0.06	0.68	3	0.99

*Mixed linear model (MLM).
†MLM comparing female EP/ELBW and TB.
‡MLM comparing male EP/ELBW and TB.
ALM, appendicular lean mass; ALMI, appendicular lean mass index; BMC, bone mineral content; BMD, bone mineral density; BMDth, total hip bone mineral density; BMI, body mass index; EP/ELBW, extremely preterm born/extremely low birth weight; LBMI, lean body mass index; STR, subscapular- triceps skinfold ratio; TB, term born; WHtR, waist-to-height ratio; m, missing; Fat mass ratio, (arms+legs fat mass)/truncal fat mass.

to significantly lower ALMI (p=0.02), but LBMI did not differ between the groups.

When adjusting for PA, the mean differences in ALM, BMC and BMD were reduced by 20% and the mean differences in BMD z-score by 36%. The measures for truncal fat deposit (STR and FM ratio) remained similar or were only slightly reduced (table 4).

Small for gestational age

Twenty of the EP/ELBW children (13 men and 7 women) were born SGA. Their mean (95% CI) height z-score was 0.88 (0.33 to 1.43) units lower than those who were not SGA. LBM, ALM, BMC, BMD and regional BMD were close to significantly reduced in the SGA group but not when comparing the respective values normalised for height^2 or z-scores (online supplementary file).

Blood samples and puberty

We found no statistically significant group differences in unadjusted or seasonally adjusted D vitamin values. The values for testosterone, LH and FSH did not differ significantly between the EP/ELBW and TB boys, and the values of oestradiol, LH and FSH did not differ significantly between the respective groups of girls. There were no significant differences in reported puberty between the EP/ELBW and TB stratified by gender (online supplementary file).

PA and body composition

Increased PA was associated with statistically significantly lower fat components (%BF and FMI) and higher BMDth z-scores in the total group of participants (table 5).

Analyses of interaction were performed to investigate if associations between PA and body composition differed in the EP/ELBW compared with the TB control group. We found there was an overall tendency for PA to have less positive effect on ALM, ALMI, total BMD z-score and BMDth z-scores in the EP/ELBW-born children compared with the TB children (table 5); however, this was statistically significant only for the BMDth z-scores.

DISCUSSION

Our main findings were that the EP/ELBW-born children were less physically active and that the EP/ELBW-born children had an unfavourable body composition with increased truncal fat deposit, less skeletal muscle mass and lower BMD compared with the TB controls. The association between PA and body composition was weaker in the EP/ELBW than the TB group.

Exercise and participation in sports activities

Our results are in line with other studies that report less PA among ELBW-born or very low BW-born children[24] or young adults.[25 26] However, Welsh *et al*[18] did not reveal differences between school-children born before 25 weeks GA and TB controls when PA was measured by accelerometers.[18] Differences in methodology as well as population lifestyle factors could explain these diverging

Table 4 Results from mixed linear regression analyses of bone mineral density, skeletal muscle mass, fat component and fat distribution measures in 47 EP/ELBW-born children and their 49 term-born age-matched and gender-matched controls in the Western Norway health region in 1999–2000 that were examined in 2010–2011

	EP/ELBW (n=47)		TB (n=49)				
Variables, units	Mean	95% CI	Mean	95% CI	Model*	Difference†	P value
BMC, g	1096	(1016 to 1176)	1256	(1177 to 1334)	1	–160	0.001
					2	–88	0.001
					3	–70	0.006
BMD, g/cm^2	0.809	(0.788 to 0.830)	0.863	(0.843 to 0.884)	1	–0.054	<0.001
					2	–0.039	<0.001
					3	–0.032	0.001
BMD, z-value	–0.07	(–0.28 to 0.14)	0.43	(0.22 to 0.64)	1	–0.50	0.001
					2	–0.33	0.001
					3	–0.21	0.04
BMDth left, z-score	–0.07	(–0.34 to 0.09)	0.44	(0.18 to 0.69)	1	–0.52	0.004
					2	–0.38	0.011
					3	–0.20	0.19
BMDth right, z-score	–0.12	(–0.37 to 0.13)	0.38	(0.14 to 0.63)	1	–0.51	0.004
					2	–0.39	0.012
					3	–0.20	0.19
BMD spine, z-score	–0.06	(–0.29 to 0.17)	–0.13	(–0.35 to 0.10)	1	0.06	0.70
					2	0.22	0.10
					3	0.28	0.054
ALM, kg	12.0	(11.2 to 12.7)	13.4	(12.7 to 14.1)	1	–1.4	0.001
					2	–0.9	0.004
					3	–0.7	0.03
ALMI, kg/m^2	5.5	(5.3 to 5.7)	5.8	(5.5 to 5.9)	1	–0.3	0.02
					2	–0.2	0.03
					3	–0.2	0.19
Body fat, %	26.0	(23.3 to 28.7)	26.2	(23.5 to 28.8)	1	–0.2	0.94
					2	0.0	0.97
					3	–1.1	0.38
Fat mass ratio	1.11	(1.05 to 1.17)	1.25	(1.19 to 1.30)	1	–0.13	<0.001
					2	–0.14	0.001
					3	–0.13	0.001
STR	0.78	(0.72 to 0.85)	0.69	(0.63 to 0.76)	1	0.09	0.04
					2	0.09	0.04
					3	0.09	0.049

*Comparing the EP/ELBW and TB pairs: model 1: unadjusted; model 2: adjusted for height z-score, weight z-score and parental-reported puberty; model 3: adjusted for height z-score, weight z-score, parental-reported puberty and physical activity.
†Estimate of difference between EP/ELBW-born and term-born children.
ALM, appendicular lean mass;ALMI, appendicular lean mass index; BMC, bone mineral content; BMD, bone mineral density; BMDth, total hip bone mineral density; EP/ELBW, extremely preterm/extremely low birth weight; STR, subscapular-triceps skinfold ratio; TB, term born; Fat mass ratio, (arms+legs fat mass)/truncal fat mass.

results in that potential differences in PA may become more apparent in societies where children in general are more active.

Several factors have been suggested to contribute to lower PA in preterm-born children, including reduced muscle mass, altered muscle fibre composition, reduced lung function and reduced physical fitness.[27] Other important aspects are their increased risk of shortcomings due to clumsiness, hyperactivity, inattention and lower physical confidence.[28] Our findings imply that EP/ELBW-born children are less inclined to attend team sports but instead prefer to perform PA alone or together

Table 5 Results from mixed linear regression analyses of effect of leisure time physical activity on body composition in 47 extremely preterm (EP) born children and their 49 age-matched and gender-matched term-born (TB) controls born in year 1999–2000 in the Western Norway health region and examined in 2010–2011 as part of the Project Extreme Prematurity

Variables, units	EP born		TB					Physical activity			Physical activity EP compared with TB		
	Mean	95% CI	Mean	95% CI	Difference*	95% CI	P value	Effect †	95% CI	P value	Effect‡	95% CI	P value
Weight, z-score	−0.34	(-0.63, to 0.05)	−0.13	(−0.43 to 0.16)	−0.20	(−0.60 to 0.20)	0.32	−0.09	(−0.28 to 0.11)	0.39	−0.03	(−0.44 to 0.36)	0.88
BMI, z-score	−0.19	(−0.47 to 0.09)	−0.21	(−0.49 to 0.07)	−0.02	(−0.39 to 0.43)	0.92	−0.10	(−0.29 to 0.09)	0.28	0.03	(−0.36 to 0.42)	0.89
FMI, kg/m^2	4.2	(3.5 to 4.9)	4.4	(3.7 to 5.0)	−0.2	(−1.1 to 0.8)	0.70	−0.9	(-1.3, to 0.4)	<0.001	0.5	(−0.5 to 1.4)	0.32
Total body fat, %	26.0	(23.3 to 28.7)	26.1	(23.5 to 28.8)	−0.16	(−4.0 to 3.7)	0.94	−4.1	(-6.0, to 2.1)	<0.001	2.3	(−1.6 to 6,2)	0.25
ALMI, kg/m^2	5.5	(5.3 to 5.7)	5.8	(5.6 to 5.9)	−0.3	(-0.5, to 0.1)	0.02	0.1	(−0.1 to 0.2)	0.44	−0.3	(-0.6, to 0.1)	0.012
LBMI, kg/m^2	11.3	(11.0 to 11.6)	11.6	(11.3 to 11.8)	−0.3	(−0.7 to 0.2)	0.20	0.1	(−0.1 to 0.4)	0.27	−0.6	(-1.1, to 0.1)	0.02
STR	0.78	(0.72 to 0.85)	0.69	(0.63 to 0.76)	0.09	(0.00 to 0.17)	0.04	0.005	(−0.04 to 0.05)	0.83	−0.09	(−0.18 to 0.01)	0.07
WHtR	0.44	(0.43 to 0.45)	0.44	(0.43 to 0.45)	0.00	(−0.01 to 0.03)	0.79	−0.01	(−0.02 to 0.00)	0.11	−0.00	(−0.02 to 0.02)	0.71
Fat mass ratio	1.11	(1.05 to 1.17)	1.25	(1.19 to 1.30)	−0.13	(-0.21, to 0.06)	0.001	0.00	(−0.04 to 0.05)	0.84	0.04	(−0.05 to 0.13)	0.42
BMC, g	1096	(1016 to 1176)	1256	(1177 to 1335)	−160	(-252, to 67)	0.001	14	(−41 to 69)	0.63	−126	(-245, to 6)	0.04
BMD, g/cm^2	0.809	(0.788 to 0.830)	0.863	(0.843 to 0.884)	−0.054	(-0.078, to 0.030)	<0.001	0.008	(−0.007 to 0.022)	0.28	−0.034	(-0.065, to 0.003)	0.03
BMD, z-score	−0.07	(−0.28 to 0.14)	0.43	(0.22 to 0.64)	−0.50	(-0.78, to 0.22)	<0.001	0.09	(−0.07 to 0.25)	0.27	−0.39	(-0.71, to 0.07)	0.02
BMD, spine z-score	−0.06	(−0.29 to 0.17)	−0.13	(-0.35, to 0.10)	0.06	(−0.26 to 0.39)	0.70	0.03	(−0.15 to 0.21)	0.73	−0.23	(−0.59 to 0.13)	0.20
BMDth left, z-score	−0.07	(−0.33 to 0.19)	0.44	(0.18 to 0.69)	−0.51	(-0.84, to 0.17)	0.004	0.21	(0.02 to 0.40)	0.03	−0.53	(-0.91 to 0.15)	0.007
BMDth right, z-score	−0.12	(−0.37, 0.14)	0.38	(0.14, 0.63)	−0.50	(-0.83, -0.17)	0.004	0.24	(0.05, 0.42)	0.001	−0.50	(-0.87 to -0.13)	0.009

*Unadjusted difference between EP born and TB.
†Estimated overall effect of physical activity.
‡Estimated difference in effect of PA on EP born compared with TB (interaction term). Boldface denotes significant group differences.
ALMI, appendicular lean mass index; BMC, bone mineral content; BMD, bone mineral density; BMDth, total hip bone mineral density; LBMI, lean body mass index; PA, physical activity; STR, subscapular-triceps skinfold ratio; WHtR, waist-to-height ratio; Fat mass ratio, (arms+legs fat mass)/truncal fat mass.

with family members. This could reflect the neuromuscular and social interaction difficulties these children may experience.

Habits of PA track from childhood into adulthood,[29] and therefore, our results suggest that the long-term health of EP/ELBW-born children may be negatively affected.

Body composition

Preterm-born children have been reported to have increased truncal fat deposit and insulin resistance, established risk factors for developing type 2 diabetes mellitus.[30 31] Our study supports these observations since the EP/ELBW-born children had a lower FM ratio and a close to significantly higher STR, indicating greater truncal fat deposits.

There is a positive association between BW and muscle strength, which is maintained during life.[32] Skeletal muscle mass, fat-free mass and muscle strength have been found to be reduced in children and adults born preterm compared with those born at term.[26 27 33] This is in line with our results, where the EP/ELBW-born children had approximately 1 kg less skeletal muscle mass than the TB children.

In addition to providing strength and mobility, skeletal muscle is insulin sensitive and an important regulator of glucose metabolism and therefore relevant in preventing cardiovascular and metabolic disease.[34] We suggest that the EP/ELBW-born children's lower muscle mass may negatively affect long-term health outcome by reducing their engagement and abilities in PA and by contributing to an ineffective metabolism.

There is an association between low BW and low peak bone mass later in life.[11 35 36] In our study, the mean total BMD z-score and BMDth z-scores in the EP/ELBW-group were within normal ranges but nevertheless lower than in the TB group. As reduced peak BMD is regarded the most important determinant of osteoporosis and fractures in later adulthood,[37] the EP/ELBW-born children may be at increased risk.

Mean BMD z-score in the TB group was greater than expected, especially among the men. The reason may be that the TB controls were more active than the children in the reference material[38] or that there are secular trends towards greater BMD values in Norwegian boys.

Measures of body composition are influenced by the size of the body. BMD is correlated with weight, height and puberty, and these measures were adjusted for by height and weight z-score in addition to parental reported puberty. However, DXA-derived BMD is based on the two-dimensional projected area of a three-dimensional structure, and it is possible that smaller bones was found to have lower BMD than larger bones. The skeletal muscle mass (ALM and LBM)) and FM were normalised for height squared, and we additionally adjusted ALMI for height and weight z-score to take into account the height and weight difference between the individuals at the given age (table 4, model 2). FM ratio and STR are less influenced by height and weight as reflected in table 4.

PA and body composition

PA is associated with numerous health benefits on a range of non-communicable diseases.[13 14] However, EP/ELBW-born children's benefits from exercise are not well studied.

The associations between PA and bone mineral and skeletal muscle mass accrual were weaker in the EP/ELBW than in the TB group. The less enduring and less vigorous physical engagement in PA among the EP/ELBW-born children may be one explanation, but it may also imply that EP/ELBW-born children benefit less from exercise compared with TB.

Nevertheless, the EP/ELBW-born children should be encouraged to be more physically active to achieve their potential peak bone and muscle mass.

The impact of the perinatal stress the preterm born individuals are exposed to is far from fully understood. One may hypothesise that early epigenetic adaptation and metabolic programming can explain later development of an unfavourable body composition.[39] Future studies should try to establish optimal growth patterns for preterm children to facilitate better and individualised nutritional treatment. Furthermore, studies are needed to assess to what extent the frequency, volume and intensity of PA might improve body composition of the preterm born children.

Strengths and limitations

The major strength of this study was the population-based and controlled design with a relatively high rate of attendance and that the participants were representative of the complete cohort. Recruitment of TB controls was based on the 'next-born subject principle', minimising the risk of selection bias. Potential bias introduced by a two-centre design was limited by paired statistical analysis with EP/ELBW and TB controls who were recruited and examined at the same institution. Moreover, potential inaccuracies introduced by collecting data on exercise habits and pubertal staging by suboptimal methods are likely to pertain similarly to the EP/ELBW and TB groups, thus allowing for group comparisons.

The EP/ELBW children were recruited based on either GA below <28 weeks or BW less than 1000 g irrespectively of GA. Therefore, the results cannot be generalised to EP-born individuals in general.

The exercise habits were determined by questionnaires rather than more objective methods like accelerometers and diaries, which represent a limitation to the study. Especially, we assume the report on unstructured exercise activity to be inaccurate. The association between PA and body composition must therefore be interpreted with caution.

Pubertal stage was not assessed by clinical examination, but rather with parental report, and the dietary intake for calcium and vitamin D was not recorded, factors that can influence the interpretation of BMD. However, a recent meta-analysis concluded that preterm born children enter puberty at the same age as term born children.[40] In addition, our paired analysis on the question regarding puberty did not find differences between the groups.

The p value has not been formally adjusted for multiple comparison and subsequent studies should be performed to confirm our observed associations.

CONCLUSIONS

Compared with TB controls, the EP/ELBW-born school children were less physically active, and our study suggests that they had an unfavourable body composition with increased truncal fat, less skeletal muscle mass and reduced BMD. Physical activity was less associated with mineral and skeletal muscle mass accrual in the EP/ELBW-born group.

What is known about the subject?

- Physical activity is associated with several health benefits and has preventive effects on several non-communicable diseases like osteoporosis and cardiometabolic disease.
- There is a positive association between birth weight and muscle strength and peak bone mass, which is maintained across the life course.
- We lack knowledge on how physical activity impacts body components in children born extremely preterm or at extremely low birth weight.

What this study adds?

- The children born extremely preterm or with extremely low birth weight (EP/ELBW) were less physically active than term born children.
- The children born EP/ELBW had an unfavourable body composition with less muscle mass, reduced bone mineral density and increased truncal fat.
- Physical activity was less associated with mineral and skeletal muscle mass accrual in the EP/ELBW-born group compared with term-born controls.

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