Gestational Age, Parent Education, and Education in Adulthood

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abstract

BACKGROUND: Adults born preterm (<37 weeks) have lower educational attainment than those born term. Whether this relationship is modified by family factors such as socioeconomic background is, however, less well known. We investigated whether the relationship between gestational age and educational attainment in adulthood differed according to parents' educational level in 4 Nordic countries.

METHODS: This register-based cohort study included singletons born alive from 1987 up to 1992 in Denmark, Finland, Norway, and Sweden. In each study population, we investigated effect modification by parents' educational level (low, intermediate, high) on the association between gestational age at birth (25–44 completed weeks) and low educational attainment at 25 years (not having completed upper secondary education) using general estimation equations logistic regressions.

RESULTS: A total of 4.3%, 4.0%, 4.8%, and 5.0% singletons were born preterm in the Danish ($n = 331\,448$), Finnish ($n = 220\,095$), Norwegian ($n = 292\,840$), and Swedish ($n = 513\,975$) populations, respectively. In all countries, both lower gestational age and lower parental educational level contributed additively to low educational attainment. For example, in Denmark, the relative risk of low educational attainment was 1.84 (95% confidence interval 1.44 to 2.26) in adults born at 28 to 31 weeks whose parents had high educational level and 5.25 (95% confidence interval 4.53 to 6.02) in adults born at 28 to 31 weeks whose parents had low educational level, compared with a reference group born at 39 to 41 weeks with high parental educational level.

CONCLUSIONS: Although higher parental education level was associated with higher educational attainment for all gestational ages, parental education did not mitigate the educational disadvantages of shorter gestational age.

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WHAT'S KNOWN ON THIS SUBJECT: Preterm birth is associated with poorer educational outcomes; however, it is less-well known whether advantageous socioeconomic background can modify the association between gestational age and educational outcomes.

WHAT THIS STUDY ADDS: In 4 Nordic countries, high parental educational level was associated with higher educational attainment within all degrees of preterm birth but did not mitigate the disadvantages of shorter gestational age on educational attainment in adulthood.

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Worldwide preterm birth (<37 weeks) contributes to substantial morbidity and mortality in early life.[1,2] However, sequelae of shorter gestational age extend well beyond the neonatal period and are not limited to health.[3–6] Children born preterm are more likely to experience difficulties such as cognitive delays and academic difficulties,[4–7] and as adults they are less likely to complete higher education than those born term (39–41 weeks).[8–12] This also applies to the Nordic countries[9,10] where education at all levels is largely publicly funded.[13] Importantly, not only adults born preterm but also those born early term (37–38 weeks) seem to attain lower educational levels.[9,10]

Educational trajectories are not only influenced by biological factors, such as gestational age at birth, but also by social and family factors. For example, parental participation in school activities, parent-child attachment, and high parental socioeconomic position have a positive impact on academic achievement.[14–16] However, less is known about the role of social and family factors on educational outcomes of preterm born individuals. Advantageous family environment may be particularly important for the development of preterm children some studies found that the association between preterm birth and poorer educational and cognitive outcomes was less pronounced in those from an advantageous compared with a disadvantageous family background.[11,17–21] Other studies found similar associations between preterm birth and poorer educational and cognitive outcomes in those from an advantageous and disadvantageous family environment.[10,22–24] Because of differences across these studies in terms of study populations, socioeconomic indicators, age at follow-up, and measures of cognitive or educational outcomes, it is unknown whether findings are generalizable to other settings. The Nordic population–covering registers provide unique opportunities to explore the interplay between social and health factors on educational attainment in different contexts that still resemble each other in many aspects. This is crucial to identify resiliency factors or vulnerable groups for long-term outcomes after preterm birth. We therefore aimed to investigate whether the association between gestational age and educational attainment in early adulthood in 4 Nordic study populations differed according to parents' educational level.

METHODS

Data Source and Study Populations

In this register-based cohort study, we identified all liveborn infants born during 1987 – 1992 in the Danish and Norwegian Medical Birth registers,[25] from January 1987 to September 1990 in the Finnish Medical Birth Register,[25] and during 1987 – 1991 in the Swedish Medical Birth Register.[25] We restricted the 4 populations to singletons (Fig 1). In each country, information from the Medical Birth Registers was linked to information on highest completed education at 25 years and parental education, emigration and death from the national registers by pseudoanonymised unique personal identifiers. Individuals who died before the calendar year they turned 25 years or did not live in their country of birth at 25 years were excluded (Fig 1). In addition, individuals with missing gestational age (Denmark = 0.7%, Finland = 1.2%, Norway = 8.5%, Sweden = 0.2%) or with implausible birth weight for gestational age using the conservative approach suggested by Alexander et al[26] (Denmark = 0.2%, Finland = 0.1%, Norway = 0.2%, Sweden <0.1%) were excluded. The populations were restricted to individuals born from 25 to 44 weeks' gestation, because few individuals were born outside this range. Furthermore, individuals with missing information on educational attainment at 25 years, maternal education, maternal age, maternal country of birth, parity, sex, and congenital anomalies were excluded. No individuals were excluded from the Finnish population because of missing educational information because the education register does not distinguish missing education from primary and lower secondary education.

Exposures and Covariates

Gestational age in completed weeks was obtained from the national Medical Birth Registers.[25] The gestational age estimates were primarily based on ultrasound examination or first day of last menstrual period.[27] In Denmark, ultrasound measurements were used increasingly during the study period to correct estimates based on last menstrual period.[28,29] In Finland, estimates of gestational age were based on last menstrual period and ultrasound examination. Gestational age was determined by ultrasound for ~40% of newborns in Northern Finland in 1985 to 1986.[30] In Norway, ultrasound-based pregnancy dating started in 1986[27]; however, before 1999 only the gestational age based on last menstrual period was recorded in the Norwegian Medical Birth Register.[31] In Sweden, second-trimester ultrasound examinations have generally been performed since the 1980s,[27] and from 1990, pregnant women were offered an early second-trimester ultrasound scan, with 95% of women accepting this offer.[29] The highest completed educational level for mothers and

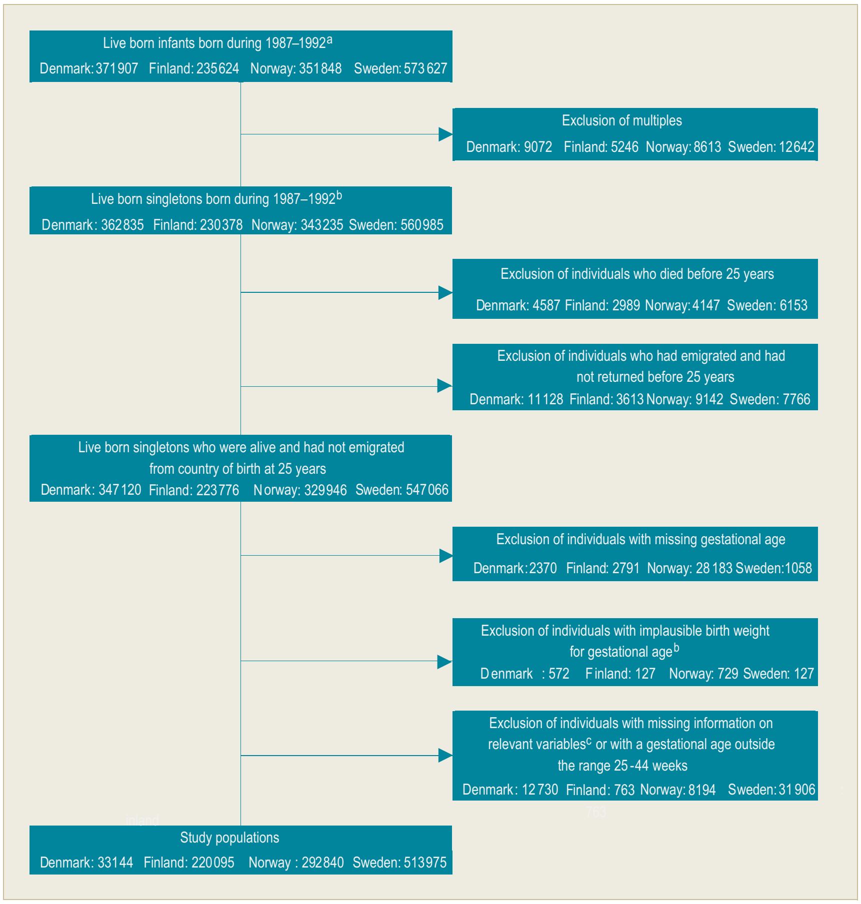

FIGURE 1
Flowchart for the Danish, Finnish, Norwegian, and Swedish populations. [a] Denmark and Norway 1987–1992; Finland 1987–1990l Sweden 1987–1991. [b] Implausible values according to Alexander et al 1996.[26] [c]Sex, congenital anomalies, parity, maternal identification number, maternal age, maternal education, and maternal country of birth.

fathers according to International Standard Classification of Education (ISCED)[32] was available from the National Education Registers.[33–36] We constructed the parental educational level variable by using the highest completed educational level at birth of the index person among the parents. If the father's educational level was missing, then the parental educational level was based on the mother's educational level only. Maternal and parental highest completed educational level at birth according to ISCED were categorized as low (ISCED 1–2), intermediate (ISCED 3–4), and high (ISCED 5–8).

Potential confounders were selected a priori on the basis of existing literature. From the Medical Birth Registers, we obtained information on sex, birth year, parity, and maternal age. Parity was defined as number of pregnancies reaching 22 weeks and was categorized as primiparous and multiparous. In the Norwegian data set, number of liveborn children was used as a proxy for parity. Information on congenital anomalies recorded at birth and up to 1 year after was obtained from the Medical Birth Registers in Norway and Sweden, the Register of Malformations[37] in Finland, and the National Patient Register[38] in Denmark. Maternal country of birth was categorized as "same as delivery," "Europe," (current European Union member countries and present-day Albania, Andorra, Belarus, Bosnia-Hercegovina, Iceland, Kosovo, Liechtenstein, Norway, Moldova, Monaco, Montenegro, North Macedonia, Russia, Ukraine, United Kingdom, Vatican City, San Marino, Serbia, Switzerland, excluding country of delivery), "outside Europe" (all remaining countries).

Outcome

The index person's highest completed educational level at 25 years, according to ISCED, was obtained from the National Education Registers[33–36] and was dichotomized as "low educational attainment," defined as not having completed upper secondary education (ISCED level 0–2, equivalent of maximum 10 years of studies), and "high educational attainment," defined as having completed upper secondary education or more (ISCED level 3–8, equivalent of minimum 12 years of studies). Thus, low educational attainment was equivalent to having completed no further education than compulsory. In all countries, schooling was compulsory for 9 to 10 years during the study period, and students started upper secondary education at ∼16 years of age.[13]

Statistical Analysis

In each country, we harmonized variables from the national registers and analyzed these data using the same statistical methods (presented below) because there are still barriers to share individual level register data between the Nordic countries.[39]

We investigated the association between gestational age and low educational attainment at 25 years according to parental educational level by using generalized estimating equations (GEEs) logistic regressions. Gestational age was modeled either as a categorical variable (25–27, 28–31, 32–33, 34–36, 37–38, 39–41, and 42–44 weeks) or as a continuous variable with possible nonlinear effects by using restricted cubic splines[40] with 3 predefined knots (at 28, 37, and 41 weeks). The models included an interaction term between gestational age and parental educational level and were adjusted for the following potential confounders: birth year, sex, congenital anomalies, parity, maternal age, and maternal country of birth (except in Finland, where maternal country of birth was not included because the proportion of mothers born outside Finland was low). All potential confounders were included as categorical variables with the categories presented in Table 1. Because the same woman could give birth more than once during the study period, we specified that data were correlated within mothers by adding maternal identification number as a clustering variable with an exchangeable working correlation structure. From the models that included gestational age as a continuous spline variable we extracted probabilities and logit values with 95% confidence intervals (CIs). From the models that included gestational age as a categorical variable we extracted probabilities and calculated relative risks (RRs). To investigate potential additive interaction we calculated relative excess risk due to interaction (RERI)[41] on the basis of the following formula RERI = $RR_{A+B+} - RR_{A+B-} - RR_{A-B+} + 1$, where RR_{A+B+} designate those being doubled exposed (ie, gestational age before or after 39–41 weeks and low or intermediate parental educational level), RR_{A+B-} designates those only exposed to gestational age, and RR_{A-B+} designate those only being exposed to parental educational level). We used a cluster sample bootstrap approach[42] to estimate 95% CIs for the RR and RERI. For a sensitivity analysis we used only maternal education as an indicator of parental socioeconomic position.

All analyses were performed in R version 3.5.0 (Denmark), 3.6.0 (Finland), 3.6.2 (Norway), 4.0.3 (Sweden) by using the package "geepack"[43] for GEE logistic regressions, the package "splines" for splines, and the package "ggeffects"[44] for extracting probabilities and logit values from the GEE logistic regressions.

RESULTS

Characteristics of the Study Populations

In the Danish, Finnish, Norwegian, and Swedish study populations 4.3%, 4.0%, 4.8%, and 5.0% young adults were born preterm, respectively. The Danish and Norwegian study populations included a higher proportion of younger mothers (<25 years) and parents with low educational level than the Finnish and Swedish study populations (Table 1). Characteristics for the study populations according to gestational age are presented for each country in Supplemental Tables 3–6.

Educational Attainment in the 4 Countries

The proportion of young adults who had low educational attainment, equivalent to not having completed upper secondary education, at 25 years was higher in the Danish (21.2%) and Norwegian (20.9%) study populations than in the Finnish (12.6%) and Swedish (11.8%) study populations (Fig 2).

Gestational Age and Educational Attainment

In all 4 Nordic countries, lower gestational age was associated with a higher probability of low educational attainment at 25 years (Fig 3). For example, among young adults born in Denmark whose parents had intermediate educational level, the probability of low educational attainment increased from 15.2% (95% CI 14.8% to 15.6%) among those born at 40 weeks to 27.2% (95% CI 24.0% to 30.6%) among those born at 28 weeks. The corresponding increase was 9.7% (95% CI 9.4% to 10.1%) to 13.8% (95% CI 10.9% to 17.4%) in Finland, 15.4% (95% CI 14.9% to 15.8%) to 22.6% (95% CI 19.5% to 26.0%) in Norway, and 7.8% (95% CI 7.5% to 8.0%) to 11.3% (95% CI 9.9% to 12.9%) in Sweden (Supplemental Tables 7–10). No association between gestational age and educational attainment was observed in the group with lower or missing parental educational level in Finland (Supplemental Table 8). Young adults born at 37 and 38 weeks had slightly higher probabilities and RRs of low educational attainment than young adults born at 40 weeks in all countries (Fig 3, Table 2).

Educational Attainment According to Gestational Age and Parental Educational Level

Lower parental educational level was associated with low educational attainment at 25 years across all gestational ages in all 4 countries. However, the association between gestational age and educational attainment did not differ substantially between different groups of parental education in Finland, Norway, and Sweden (*P* values for interaction: 0.51 in Finland, 0.94 in Norway, and 0.09 in Sweden) (Fig 3, Supplemental Fig 3). In Denmark, the association between gestational age and educational attainment was similar for those whose parents had higher and lower educational level but differed for those with intermediate educational level (*P* value for interaction: = .01). In the group whose parents had intermediate educational level, the probability of low educational attainment increased in a more linear way with lower gestational age (before 40 weeks), and no increase in probability was observed in the postterm period (Fig 3, Supplemental

TABLE 1 Characteristics in the Danish, Finnish, Norwegian, and Swedish Study Population

Study Population	Denmark (*n* = 331 448), *n* (%)	Finland (*n* = 220 095), *n* (%)	Norway (*n* = 292 840), *n* (%)	Sweden (*n* =512 975), *n* (%)
Gestational, completed wk				
25–27	274 (0.1)	179 (0.1)	250 (0.1)	444 (0.1)
28–31	1373 (0.4)	713 (0.3)	1264 (0.4)	2109 (0.4)
32–33	1843 (0.6)	981 (0.4)	1837 (0.6)	2947 (0.6)
34–36	10 612 (3.2)	7136 (3.2)	10 800 (3.7)	19 824 (3.9)
37–38	44 343 (13.4)	37 702 (17.1)	38 364 (13.1)	94 909 (18.5)
39–41	241 269 (72.8)	164 000 (74.5)	199 464 (68.1)	357 424 (69.5)
42–44	31 734 (9.6)	9384 (4.3)	40 861 (14.0)	36 318 (7.1)
Birth year				
1987	49 940 (15.1)	55 776 (25.3)	44 765 (15.3)	92 483 (18.0)
1988	52 679 (15.9)	58 860 (26.7)	47 571 (16.2)	99 403 (19.3)
1989	55 104 (16.6)	59 009 (26.8)	49 251 (16.8)	103 073 (20.1)
1990[a]	56 985 (17.2)	46 450 (21.1)	51 025 (17.4)	109 423 (21.3)
1991	56 735 (17.1)	—	50 597 (17.3))	109 593 (21.3)
1992	60 005 (18.1)	—	49 631 (19.9)	—
Sex				
Female	161 314 (48.7)	107 189 (48.7)	142 064 (48.5)	249 602 (48.6)
Male	170 134 (51.3)	112 906 (51.3)	150 776 (51.5)	264 373 (51.4)
Congenital anomaly				
No	325 967 (98.3)	217 700 (98.9)	284 067 (97.0)	491 295 (95.6)
Yes	5481 (1.7)	2395 (1.1)	8773 (3.0)	22 680 (4.4)
Maternal age, y				
≤24	81 950 (24.7)	50 267 (22.8)	75 989 (25.9)	115 272 (22.4)
25–29	138 268 (41.7)	82 385 (37.4)	109 600 (37.4)	188 945 (36.8)
30–34	81 698 (24.6)	58 196 (26.4)	76 535 (26.1)	140 116 (27.3)
≥35	29 532 (8.9)	29 247 (13.3)	30 716 (10.5)	69 642 (13.5)
Mother's education[b]				
Lower	109 431 (33.0)	46 316 (21.0)	100 114 (34.2)	140 811 (27.4)
Intermediate	134 233 (40.5)	104 435 (47.4)	121 321 (41.4)	255 739 (49.8)
Higher	87 784 (26.5)	69 344 (31.5)	71 405 (24.4)	117 425 (22.8)
Father's education[b]				
Lower	81 771 (24.7)	57 209 (26.0)	81 890 (28.0)	120 733 (23.5)
Intermediate	158 546 (47.8)	103 032 (46.8)	127 618 (43.6)	295 683 (57.5)
Higher	74 347 (22.4)	59 854 (27.2)	77 521 (26.5)	88 533 (17.2)
Missing	16 784 (5.1)	—	5811 (2.0)	9026 (1.8)
Parents' education[b]				
Lower	52 641 (15.9)	20 407 (9.3)	47 673 (16.3)	55 222 (10.7)
Intermediate	163 288 (49.3)	105 712 (48.0)	140 032 (47.8)	306 312 (59.6)
Higher	115 519 (34.9)	93 976 (42.7)	105 135 (35.9)	152 441 (29.7)
Maternal parity				
Multiparous	175 283 (52.9)	132 150 (60.0)	165 055 (56.4)	298 265 (58.0)
Primiparous	156 165 (47.1)	87 945 (40.0)	127 785 (43.6)	215 710 (42.0)
Maternal country of birth				
Same as delivery	315 736 (95.3)	220 095 (100)	275 673 (94.1)	459 971 (89.5)
Europe	5328 (1.6)	—	7194 (2.5)	35 800 (7.0)
Outside Europe	10 384 (3.1)	—	9973 (3.4)	18 204 (3.5)

—, not applicable.

[a] The Finnish study population included singletons born from January 1987 to September 1990.

[b] Parental highest educational level at birth according to ISCED lower (ISCED 0–2), intermediate (ISCED 3–4), higher (ISCED 5–8). In the Finnish study population, "lower education" included individuals with lower and missing educational levels.

Fig 3). Findings from the model with gestational age modeled as a categorical variable were similar to those in which gestational modeled as a spline (Supplemental Fig 4). Findings were similar in the sensitivity analyses using maternal instead of parental educational level (Supplemental Fig 5).

The RR of low educational attainment was higher in adults born term (39–41 weeks) whose parents had low educational level than adults born extremely preterm (25–27 weeks) whose parents had high educational level compared with the reference group of adults born term whose parental had high educational level (Table 2). In each country, the RERIs indicated no or little excess risk of low educational attainment in groups of adults exposed to both lower gestational age and lower parental educational level as most RERI estimates were close to

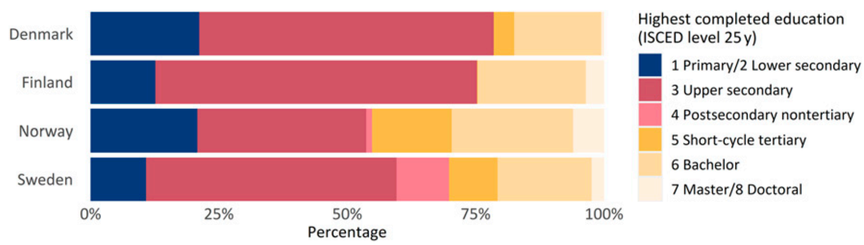

FIGURE 2
Educational level at 25 years according to ISCED in the Danish, Finnish, Norwegian, and Swedish study population.

0 or not statistically significantly different from 0 (Table 2). For instance, in Sweden, the RERI for the group born from 28 to 31 weeks whose parents had higher educational level was 0.40 (95% CI −0.84 to 1.79), meaning that the RR of low educational attainment for this group was 0.40 higher than would have been expected by combing the risk of low gestational age and lower parental educational level additively (reference group: born at 39–41 weeks with higher parental educational level). However, the wide CI overlapping 0 for this group reflects that there could also be no excess risk related to being exposed to both lower gestational age and lower parental educational level.

DISCUSSION

In all 4 Nordic countries, lower gestational age and lower parental educational level were additively associated with low educational attainment at 25 years. Even being born at 37 and 38 weeks of gestation was associated with a slightly lower educational attainment compared with those born at 40 weeks. Although parental educational level was more strongly associated with educational

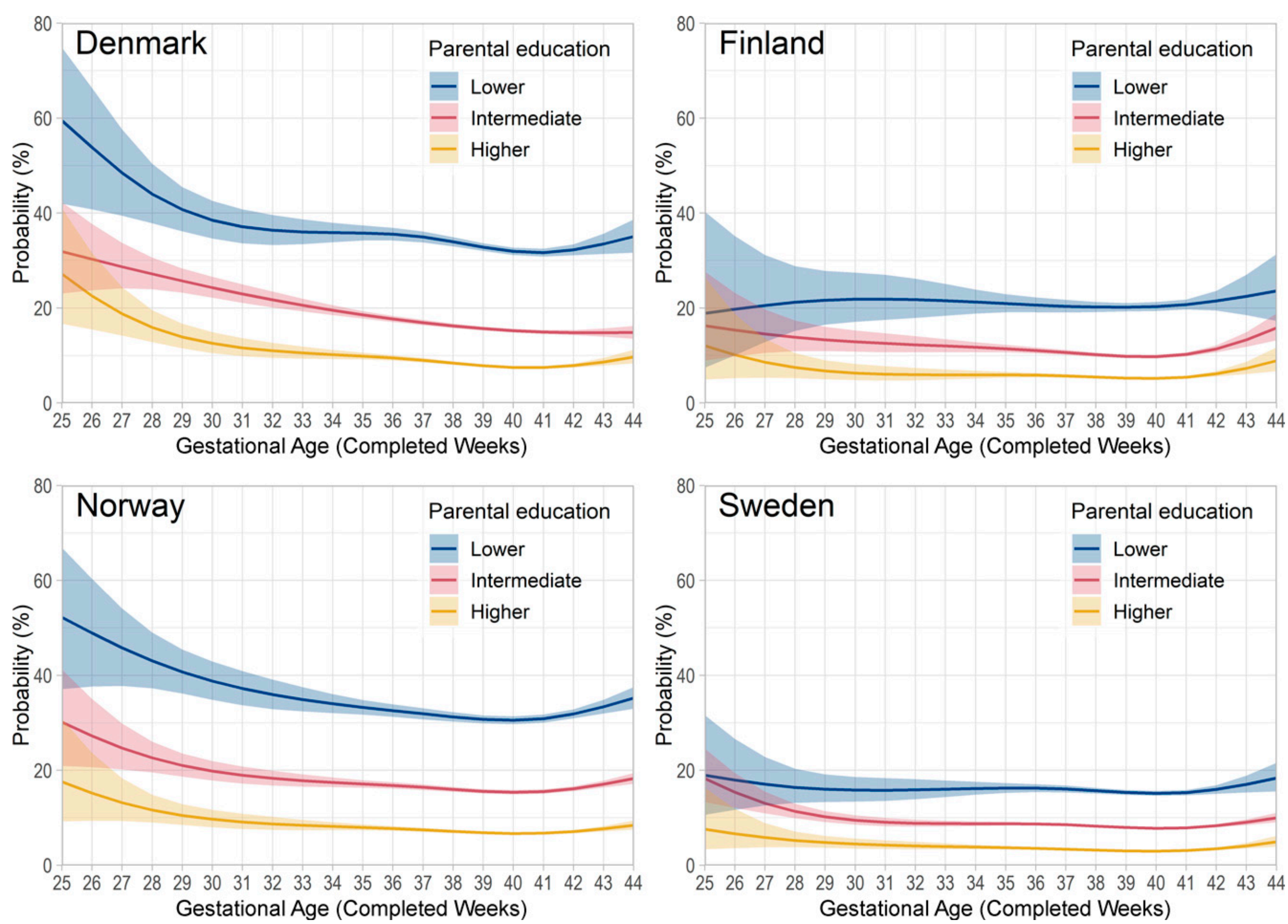

FIGURE 3
Probability of low educational attainment at 25 years according to gestational age and parental educational level by country. Estimates were adjusted for birth year, sex, congenital anomalies, parity, maternal age, and maternal country of birth and were obtained from models that included an interaction term between gestational age and parental educational level (Denmark: $P = .01$; Finland: $P = .51$; Norway: $P = .94$; Sweden: $P = .09$). Areas represent 95% CIs.

TABLE 2 RR and RERI With 95% CIs for Low Educational Attainment at 25 Years According to Gestational Age and Parental Educational Level in Denmark, Finland, Norway, and Sweden

	Parental Educational Level									
	High		Intermediate				Low			
Country, Gestational Age, wk	RR	95% CI	RR	95% CI	RERI	95% CI	RR	95% CI	RERI	95% CI
Denmark										
25–27	2.60	1.52 to 3.75	3.34	2.49 to 4.23	−0.27	−1.68 to 1.07	6.98	4.88 to 8.84	1.15	−1.32 to 3.42
28–31	1.83	1.44 to 2.29	3.59	3.17 to 4.02	0.74	0.11 to 1.30	5.12	4.40 to 5.82	0.05	−0.77 to 0.84
32–33	1.38	1.07 to 1.69	2.72	2.39 to 3.05	0.33	−0.09 to 0.78	4.80	4.20 to 5.42	0.19	−0.49 to 0.91
34–36	1.25	1.14 to 1.38	2.34	2.21 to 2.47	0.07	−0.10 to 0.25	4.67	4.39 to 4.93	0.19	−0.10 to 0.48
37–38	1.15	1.09 to 1.21	2.19	2.12 to 2.27	0.03	−0.05 to 0.12	4.54	4.38 to 4.72	0.16	0.01 to 0.31
39–41	1.00	Reference	2.01	1.96 to 2.06	—	—	4.23	4.11 to 4.34	—	—
42–44	1.03	0.97 to 1.09	1.95	1.87 to 2.02	−0.10	−0.20 to −0.01	4.30	4.12 to 4.50	0.04	−0.15 to 0.22
Finland										
25–27	1.85	0.74 to 3.13	2.42	1.27 to 3.84	−0.30	−2.05 to 1.48	3.14	1.14 to 5.99	−1.56	−3.95 to 1.53
28–31	1.10	0.69 to 1.60	2.49	1.96 to 3.12	0.52	−0.20 to 1.29	4.81	3.41 to 6.33	0.85	−0.57 to 2.32
32–33	1.09	0.69 to 1.51	2.15	1.68 to 2.61	0.20	−0.47 to 0.80	3.88	2.73 to 5.06	−0.06	−1.24 to 1.14
34–36	1.15	1.01 to 1.31	2.22	2.02 to 2.41	0.19	−0.05 to 0.42	3.71	3.29 to 4.19	−0.29	−0.74 to 0.19
37–38	1.04	0.97 to 1.11	1.93	1.84 to 2.02	0.02	−0.08 to 0.12	3.85	3.61 to 4.11	−0.04	−0.29 to 0.22
39–41	1.00	Reference	1.87	1.81 to 1.93	—	—	3.85	3.69 to 4.00	—	—
42–44	1.13	1.00 to 1.25	2.23	2.07 to 2.41	0.23	0.04 to 0.43	4.25	3.76 to 4.76	0.26	−0.25 to 0.81
Norway										
25–27	2.35	1.28 to 3.63	4.13	3.07 to 5.30	0.49	−1.21 to 2.14	7.34	5.51 to 9.15	1.46	−0.72 to 3.58
28–31	1.36	1.00 to 1.72	2.64	2.23 to 3.08	−0.02	−0.59 to 0.54	5.75	4.91 to 6.65	0.86	−0.03 to 1.82
32–33	1.40	1.08 to 1.74	3.12	2.77 to 3.47	0.42	−0.05 to 0.89	4.81	4.19 to 5.55	−0.12	−0.83 to 0.70
34–36	1.14	1.03 to 1.27	2.44	2.29 to 2.58	0.00	−0.20 to 0.17	5.01	4.71 to 5.30	0.34	0.01 to 0.64
37–38	1.06	1.01 to 1.13	2.39	2.30 to 2.49	0.03	−0.06 to 0.12	4.71	4.50 to 4.92	0.12	−0.06 to 0.30
39–41	1.00	Reference	2.30	2.23 to 2.36	—	—	4.53	4.40 to 4.67	—	—
42–44	1.09	1.03 to 1.16	2.42	2.33 to 2.52	0.02	−0.07 to 0.12	4.85	4.65 to 5.05	0.23	0.05 to 0.40
Sweden										
25–27	2.08	0.93 to 3.50	4.53	3.43 to 5.82	0.86	−0.90 to 2.50	4.29	2.12 to 6.74	−1.78	−4.35 to 1.14
28–31	1.43	0.97 to 1.95	3.49	3.02 to 3.99	0.46	−0.25 to 1.11	5.83	4.65 to 7.11	0.40	−0.84 to 1.79
32–33	1.25	0.85 to 1.67	2.73	2.39 to 3.09	−0.11	−0.65 to 0.42	5.02	3.99 to 6.14	−0.22	−1.32 to 0.89
34–36	1.32	1.16 to 1.48	2.82	2.67 to 2.99	−0.09	−0.31 to 0.11	5.09	4.68 to 5.55	−0.21	−0.66 to 0.24
37–38	1.04	0.97 to 1.11	2.75	2.66 to 2.86	0.12	0.03 to 0.22	5.31	5.05 to 5.56	0.28	0.04 to 0.50
39–41	1.00	Reference	2.59	2.52 to 2.68	—	—	4.99	4.82 to 5.19	—	—
42–44	1.13	1.02 to 1.23	2.74	2.61 to 2.87	0.02	−0.13 to 0.15	5.42	5.05 to 5.81	0.30	−0.07 to 0.70

RR and RERI were adjusted for sex, congenital anomaly, birth year, parity, maternal age, and maternal country of origin. RERI was estimated for groups being “exposed” to gestational age outside the range 39–41 wk and to either lower or intermediate parental educational level. —, not applicable.

attainment than gestational age, the association between gestational age and educational attainment in early adulthood did not differ substantially according to parental educational level.

Several studies have found that lower gestational age is associated with poorer school performance[5,45,46] and educational qualifications in adulthood.[8–12] However, fewer studies have investigated whether socioeconomic background modified these associations. Findings from our study indicate that parental educational level did not modify the relationship between gestational age and educational attainment. Some previous studies had similar findings,[10,22,23] whereas other studies found that the association between gestational age and cognitive/educational outcomes was stronger for individuals from a low socioeconomic background than those from a high socioeconomic background.[11,17–20,21] The inconsistent findings could be attributable to differences in age at follow-up, categorization of gestational age, and measures of socioeconomic background and cognitive and educational outcomes. Additionally, findings may be context specific. In the 4 Nordic countries included in this study, findings indicated no or little effect modification by parental educational level on the association between gestational age and educational attainment in adulthood.

Parental educational level is associated not only with postnatal factors but also prenatal factors, and therefore, stratification on gestational age may introduce collider stratification bias. Thus, findings cannot be interpreted causally but provide a comprehensive description of the interplay between gestational age and parental educational background. Based on our findings, higher parental education seems to be a universal protective factor that promotes educational attainment for adults born preterm, early term, and term equally. Parental educational level was more-strongly related to later educational attainment than gestational age. The mechanisms linking parental educational level and educational attainment are probably multiple and may include cognitive potential and postnatal factors such as homework assistance, parenting, and cognitive stimulation. Thus, to enhance the understanding of the development of children born preterm, not only biological factors but also social factors including those mentioned above must be assessed comprehensively.

Not only young adults born preterm but also those born early term (37–38 weeks) had on average lower educational level. The few studies in which researchers examined early term birth and education in adulthood also indicate that adults born early term have slightly lower educational attainment than adults born term.[10,11] Early term birth has traditionally been seen as a low-risk group, and often individuals born from 37 to 41 weeks have been studied as one term group.[47] Nonetheless, emerging evidence suggests that the risk of several adverse outcomes is increased for those born early term compared with term (39–41 weeks).[9,45–49] Although early term birth is not as strongly associated with low educational attainment as preterm birth, adults born early term are important to consider from a population perspective given that even a small increased risk in this group results in a high number of cases because of their large proportion of all births.

The pathways linking gestational age and educational attainment are presumably multiple and may include pathologic causes of preterm birth (eg, congenital anomalies and intrauterine growth restriction), alterations in brain development (due to more extrauterine brain development), and morbidity related to preterm birth (eg, intraventricular hemorrhage).[50] Preterm birth has been associated with poorer mental and physical health and cognition,[4,6,45,51] and these may also influence choice and completion of education. A Norwegian study found that one of the most common reasons for dropping out of upper secondary education was poor mental health.[52]

Education is an important condition for obtaining a foothold in the labor market, and educational qualifications influence the job and income opportunities.[16] Adults with low educational attainment have lower employment rates, which is related to an increased risk of social exclusion[53] and receiving welfare benefits. Thus, low educational attainment among adults born preterm and early term has implications for both the individual and society.

The Nordic educational systems share common traits such as being largely publicly funded and absence of tuition fees.[13] Nevertheless, substantial socioeconomic inequality in educational attainment was observed in the 4 countries. In addition, this study demonstrates great differences in educational levels between Nordic countries. This could be a result of different education policies but also dissimilar labor market entry conditions for young adults, which has been shown to be poorer in Sweden and Finland compared with Norway and Denmark.[13] Generally, more young people enroll in further education when job opportunities are sparse.[53] Despite substantial differences in the general educational level between the study populations, the findings were similar across the 4 Nordic countries.

In this longitudinal register-based cohort study, we followed 4 nationwide populations from birth into young adulthood. All births were recorded in the national birth registers, which minimizes selection into the study population. Follow-up regarding educational attainment was close to complete. The large study populations enabled investigation of the interplay between the full range of gestational ages and parents' educational level. The 4-country design allowed us to investigate the robustness of the findings and strengthens the interpretations.

Gestational age estimates were primarily based on ultrasound examination and first day of last menstrual period in the 4 study populations. Ultrasound examination has been shown to lower the estimated gestational age compared with last menstrual period across the entire gestational age range,[48] which increases the rate of preterm birth. However, this misclassification is most likely nondifferential because measurement errors of gestational age are not related to later education. To reduce the level of registration errors for gestational age, we excluded individuals with implausible birth weight for gestational age.

In this study, we focused on lower secondary education, because not all adults have completed tertiary education at 25 years. Researchers in future studies could also consider differences in tertiary education, given that some studies indicate that lower gestational age is also related to tertiary education.[10–12] In the Finnish study population, individuals with lower and missing educational level were studied as one group because these individuals could not be distinguished. Thus, the Finnish group with lower educational level is likely to be more heterogenous than in the other 3 Nordic countries.

We were able to adjust for several potential confounders. Geographical area is a potential confounder that may have influenced the received specialized antenatal and neonatal care and the choice of higher education, which we did not adjust for because it is difficult to operationalize using register-based information and to harmonize across countries. Moreover, our study was restricted to singletons, and we did not take into account pregnancy conditions potentially underlying preterm birth. We suggest that the roles of such factors are better addressed in a 1-country analysis in which we can go into more detail and ensure homogenous definitions of pregnancy conditions.

The stillbirth and infant mortality rates have declined in recent decades, and consequently, more individuals survive into adulthood.[2,54,55] Thus, the educational difficulties of children born after shorter gestational age may be different for children born today. This is an unescapable premise when investigating long-term outcomes of individuals born preterm. However, studies suggest that despite the increased survival, cognitive and academic outcomes of preterm individuals have remained unchanged.[5,6,56,57]

CONCLUSIONS

Young adults born preterm whose parents had lower educational level had the lowest educational attainment because both lower gestational age and lower parental educational level contributed additively to low educational attainment in 4 Nordic countries. Although findings suggest that high parental education did not mitigate the disadvantage of shorter gestational age on educational attainment, the findings support that parents' educational level was an important factor for educational attainment for all degrees of preterm birth. We suggest that socioeconomic background should be considered when predicting long-term outcomes in individuals born preterm and in planning of future interventions for improvement of health and wellbeing based on individual vulnerability.

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ABBREVIATIONS

CI: confidence interval
GEE: generalized estimating equation
ISCED: International Standard Classification of Education
RERI: relative excess risk due to interaction
RR: relative risk

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REFERENCES

1. Harrison MS, Goldenberg RL. Global burden of prematurity. *Semin Fetal Neonatal Med*. 2016;21(2):74–79 26740166
2. Saigal S, Doyle LW. An overview of mortality and sequelae of preterm birth from infancy to adulthood. *Lancet*. 2008; 371(9608):261–269 18207020
3. Ritchie K, Bora S, Woodward LJ. Social development of children born very preterm: a systematic review. *Dev Med Child Neurol*. 2015;57(10):899–918 25914112
4. Brydges CR, Landes JK, Reid CL, Campbell C, French N, Anderson M. Cognitive outcomes in children and adolescents born very preterm: a meta-analysis. *Dev Med Child Neurol*. 2018;60(5):452–468 29453812
5. Twilhaar ES, de Kieviet JF, Aarnoudse-Moens CS, van Elburg RM, Oosterlaan J. Academic performance of children born preterm: a meta-analysis and meta-regression. *Arch Dis Child Fetal Neonatal Ed*. 2018; 103(4):F322–F330 28847871
6. Twilhaar ES, Wade RM, de Kieviet JF, van Goudoever JB, van Elburg RM, Oosterlaan J. Cognitive outcomes of children born extremely or very preterm since the 1990s and associated risk factors: a meta-analysis and meta-regression. *JAMA Pediatr*. 2018;172(4):361–367 29459939
7. Pascal A, Govaert P, Oostra A, Naulaers G, Ortibus E, Van den Broeck C. Neurodevelopmental outcome in very preterm and very-low-birthweight infants born over the past decade: a meta-analytic review. *Dev Med Child Neurol*. 2018;60(4):342–355 29350401
8. Bilgin A, Mendonca M, Wolke D. Preterm birth/low birth weight and markers reflective of wealth in adulthood: a meta-analysis. *Pediatrics*. 2018;142(1):e20173625 29875181
9. Kajantie E, Strang-Karlsson S, Evensen KAI, Haaramo P. Adult outcomes of being born late preterm or early term - what do we know? *Semin Fetal Neonatal Med*. 2019;24(1):66–83 30420114
10. Bilsteen JF, Taylor-Robinson D, Børch K, Strandberg-Larsen K, Nybo Andersen AM. Gestational age and socioeconomic achievements in young adulthood: a Danish population-based study. *JAMA Netw Open*. 2018;1(8):e186085 30646301
11. Lindström K, Winbladh B, Haglund B, Hjern A. Preterm infants as young adults: a Swedish national cohort study. *Pediatrics*. 2007;120(1):70–77 17606563
12. Moster D, Lie RT, Markestad T. Long-term medical and social consequences of preterm birth. *N Engl J Med*. 2008;359(3): 262–273 18635431
13. Olofsson J, Wadensjö E. *Youth, Education and Labour Market in the Nordic Countries*. Berlin: Friedrich-Ebert-Stiftung, International; 2012
14. Wilder S. Effects of parental involvement on academic achievement: a meta-synthesis. *Educational Review*. 2014;66(3): 377–397
15. Ramsdal G, Bergvik S, Wynn R. Parent-child attachment, academic performance and the process of high-school dropout: a narrative review. *Attach Hum Dev*. 2015;17(5):522–545 26245192
16. Strenze T. Intelligence and socioeconomic success: a meta-analytic review of longitudinal research. *Intelligence*. 2007;35(5): 401–426
17. Nomura Y, Halperin JM, Newcorn JH, et al. The risk for impaired learning-related abilities in childhood and educational attainment among adults born near-term. *J Pediatr Psychol*. 2009; 34(4):406–418 18794190
18. Richards JL, Chapple-McGruder T, Williams BL, Kramer MR. Does neighborhood deprivation modify the effect of preterm birth on children's first grade academic performance? *Soc Sci Med*. 2015;132:122–131 25797101
19. Wang WL, Sung YT, Sung FC, Lu TH, Kuo SC, Li CY. Low birth weight, prematurity, and paternal social status: impact on the basic competence test in Taiwanese adolescents. *J Pediatr*. 2008;153(3): 333–338 18534212
20. Gisselmann M, Koupil I, De Stavola BL. The combined influence of parental education and preterm birth on school performance. *J Epidemiol Community Health*. 2011;65(9):764–769 20508005
21. Ekeus C, Lindström K, Lindblad F, Rasmussen F, Hjern A. Preterm birth, social disadvantage, and cognitive competence in Swedish 18- to 19-year-old men. *Pediatrics*. 2010;125(1). Available at: www.pediatrics.org/cgi/content/full/125/1/e67 19969613
22. Beauregard JL, Drews-Botsch C, Sales JM, Flanders WD, Kramer MR. Does socioeconomic status modify the association between preterm birth and children's early cognitive ability and kindergarten academic achievement in the United States? *Am J Epidemiol*. 2018;187(8): 1704–1713 29757345
23. Beauregard JL, Drews-Botsch C, Sales JM, Flanders WD, Kramer MR. Preterm birth, poverty, and cognitive development. *Pediatrics*. 2018;141(1):e20170509 29242268
24. Brown HK, Speechley KN, Macnab J, Natale R, Campbell MK. Mild prematurity, proximal social processes, and development. *Pediatrics*. 2014;134(3). Available at: www.pediatrics.org/cgi/content/full/134/3/e814 25113289
25. Langhoff-Roos J, Krebs L, Klungsøyr K, et al. The Nordic medical birth registers–a potential goldmine for clinical research. *Acta Obstet Gynecol Scand*. 2014;93(2):132–137 24237585
26. Alexander GR, Himes JH, Kaufman RB, Mor J, Kogan M. A United States national reference for fetal growth. *Obstet Gynecol*. 1996;87(2):163–168 8559516
27. Skalkidou A, Kullinger M, Georgakis MK, Kieler H, Kesmodel US. Systematic misclassification of gestational age by ultrasound biometry: implications for clinical practice and research methodology in the Nordic countries. *Acta Obstet Gynecol Scand*. 2018;97(4): 440–444 29352467
28. Jørgensen FS. Epidemiological studies of obstetric ultrasound examinations in Denmark 1989-1990 versus 1994-1995. *Acta Obstet Gynecol Scand*. 1999;78(4): 305–309 10203297
29. Liu X, Olsen J, Agerbo E, et al. Birth weight, gestational age, fetal growth and childhood asthma hospitalization. *Allergy Asthma Clin Immunol*. 2014;10(1):13 24602245
30. Sipola-Leppänen M, Vääräsmäki M, Tikanmäki M, et al. Cardiovascular risk factors in adolescents born preterm. *Pediatrics*. 2014;134(4). Available at: www.pediatrics.org/cgi/content/full/134/4/e1072 25180275
31. Helsedata. Variabler Documentation of the variables in the Norwegian Medical Birth Register] Available at: http://

helsedata.no/no/variabler/. Accessed February 8, 2021

32. UNESCO Institute for Statistics. International Standard Classification of Education: ISCED 2011. Available at: http://uis.unesco.org/sites/default/files/documents/international-standard-classification-of-education-isced-2011-en.pdf. Accessed March 17, 2017
33. Jensen VM, Rasmussen AW. Danish education registers. *Scand J Public Health.* 2011;39(7, suppl):91–94 21775362
34. Official Statistics of Finland. Educational structure of population [e-publication]. Available at: www.stat.fi/til/vkour/meta_en.html. Accessed February 6, 2021
35. Statistics Norway. National education database. Available at: https://www.ssb.no/en/omssb/tjenester-og-verktoy/data-til-forskning/utdanning/om-nasjonal-utdanningsdatabase. Accessed February 6, 2021
36. Ludvigsson JF, Svedberg P, Olén O, Bruze G, Neovius M. The longitudinal integrated database for health insurance and labour market studies (LISA) and its use in medical research. *Eur J Epidemiol.* 2019;34(4):423–437 30929112
37. Finnish Institute for Health and Welfare. Register of congenital malformations - THL. Available at: https://thl.fi/en/web/thlfi-en/statistics-and-data/data-and-services/register-descriptions/register-of-congenital-malformations. Accessed November 16, 2021
38. Lynge E, Sandegaard JL, Rebolj M. The Danish national patient register. *Scand J Public Health.* 2011;39(7, suppl):30–33 21775347
39. Van Der Wel KA, Östergren O, Lundberg O, et al. A gold mine, but still no Klondike: Nordic register data in health inequalities research. *Scand J Public Health.* 2019;47(6):618–630 31291822
40. Harrell J. General aspects of fitting regression models In: *Regression Modeling Strategies: With Applications to Linear Models, Logistic and Ordinal Regression, and Survival Analysis.* 2nd ed. Cham: Springer International Publishing; 2015
41. Knol MJ, VanderWeele TJ, Groenwold RH, Klungel OH, Rovers MM, Grobbee DE. Estimating measures of interaction on an additive scale for preventive exposures. *Eur J Epidemiol.* 2011;26(6):433–438 21344323
42. Field CA, Welsh AH. Bootstrapping clustered data. *J R Stat Soc Series B Stat Methodol.* 2007;69(3):369–390
43. Højsgaard S, Ulrich H, Yan J. The R package geepack for generalized estimating equations. *J Stat Softw.* 2005;15(1):1–11
44. Lüdecke D. ggeffects: tidy data frames of marginal effects from regression models. *J Open Source Softw.* 2018;3(26):772
45. Chan E, Leong P, Malouf R, Quigley MA. Long-term cognitive and school outcomes of late-preterm and early-term births: a systematic review. *Child Care Health Dev.* 2016;42(3):297–312 26860873
46. Dong Y, Chen SJ, Yu JL. A systematic review and meta-analysis of long-term development of early term infants. *Neonatology.* 2012;102(3):212–221 22814228
47. Gill JV, Boyle EM. Outcomes of infants born near term. *Arch Dis Child.* 2017;102(2):194–198 27543506
48. Yang H, Kramer MS, Platt RW, et al. How does early ultrasound scan estimation of gestational age lead to higher rates of preterm birth? *Am J Obstet Gynecol.* 2002;186(3):433–437 11904603
49. Crump C, Sundquist K, Winkleby MA, Sundquist J. Early-term birth (37-38 weeks) and mortality in young adulthood. *Epidemiology.* 2013;24(2):270–276 23337240
50. Kugelman A, Colin AA. Late preterm infants: near term but still in a critical developmental time period. *Pediatrics.* 2013;132(4):741–751 24062372
51. Lindström K, Lindblad F, Hjern A. Psychiatric morbidity in adolescents and young adults born preterm: a Swedish national cohort study. *Pediatrics.* 2009;123(1). Available at: www.pediatrics.org/cgi/content/full/123/1/e47 19117846
52. Anvik CH, Gustavsen A. Ikke slip meg! Unge psykiske helseprobblemer utdanning og arbeid (Don't let go of me! Young people, mental health issues, education and work). Available at: https://nforsk.brage.unit.no/nforsk-xmlui/bitstream/handle/11250/2728517/Rapport_13_2012.pdf?sequence=1&isAllowed=y. Accessed November 16, 2021
53. Tagstrom J, Olsen T. *Nordic Projects to Combat School Dropout: Good Practice in Helping Young People Complete Upper Secondary Education.* Stockholm, Sweden: Nordic Welfare Centre, 2016
54. Lorenz JM, Wooliever DE, Jetton JR, Paneth N. A quantitative review of mortality and developmental disability in extremely premature newborns. *Arch Pediatr Adolesc Med.* 1998;152(5):425–435 9605024
55. Stoll BJ, Hansen NI, Bell EF, et al; Eunice Kennedy Shriver National Institute of Child Health and Human Development Neonatal Research Network. Trends in care practices, morbidity, and mortality of extremely preterm neonates, 1993-2012. *JAMA.* 2015;314(10):1039–1051 26348753
56. Cheong JL, Spittle AJ, Burnett AC, Anderson PJ, Doyle LW. Have outcomes following extremely preterm birth improved over time? *Semin Fetal Neonatal Med.* 2020;25(3):101114 32451304
57. Marlow N, Ni Y, Lancaster R, et al. No change in neurodevelopment at 11 years after extremely preterm birth. *Arch Dis Child Fetal Neonatal Ed.* 2021;106(4):418–424 33504573