

Gestational Age, Parent Education, and Education in Adulthood

Josephine Funck Bilsteen, PhD,^{a,b} Suvi Alenius, MD,^{c,d} Magne Bråthen, PhD,^e Klaus Børch, PhD,^a Claus Thorn Ekstrøm, PhD,^f Eero Kajantie, PhD,^{c,d,g,h} Mariam Lashkariani, BSc,ⁱ Markku Nurhonen, MSc,^c Kari Risnes, PhD,^{j,g} Sven Sandin, PhD,^{k,l,m,i} Kjetil A. van der Wel, PhD,^e Dieter Wolke, PhD,ⁿ Anne-Marie Nybo Andersen, PhD^b

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.

Full article can be found online at www.pediatrics.org/cgi/doi/10.1542/peds.2021-051959

^aDepartment of Paediatrics, Hvidovre University Hospital, Hvidovre, Denmark; ^bSection of Epidemiology, Department of Public Health, University of Copenhagen, Copenhagen, Denmark; ^cPopulation Health Unit, Finnish Institute for Health and Welfare, Helsinki, Finland; ^dChildren's Hospital, University of Helsinki and Helsinki University Hospital, Helsinki, Finland; ^eDepartment of Social Work, Child Welfare and Social Policy, Oslo Metropolitan University, Norway; ^fSection of Biostatistics, Department of Public Health, University of Copenhagen, Copenhagen, Denmark; ^gDepartment of Clinical and Molecular Medicine, Norwegian University of Science and Technology, Trondheim, Norway; ^hPEDEGO Research Unit, MRC Oulu, Oulu University Hospital and University of Oulu, Oulu, Finland; ⁱDepartment of Medical Epidemiology and Biostatistics, Karolinska Institutet, Stockholm, Sweden; ^jDepartment of Research, Innovation, and Education and Children's Clinic, St Olavs Hospital, Trondheim University Hospital, Trondheim, Norway; ^kJockey Club School of Public Health and Primary Care, The Chinese University of Hong Kong, Hong Kong Special Administrative Region, China; ^lDepartment of Psychiatry, Icahn School of Medicine at Mount Sinai, New York, New York; ^mSeaver Autism Center for Research and Treatment at Mount Sinai, New York, New York; and ⁿDepartment of Psychology and Centre of Early Life, University of Warwick, Coventry, United Kingdom

Ms Bilsteen conceptualized and designed the study and obtained access to part of the data and prepared it for analysis, analyzed and interpreted the data, and drafted the first version of the manuscript; Dr

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.

To cite: Bilsteen JF, Alenius S, Bråthen M, et al. Gestational Age, Parent Education, and Education in Adulthood. *Pediatrics*. 2022;149(1):e2021051959

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 al²⁶ (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 1986²⁷; 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

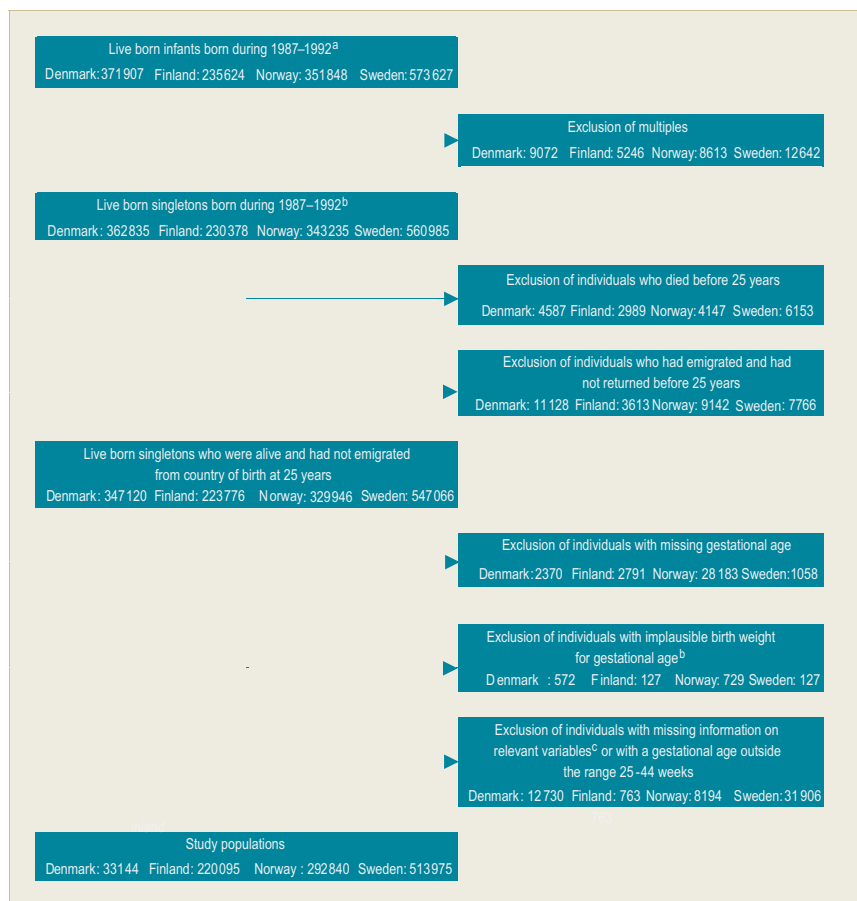


FIGURE 1

Flowchart for the Danish, Finnish, Norwegian, and Swedish populations. ^a Denmark and Norway 1987–1992; Finland 1987–1990; 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 Malformations³⁷ in Finland, and the National Patient Register³⁸ 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-Herzegovina, 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 splines⁴⁰ 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 approach⁴² 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 (<i>n</i> = 331 448), <i>n</i> (%) | Finland (<i>n</i> = 220 095), <i>n</i> (%) | Norway (<i>n</i> = 292 840), <i>n</i> (%) | Sweden (<i>n</i> = 512 975), <i>n</i> (%) |
|---------------------------------|---|---|--|--|
| 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) | 109 595 (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

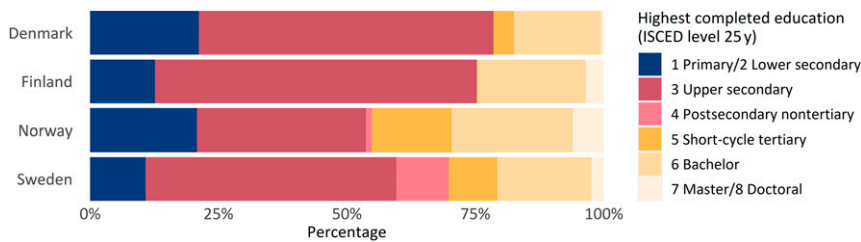


FIGURE 2
Educational level at 25 years according to ISCED in the Danish, Finnish, Norwegian, and Swedish study population.

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 combining 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

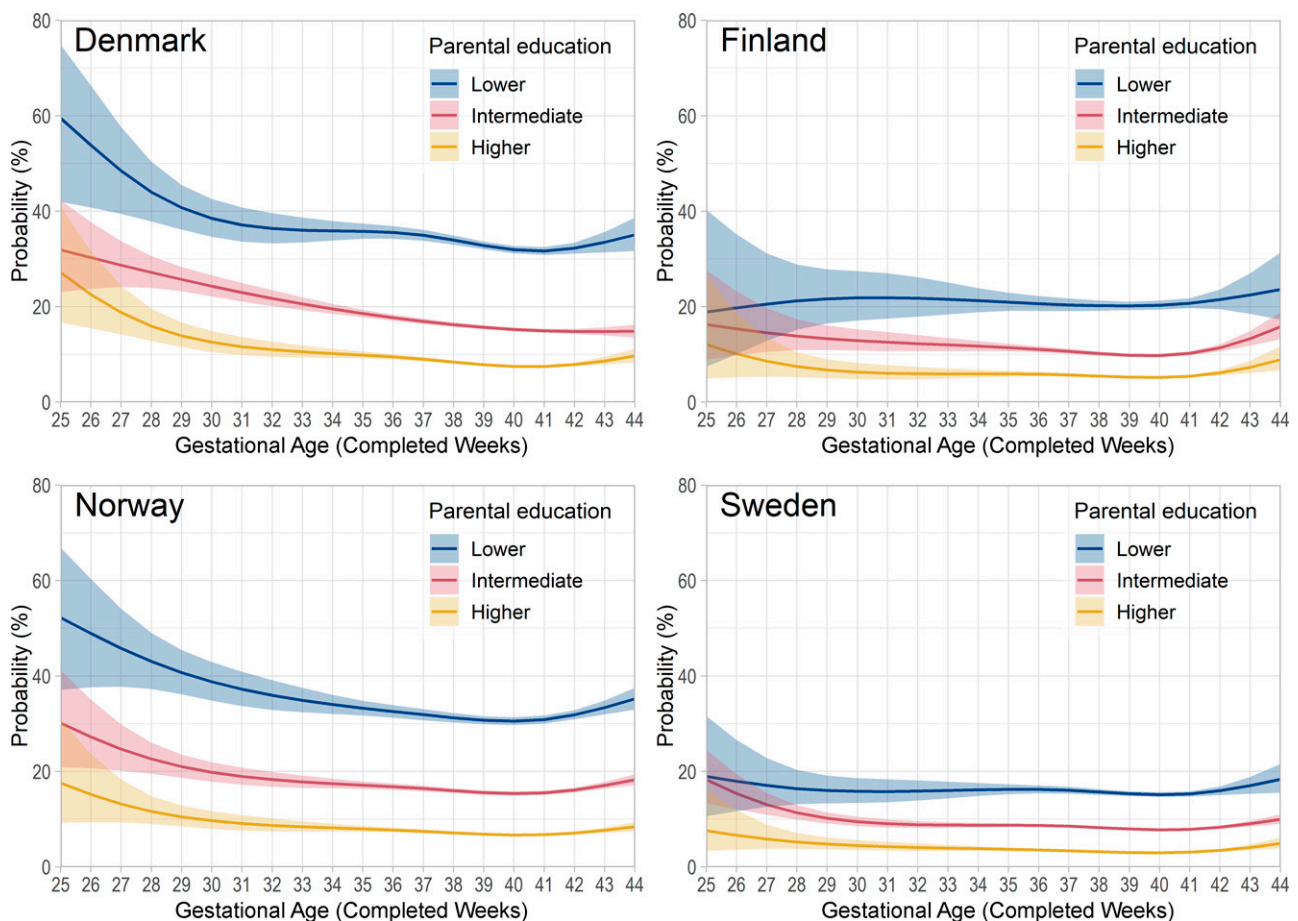


FIGURE 3
Probability of low educational attainment at 25 years according to gestational age and parental educational level by country. Estimates were adjusted for birth year, sex, congenital anomalies, parity, maternal age, and maternal country of birth and were obtained from models that included an 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

| Country, Gestational Age, wk | Parental Educational Level | | | | | | | | | |
|------------------------------|----------------------------|--------------|--------------|--------------|-------|----------------|------|--------------|-------|---------------|
| | High | | Intermediate | | | | Low | | | |
| | 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 exclusion⁵³ 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.

ACKNOWLEDGMENTS

The authors thank other RECAP preterm consortium members and particularly those involved in the research group working with the Nordic registers.

ABBREVIATIONS

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

Alenius designed the study and obtained access to part of the data and prepared it for analysis, interpreted the data, and reviewed and revised the manuscript critically for important intellectual content; Dr Bråthen designed the study, obtained access to part of the data and prepared it for data analysis, interpreted the data, and reviewed and revised the manuscript critically for important intellectual content; Drs Børch, Risnes, and Wolke designed the study, interpreted the data, and reviewed and revised the manuscript critically for important intellectual content; Dr Ekstrøm and Mr Nurhonen designed the study, analyzed and interpreted the data, and reviewed and revised the manuscript critically for important intellectual content; Drs Kajantie, Sandin, van der Wel, and Andersen designed the study, obtained access to data, interpreted the data, and reviewed and revised the manuscript critically for important intellectual content; Ms Lashkariani designed the study, obtained access to part of the data and prepared it for analysis, analyzed and interpreted the data, and reviewed and revised the manuscript critically for important intellectual content; and all authors approved the final manuscript as submitted and agree to be accountable for all aspects of the work.

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DOI: <https://doi.org/10.1542/peds.2021-051959>

Accepted for publication Sep 15, 2021

Address correspondence to Josephine Funck Bilsteen, MSc, Section of Epidemiology, Department of Public Health, University of Copenhagen, Copenhagen, Denmark, Øster Farimagsgade 5, 1014 København K. E-mail: jfb@sund.ku.dk

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

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

FUNDING: Supported by Research on European Children and Adults born Preterm (RECAP preterm). RECAP preterm has received funding from the European Union's Horizon 2020 research and innovation program under grant agreement 733280. In addition, the study was supported by Welfare state life courses: Social inequalities in the coevolution of employment, health and critical life events, which was supported by grant 75970 from the NordForsk program, Nordic Program on Health and Welfare: Nordic Register Pilots: Contingent Life Courses. Additionally, this study was supported by PREMLIFE Norface DIAL Programme award 462-16-040 PREMLIFE (Life Course Dynamics after Preterm Birth) Protective Factors for Social and Educational Transitions, Health, and Prosperity, Academy of Finland (grant 315690), Finnish Foundation for Pediatric Research, Novo Nordisk Foundation, Sigrid Jusélius Foundation.

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

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