American Journal of Epidemiology

Vol. 177, No. 7
DOI: 10.1093/aje/kws237
Advance Access publication:
March 6, 2013

Original Contribution

Is Later Better or Worse? Association of Advanced Parental Age With Offspring Cognitive Ability Among Half a Million Young Swedish Men

Mikko Myrskylä*, Karri Silventoinen, Per Tynelius, and Finn Rasmussen

* Correspondence to Dr. Mikko Myrskylä, Max Planck Research Group Lifecourse Dynamics and Demographic Change, Max Planck Institute for Demographic Research, Konrad-Zuse-Str 1, 18057 Rostock, Germany (e-mail myrskyla@demogr.mpg.de).

Initially submitted January 24, 2012; accepted for publication April 27, 2012.

Parental ages are increasing in the developed world, and postponed parenthood may have a negative association with the cognitive ability of offspring. There is, however, inconclusive evidence regarding the impact of both maternal and paternal ages. We have been able to reduce or eliminate unobserved confounding by using methods that account for fixed parental characteristics shared by brothers. Associations between parental age and intelligence quotient (IQ) among 565,433 Swedish males (birth cohorts 1951 to 1976) were analyzed, with IQ measured at conscription examinations (given between ages 17 and 20 years). When we accounted for the IQ time trend by adjusting for birth year, advanced paternal age showed no association with offspring IQ; however, maternal ages above 30 years were inversely associated with offspring IQ. For example, maternal ages 40–44 years were associated with an offspring IQ that was 0.07 standard deviations lower than that for maternal ages 25–29 years ($P < 0.001$). However, the IQ trend more than offset the impact of age, as without birth year adjustment, advanced maternal age was positively associated with IQ. Although the results confirmed that maternal age was negatively associated with offspring IQ, the association was small enough that delaying parenthood resulted in higher offspring IQ scores because of the positive IQ test score trend.

cognitive ability; intelligence; maternal age; paternal age

Abbreviations: IQ, intelligence quotient.

Postponement of parenthood has been an important demographic trend in many developed countries over the past several decades. In countries that are part of the Organization for Economic Co-operation and Development, the mean maternal age at first birth increased from 24 years in 1970 to 28 years in 2008 (1). The trend has been similar for paternal age (2). Thus, understanding how advancing parental age influences offspring outcomes is increasingly important. Accumulating evidence has suggested that advanced maternal and paternal ages are inversely associated with offspring health, and it has even been suggested that parental ages are important determinants of life expectancy (3). Parental ages may also influence offspring cognitive ability, or intelligence quotient (IQ) (4–7). This is important because cognitive ability is positively associated with adult health (8) and inversely associated with all-cause mortality (9, 10), cardiovascular diseases (11, 12), injuries (13), schizophrenia (14), and Alzheimer's disease (15).

Advanced parental age may adversely influence offspring IQ through age-related alterations in the intrauterine environment or in the gamete (4). Increasing maternal age is associated with pregnancy complications (16), accumulation of DNA damage in the germ cells (17), and a decrease in oocyte quality (18, 19), all of which may influence offspring development and IQ. Advanced paternal age may influence IQ through age-related accumulation of DNA damage and de novo mutations in the germ cells (2, 20). However, older parents tend to have greater economic and social resources, which may offset or even reverse the parental age-IQ association (3, 21). Although some researchers have reported positive associations between advanced maternal age and IQ (5, 6), the overall evidence is mixed. A study of Israeli military conscription data found negative associations between IQ and advanced maternal and paternal ages (4). Two recent studies on advanced paternal age, both using US data, reported negative (5) or flat (7) associations. The mixed results may be partially attributable to the prior studies using small samples or not controlling for unobserved parental characteristics.

Further, the secular trend in cognitive ability may influence the association between parental age and IQ. Over the past century, IQ scores measured in various birth cohorts have increased (22). In Sweden, adult IQ scores increased by approximately 1 standard deviation between the 1909 and 1969 cohorts (23). This upward trend may be driven by improved early life nutrition, lower morbidity from infectious and other diseases, or better socioeconomic circumstances, including education, although it has also been suggested that the trend reflects better knowledge of how to conduct IQ tests rather than a true increase in cognitive ability (24). Nevertheless, the time trend may influence the parental age-IQ association by offsetting the impact of parental age.

MATERIALS AND METHODS

Data

We analyzed data from the nationwide Swedish Military Service Conscription Register for the years 1969–1993, which included men born in 1951–1976 (25) (Web Appendix 1, available at http://aje.oxfordjournals.org/). Conscription examinations were compulsory by law for all men with Swedish citizenship; only those with severe disabilities documented by physician-written certificates were exempted. The examinations were administered in 6 centers across Sweden, and most men attended a conscription examination between the ages of 17 and 20 years. To keep the sample age-homogenous, men less than 17 years of age or more than 20 years of age at conscription were excluded (2% of the conscripts). The Swedish Military Service Conscription Register was linked to the Swedish Multi-Generation Register, which we used to identify the participants' biological parents (and their ages at the participants' births), birth order, and number of biological siblings. Fixed-effects regression models, which identify the parental age-IQ association from variation between brothers, were used (26). Therefore, in the maternal age analysis, we excluded participants who did not have a brother by the same mother within the study timeframe, and we did the same for participants with no brothers by the same father in the paternal age analysis. The resulting sample sizes for the maternal and paternal age analyses were 561,116 and 565,433, respectively.

Cognitive ability

The cognitive ability test, also referred to as the IQ test, consisted of 4 subtests that measured logical, spatial, verbal, and technical abilities. Each subtest was first evaluated on a normalized 9-point (stanine) scale. The subtest scores were summed to obtain an overall score and transformed onto a stanine scale with a mean of 5 and a standard deviation of 2. This IQ test measured general cognitive ability with high validity (27). The IQ test was unchanged between 1969 and 1980, when a subtest of synonyms replaced the earlier subtest of concept discrimination and a subtest of metal folding was chosen to improve assessment of spatial ability (28). The 1980 change does not compromise our results because: 1) the test scores changed minimally (25), 2) we controlled for birth year and age at conscription to account for testing year, and 3) direct adjustment for conscription year did not change the results (Web Appendix 2).

Other variables

We categorized participants by parental age in 5-year increments, from 15–19 years to 45–49 years, with an additional group of 50–69 years for fathers only. We used the group that was 25–29 years of age as the reference because this was the most common age range. We adjusted for birth year (1951 was the reference year and the others were indicator variables), birth order (1 was the reference and 2 through ≥10 were indicator variables), conscription age (continuous), and conscription center (indicator variables) because these variables are not shared by brothers and may be associated with cognitive ability. The IQ scores increased with increasing year of birth (22) and declined with birth order (29); younger age was associated with lower scores, and though the test did not vary, there may have been testing center differences.

Statistical analyses

We used linear regression models to study the association between parental age and IQ. Our first model documented the nonadjusted parental age-IQ association. The second model introduced controls for parent fixed effects, birth order, conscription age, and conscription center. The third model added a control for birth year. We estimated the models separately for maternal and paternal age. For maternal age, the model equations were:

$$\mathrm{IQ}_{ij} = \alpha + \beta_1 \mathrm{MatAge}_{ij} + \varepsilon_{ij}, \quad (1)$$

$$\mathrm{IQ}_{ij} = \alpha_j + \beta_1 \mathrm{MatAge}_{ij} + \beta_2 \mathrm{BirthOrder}_{ij} + \beta_3 \mathrm{ConscrAge}_{ij} + \beta_3 \mathrm{ConscrCenter}_{ij} + \varepsilon_{ij}, \quad (2)$$

and

$$\mathrm{IQ}_{ij} = \alpha_j + \beta_1 \mathrm{MatAge}_{ij} + \beta_2 \mathrm{BirthOrder}_{ij} + \beta_3 \mathrm{ConscrAge}_{ij} + \beta_3 \mathrm{ConscrCenter}_{ij} + \beta_4 \mathrm{BY}_{ij} + \varepsilon_{ij}. \quad (3)$$

Here, IQ_{ij} is the IQ score of individual i born to mother j; α_j is the mother fixed effect; MatAge_{ij} is maternal age; and $\mathrm{BirthOrder}_{ij}$ $\mathrm{ConscrAge}_{ij}$ $\mathrm{ConscrCenter}_{ij}$ and BY_{ij} are $\mathrm{BirthOrder}_{ij}$, conscription age, conscription center, and birth year, respectively. For paternal age, an analogous set of models was estimated, with the differences that the index j refers to the father and MatAge_{ij} is replaced by paternal age, or

$PatAge_{ij}$. The coefficient β_1 is the key parameter that describes the association between IQ and maternal or paternal age.

Model 1 gives the unadjusted maternal or paternal age-IQ associations. Model 2 controls for birth order, conscription age, conscription center, and most importantly, unobserved parental characteristics shared by brothers, which is a key innovation in this study. The model compares brothers with either the same mother or father (or both) and removes the confounding influences of all fixed observed and unobserved genetic and social characteristics shared by brothers (26). For example, the model controlled for parental educational level, socioeconomic status, IQ, and personality, to the extent that they do not vary between brothers. Factors that varied over time (e.g., financial resources, health) were not captured by the model. Consequently, the parental age coefficient represented the total impact of all factors, including biological aging, other factors that vary over time (e.g., financial resources), and changing environmental conditions.

Model 3 adds controls for the population-level IQ trend by including a birth year control. This allows us to estimate impact of parental age after accounting for the effect of the IQ trend (22). All models accounted for clustering of brothers within a parent and were estimated using Stata/SE, version 11.2 (StataCorp LLP, College Station, Texas). The results are presented using standardized regression coefficients that are fractions of the standard deviation of IQ.

RESULTS

Descriptive analyses

The most common parental age group was 25–29 years (33.2% for maternal age, presented in Table 1; 33.8% for paternal age, presented in Table 2). Offspring birth year ranged from 1951 to 1976 in all parental age categories. The mean IQ test score was 5.1, with IQ showing inverted U-shaped associations with maternal and paternal ages; individuals born to mothers or fathers aged 25–34 years scored higher, whereas those born to younger or older parents scored lower. Mean age at conscription was 18.3 years, decreasing slightly to 18.2 years for maternal ages above 40 years and paternal ages above 45 years. Mean birth order was on average 2.1, and it increased with parental age. The mean number of brothers was 1.4 (range, 1–8).

The decline in IQ with advanced parental age suggests a negative association between these variables. However, birth order increased and conscription age decreased with parental age, and both are associated with IQ score. These factors highlight the importance of accounting for nonshared variables, as well as for parental fixed effects.

Regression analyses

Figure 1 shows the association between parental age and offspring IQ in regression models 1–3; for numerical values of the coefficients, including those of the control variables, see the Web Appendix 2. The coefficients are standardized to express IQ changes as standard deviations per unit increases in parental age (e.g., a parental age

Table 1. Descriptive Statistics of Conscripted Men by Maternal Age, Swedish Military Conscription Register, 1969–1993

Maternal Age, years	No. of Participants		Birth date, year[a]	IQ Score, Stanine Scale		Paternal Age, years		Conscription Age, years		Birth Order		No. Brothers	
	Total No.	%	Mean (SD)	Mean (SD)	Range	Mean (SD)	Range	Mean (SD)	Range	Mean (SD)	Range	Mean (SD)	Range
All	561,116	100.0	1963.5 (6.78)	5.12 (1.95)	1–9	30.1 (6.43)	15.1–69.8	18.3 (0.46)	17.0–20.0	2.15 (1.30)	1–16	1.39 (0.59)	1–8
15–19	48,646	8.7	1961.8*** (6.00)	4.64*** (1.83)	1–9	22.9*** (3.62)	15.1–64.5	18.3 (0.48)	17.0–20.0	1.14*** (0.40)	1–5	1.38** (0.57)	1–7
20–24	180,549	32.2	1962.7*** (6.69)	5.00*** (1.91)	1–9	26.3*** (3.94)	16.3–66.8	18.3 (0.47)	17.0–20.0	1.65*** (0.75)	1–7	1.37 (0.56)	1–7
25–29	186,185	33.2	1963.7 (7.01)	5.33 (1.96)	1–9	30.4 (4.24)	17.4–68.9	18.3 (0.46)	17.0–20.0	2.14 (1.02)	1–11	1.37 (0.56)	1–8
30–34	97,972	17.5	1963.8* (6.83)	5.27*** (1.96)	1–9	34.9*** (4.72)	17.7–69.8	18.3 (0.46)	17.0–20.0	2.84*** (1.30)	1–14	1.41*** (0.62)	1–8
35–39	38,723	6.9	1963.9** (6.40)	5.10*** (1.97)	1–9	39.5*** (5.16)	19.2–69.8	18.3 (0.45)	17.0–20.0	3.62*** (1.70)	1–15	1.44*** (0.68)	1–8
40–44	8,570	1.5	1964.1*** (6.11)	4.92*** (1.98)	1–9	43.7*** (5.50)	21.0–68.6	18.2*** (0.44)	17.1–20.0	4.53*** (2.17)	1–16	1.48*** (0.73)	1–8
45–49	471	0.1	1964.4*** (5.85)	4.71*** (2.00)	1–9	47.6*** (5.22)	30.3–61.6	18.2** (0.42)	17.1–19.9	5.52*** (2.60)	2–14	1.50*** (0.75)	1–6

Abbreviations: IQ, intelligence quotient; SD, standard deviation.

* $P < 0.05$, ** $P < 0.01$, *** $P < 0.001$ for the difference in means between the maternal age group under consideration and the age group 25–29 years.

[a] Values are expressed as the mean birth year.

Table 2. Descriptive Statistics of Conscripts by Paternal Age, Swedish Military Conscription Register, 1969–1993

Paternal Age, years	No. of Participants		Birth date, years[a]	IQ Score, Stanine Scale		Maternal Age, years		Conscription Age, years		Birth Order		No. Brothers	
	Total No.	%	Mean (SD)	Mean (SD)	Range	Mean (SD)	Range	Mean (SD)	Range	Mean (SD)	Range	Mean (SD)	Range
All	565,433	100.0	1962.7 (6.78)	5.13 (1.94)	1–9	26.8 (5.46)	15–49.9	18.3 (0.46)	17–20	2.14 (1.29)	1–16	1.40 (0.60)	1–8
15–19	11,085	2.0	1960.9*** (5.72)	4.64*** (1.79)	1–9	18.9*** (2.01)	15–37.3	18.3 (0.49)	17.1–20	1.10*** (0.34)	1–5	1.38* (0.58)	1–7
20–24	112,676	19.9	1962.1*** (6.49)	4.92*** (1.88)	1–9	21.6*** (2.64)	15–43.2	18.3 (0.47)	17–20	1.42*** (0.65)	1–12	1.37 (0.56)	1–7
25–29	191,345	33.8	1963.0 (7.00)	5.26 (1.94)	1–9	25.2 (3.13)	15–44.9	18.3 (0.46)	17–20	1.84 (0.88)	1–13	1.37 (0.56)	1–8
30–34	136,588	24.2	1962.8** (6.94)	5.27*** (1.96)	1–9	28.6*** (3.70)	15.5–46.9	18.3 (0.46)	17–20	2.35*** (1.12)	1–12	1.40*** (0.60)	1–8
35–39	69,824	12.3	1962.7*** (6.59)	5.16*** (1.96)	1–9	31.8*** (4.30)	15.6–47	18.3 (0.46)	17–20	2.84*** (1.43)	1–14	1.46*** (0.66)	1–8
40–44	30,245	5.3	1962.9* (6.43)	5.03*** (1.98)	1–9	34.5*** (4.85)	15.2–48	18.3 (0.45)	17–20	3.43*** (1.80)	1–16	1.48*** (0.69)	1–8
45–49	10,025	1.8	1963.1 (6.46)	4.96*** (1.98)	1–9	35.9*** (5.34)	16.8–48.2	18.2** (0.45)	17.1–20	3.74*** (2.11)	1–15	1.51*** (0.72)	1–7
50–69	3,645	0.6	1963.3* (6.57)	4.85*** (2.02)	1–9	36.5*** (5.75)	15.6–49.9	18.2** (0.45)	17–20	4.02*** (2.37)	1–15	1.50*** (0.72)	1–6

Abbreviations: IQ, intelligence quotient; SD, standard deviation.

* $P < 0.05$, ** $P < 0.01$, *** $P < 0.001$ for the difference in means between the paternal age group under consideration and the age group 25–29.

[a] Values are expressed as the mean birth year.

increase from 25–29 years to 30–34 years). Each model provides a different insight.

Model 1 reports unadjusted parental age-IQ associations with ages 25–29 years as reference. Individuals born to mothers aged 25–29 years (Figure 1 A) or to fathers aged 30–34 years (Figure 1 B) scored highest on the IQ test, wheras those born to younger or older parents scored significantly lower. For example, maternal and paternal ages of 40–44 years were associated with IQ scores that were 0.19 ($P < 0.001$) and 0.10 ($P < 0.001$) standard deviations lower, respectively, than those for maternal and paternal ages of 25–29 years.

Model 2 included controls for birth order, conscription age, conscription center, and maternal (Figure 1 A) or paternal (Figure 1 B) fixed effects. The results, which represent the combined impact of parental age and the IQ time trend after controlling for confounding factors shared by the brothers, were in striking contrast to those from model 1; in model 2, offspring IQ was positively and monotonically associated with the ages of both mothers and fathers. For example, maternal and paternal ages of 40–44 years were associated with IQ scores that were 0.06 ($P < 0.001$) and 0.07 ($P < 0.001$) standard deviations higher, respectively, than those for parental ages of 25–29 years. The negative association between advanced parental age and IQ in model 1 was confounded by parental characteristics shared by brothers and by birth order. Young parental age remained negatively associated with IQ in model 2.

In model 3, the population-level IQ trend was accounted for by using birth year controls. Again, the associations changed; advanced maternal age was associated with a lower IQ. For example, maternal ages of 40–44 years were associated with IQ scores that were 0.07 ($P < 0.001$) standard deviations lower than those for maternal ages of 25–29 years. The associations were not significant for advanced paternal age. Thus, the positive association between advanced parental age and IQ in model 2 was driven by the IQ time trend. For any particular parent, children who were born later benefitted from the secular increase in IQ, and the secular trend more than offset the impact of individual parental aging. Therefore, later-born children tend to score higher on IQ tests, despite the maternal age influence revealed by model 3. Maternal and paternal ages below 20 years continued to be significantly associated with decreased IQ in model 3.

Sensitivity analyses

We subjected our key results, obtained from model 3, to various robustness checks (Web Appendix 2 provides full results). First, we controlled model 3 for the age of the parent not included in the original analysis. Although maternal and paternal ages were positively associated, the ages of both parents could be simultaneously included in the fixed-effects model because parental ages have been categorized and because not all brothers are full brothers. The key results did not change when we controlled for the parent who was not included in the original analysis.

Second, model 3 was estimated separately for large and small families (≥5 children vs. ≤4 children) to study

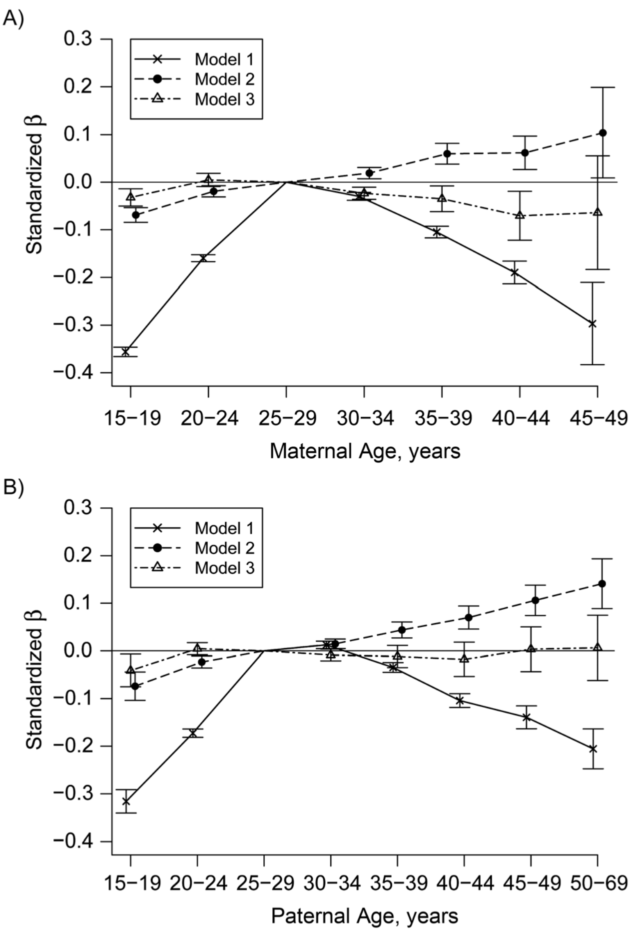

Figure 1. Cognitive ability at age 18 by maternal age (A; n = 561,116) and paternal age (B; n = 564,433) in Swedish men in the 1951–1976 birth cohorts of the Swedish Multi-Generation Register and Military Conscript Register. Cognitive ability (or intelligence quotient) was recorded at conscription using a 9-point scale; the coefficients were scaled to represent fractions of a standard deviation in the dependent variable. Model 1 is the unadjusted association between maternal or paternal age and IQ. Model 2 controls for social and genetic characteristics shared by brothers by adding fixed effects (indicators) for either the mother or father and for birth order, conscription age, and conscription center. Model 3 additionally controls for the intelligence quotient time trend using birth year indicators. The reference parental age group is 25–29 years. Bars, 95% confidence interval.

whether the results were driven by very large families. The statistical significance was markedly reduced for both subsamples, but the point estimates for advanced parental age were consistent with those obtained from the full sample.

Third, we considered alternative specification of the IQ time trend by adjusting for conscription year (indicator for each year) in model 3. Such control also takes into account any potential but unreported differences in testing practices. Fourth, we studied whether the inclusion of half-siblings influenced our results by repeating the analysis with half-siblings excluded (28,013 in the maternal age analysis and 32,251 in the paternal age analysis). Fifth, we studied whether the exclusion of participants conscripted before 17 years of age or after 20 years of age influenced our results by repeating our analyses with all eligible participants included. The sample sizes increased by 10,746 and 10,826 persons in the maternal and paternal age analyses, respectively. The key results remained virtually unchanged across all of these robustness checks.

DISCUSSION

We used a large Swedish data set to analyze the associations of men's IQs at 18 years of age with the ages of their biological parents at the time of birth. Prior studies have provided mixed evidence on the parental age-offspring IQ association (3–7), potentially because they were based on small samples or did not control for unobserved parental characteristics. Our results are based on an unprecedentedly large population-based data set that included more than 500,000 men and on methods that controlled for observed and unobserved parental characteristics shared by brothers. The results showed that after controlling for the time trend in IQ and for both observed and unobserved confounders, advanced paternal age was not associated with IQ but advanced maternal age was negatively associated. Future studies should focus on the mechanisms linking maternal age to offspring IQ. Candidate mechanisms include age-related deterioration of the ovum (4, 16–19) and postnatal factors, such as parenting behaviors or health of the mother, which may have a cost in terms of the development of the child.

The inverse impact of maternal age on offspring IQ was not large, but it was shown to be robust in our main and sensitivity analyses. The magnitude of the inverse maternal age association with offspring IQ was small enough to be counteracted by the positive population-level IQ trend that "lifted" individuals born to older mothers above the level that they would have achieved if, hypothetically, they had been born earlier to the same mothers when those mothers were younger. Thus, the positive population-level trend does more than offset individual-level negative effects. Delayed parenthood in the cohorts born in 1951–1976 gave rise to later-born children, who grew up in a better environment and who, despite the impact of maternal age, scored higher on IQ tests.

Although small, the magnitude of the parental age association is still important. The unadjusted IQ difference between maternal ages 25–29 years and 40–44 years was 0.19 standard deviations. In an earlier study using the same database, Batty et al. (10) showed that a 1-standard-deviation difference in IQ corresponded to a 32% increase in all-cause mortality during middle age. This suggests that the 0.19-standard-deviation difference in IQ according to maternal age results in increased mortality of approximately 6%. In terms of the traditional IQ scale, with a mean of 100 and a standard deviation of 15, the 0.19-standard-deviation difference corresponds to 3 points (30, 31). In the fully adjusted model, which removes the influence of the IQ time trend, the difference in IQ between maternal ages 25–29 years and 40–44 years was 0.07 standard deviations, corresponding to a 2% increase in mortality or a 1-point decrease on the traditional IQ scale. Although this is not a very strong association, its population-level importance should not be disregarded given the substantial increase in maternal age seen in most developed countries. Recognition of the need to disentangle the effect of maternal age on offspring IQ from the macro-level time trend in IQ test scores may also increase understanding of population variations in cognitive ability.

The reasons for and the potential continuation of the IQ trend are not critical to the interpretation of our key finding, namely that after we controlled for the time trend, advanced paternal age had no effect on offspring cognitive ability but that maternal ages above 30 years were associated with a decrease in offspring IQ. IQ test results improved during the 20th century (22),but it is unclear whether this so-called "Flynn effect" represents a true increase in cognitive ability or just improved performance in IQ tests (24). Factors such as improved nutrition and better socioeconomic circumstances, including increased educational level and a decrease in disease exposure during childhood, might be interpreted as indications that true increases in cognitive ability are possible (23, 32, 33). Our key result concerns the parental age effect after the IQ time trend is taken into account. Thus, our conclusion that advancing maternal age is associated with a decrease in offspring cognitive ability is not sensitive to the origins or the potential continuation of the IQ time trend.

Our second finding is that, for the Swedish 1951–1976 birth cohorts, the positive trend in IQ more than offset the parental aging effect. This finding is related to the Flynn effect. In a different context, or in the future, the IQ trend may be different. Consequently, the total parental age effect, which combines individual and macro factors, would be different. In Sweden, when comparing a later-born cohort to earlier cohorts, IQ for the later-born cohorts has increased (23, 32). Anticipating the future of the Flynn effect is beyond the scope of this study, but it may be speculated that societies that are currently or will in the future be at a developmental level similar to that of Sweden from the early 1970s to the mid-1990s might exhibit a similar trend in IQ. Recent research, however, has suggested that in the late 1990s, the Flynn effect was reduced in Norway (33) and even reversed in Denmark (34), which makes us particularly cautious about speculating on the future trend.

Our study has 4 distinct strengths that enable resolution of much of the confusion in the prior literature on associations between parental age and offspring IQ. First, the data set is so large that most considerations of statistical significance are irrelevant, and we can therefore focus on the direction and magnitude of the association. The large sample size also helps overcome the problem of collinearity. Some of the covariates, particularly parental age and birth order, were strongly associated, and such collinearity might have resulted in unstable estimates in a smaller sample. Second, because military conscription was mandatory during the study period, the data are truly population-based and not prone to self-selection. Third, we used a statistical design in which fixed effects were included for the biological parents. This method removes the confounding influences of the time-invariant observed and unobserved genetic and social characteristics shared by brothers. For example, parenting skills and parental socioeconomic status, personality, and IQ are, to the extent that they do not vary between brothers, taken into account. Fourth, we separately studied the gross impact of advancing parental age (without removing the positive population-level IQ trend (22)) and the net effect (for which the IQ trend is removed). This distinction is important because for a particular parent, later-born children benefit from improving macro conditions.

Our study also has limitations. First, our sample included only men who had at least 1 brother; the associations may be different for women or for men who do not have brothers. Second, our design does not allow generalization to other countries or time periods. Third, although we controlled for factors shared by brothers and for several potential confounding factors that varied between pregnancies and brothers (including birth order, birth year, and conscription age), there are other nonshared factors, such as genetic differences (which are only 50% shared between full siblings), parental health, and financial resources, that could have influenced our results. Further studies should consider the importance of these factors. Fourth, although military conscription was mandatory during the study period, individuals with severe mental disabilities or severe chronic diseases were exempt from conscription. Thus, our results apply only to those who did not have such disabling conditions. Fifth, it is possible that there is heterogeneity in the associations. We focused on the population-averaged parental age-IQ associations. Some investigators have suggested that the Flynn effect is more pronounced at the lower end of the IQ distribution (35). Future studies should analyze heterogeneity in parental age-IQ associations.

Although it is known that intelligence scores are associated with environment (22), our findings place parental age effects into a new perspective and raise additional questions. Negative parental age impacts, such as those documented here for maternal age and IQ, have been found for many outcomes that are subject to positive time trends, including adult health and life expectancy (3, 36, 37). Because parenthood is being postponed, it becomes increasingly important to understand how advancing parental age influences offspring health and other outcomes. Prior research has overlooked the fact that at the individual level, advancing parental age entails that children are born at a later date, which may benefit those children. Future research might benefit from the design used in our study whenever there is an underlying time trend in the outcome variable of interest that might offset the putative causal influence of a particular exposure.

ACKNOWLEDGMENTS

Author affiliations: Max Planck Research Group Lifecourse Dynamics and Demographic Change, Max Planck Institute for Demographic Research, Rostock, Germany (Mikko Myrskylä); Department of Social Research, Population Research Unit, University of Helsinki, Helsinki, Finland (Karri Silventoinen); and Department of Public Health Sciences, Child and Adolescent Public Health

Epidemiology, Karolinska Institutet, Stockholm, Sweden (Per Tynelius, Finn Rasmussen).

Conflict of interest: none declared.

REFERENCES

1. Organization for Economic Co-operation and Development. *OECD Family Database*. Paris, France: OECD; 2011. (http://www.oecd.org/els/social/family/database). (Accessed June 10, 2011).
2. Bray I, Gunnell D, Davey Smith G. Advanced paternal age: how old is too old? *J Epidemiol Community Health*. 2006; 60(10):851–853.
3. Liu Y, Zhia M, Li X. Parental age and characteristics of the offspring. *Ageing Res Rev*. 2011;10(1):115–123.
4. Malaspina D, Reichenberg A, Weiser M, et al. Paternal age and intelligence: implications for age-related genomic changes in male germ cells. *Psychiatr Genet*. 2005;15(2): 117–125.
5. Saha S, Barnett AG, Foldi C, et al. Advanced paternal age is associated with impaired neurocognitive outcomes during infancy and childhood. *PLoS Med*. 2009;6(3):e1000040.
6. Zybert P, Stein Z, Belmont L. Maternal age and children's ability. *Percept Mot Skills*. 1978;47(3 I):815–818.
7. Edwards RD, Roff J. Negative effects of paternal age on children's neurocognitive outcomes can be explained by maternal education and number of siblings. *PLoS One*. 2010;5(9):e12157.
8. Batty G, Wennerstad K, Smith G, et al. IQ in early adulthood and later cancer risk: cohort study of one million Swedish men. *Ann Oncol*. 2007;18(1):21–28.
9. Hemmingsson T, Melin B, Allebeck P, et al. The association between cognitive ability measured at ages 18–20 and mortality during 30 years of follow-up—a prospective observational study among Swedish males born 1949–51. *Int J Epidemiol*. 2006;35(3):665–670.
10. Batty G, Wennerstad K, Smith G, et al. IQ in early adulthood and mortality by middle age: cohort study of 1 million Swedish men. *Epidemiology*. 2009;20(1):100–109.
11. Hemmingsson T, Essen J, Melin B, et al. The association between cognitive ability measured at ages 18–20 and coronary heart disease in middle age among men: a prospective study using the Swedish 1969 conscription cohort. *Soc Sci Med*. 2007;65(7):1410–1419.
12. Hart C, Taylor M, Smith G, et al. Childhood IQ and cardiovascular disease in adulthood: prospective observational study linking the Scottish Mental Survey 1932 and the Midspan studies. *Soc Sci Med*. 2004;59(10): 2131–2138.
13. Osler M, Andersen A, Laursen B, et al. Cognitive function in childhood and early adulthood and injuries later in life: the Metropolit 1953 male birth cohort. *Int J Epidemiol*. 2007; 36(1):212–219.
14. Gunnell D, Harrison G, Rasmussen F, et al. Associations between premorbid intellectual performance, early-life exposures and early-onset schizophrenia. Cohort study. *Br J Psychiatry*. 2002;181(4):298–305.
15. Snowdon D, Kemper S, Mortimer J, et al. Linguistic ability in early life and cognitive function and Alzheimer's disease in late life. Findings from the Nun Study. *JAMA*. 1996; 275(7):528–532.
16. Heffner LJ. Advanced maternal age — how old is too old? *N Engl J Med*. 2004;351(19):1927–1929.
17. Kaytor MD, Burright EN, Duvick LA, et al. Increased trinucleotide repeat instability with advanced maternal age. *Hum Mol Genet*. 1997;6(12):2135–2139.
18. Armstrong DT. Effects of maternal age on oocyte developmental competence. *Theriogenology*. 2001;55(6): 1303–1322.
19. Eichenlaub-Ritter U. Genetics of oocyte ageing. *Maturitas*. 1998;30(2):143–169.
20. Aitken RJ, Koopman P, Lewis SEM. Seeds of concern. *Nature*. 2004;432(7013):48–52.
21. Powell B, Steelman LC, Carini RM. Advancing age, advantaged youth: parental age and the transmission of resources to children. *Soc Forces*. 2006;84(3):1359–1390.
22. Flynn JR. Massive IQ gains in 14 nations: what IQ tests really measure. *Psychol Bull*. 1987;101(2):171–191.
23. Rönnlund M, Nilsson L-G. The magnitude, generality, and determinants of Flynn effects on forms of declarative memory and visuospatial ability: time-sequential analyses of data from a Swedish cohort study. *Intelligence*. 2008;36(3):192–209.
24. Flynn J. *What is Intelligence? Beyond the Flynn Effect*. New York, NY: Cambridge University Press; 2007.
25. Wennerstad K. *Intelligence and Cardiovascular Health: Epidemiological Studies of Swedish Men* [dissertation]. Stockholm, Sweden: Karolinska Institutet; 2010.
26. Wooldridge J. *Econometric Analysis of Cross Section and Panel Data*. 2nd ed. Cambridge, MA: MIT Press; 2010.
27. Carlstedt B, Mardberg B. Construct validity of the Swedish Enlistment Battery. *Scand J Psychol*. 1993;34(4):353–362.
28. Carlstedt B. *Cognitive Abilities – Aspect of Structure, Process and Measurement* [dissertation]. Gothenburg, Germany: University of Gothenburg; 2000.
29. Kristensen P, Bjerkedal T. Explaining the relation between birth order and intelligence. *Science*. 2007;316(5832):1717.
30. Ross A. The Output Capacity of Conscripts at Military Conscription Examinations in Sweden 1969–1979: History and Description of Conscription Examinations *[in Swedish]*. Pedagogiska rapporter no. 15.Umeå, Sweden: Umeå University; 1988.
31. David A, Malmberg A, Brandt L, et al. IQ and risk for schizophrenia: a population-based cohort study. *Psychol Med*. 1997;27(6):1311–1323.
32. Emanuelson I, Reuterberg S, Svensson A. Changing differences in Intelligence? Comparisons between groups of 13-year-olds tested from 1960 to 1990. *Scand J Educ Res*. 1993;37(4):259–277.
33. Sundet J, Barlaug D, Torjussen T. The end of the Flynn effect? A study of secular trends in mean intelligence test scores of Norwegian conscripts during half a century. *Intelligence*. 2004;32(4):349–362.
34. Teasdale TW, Owen DR. Secular declines in cognitive test scores: a reversal of the Flynn Effect. *Intelligence*. 2008; 36(2):121–126.
35. Colom R, Lluis-Font JM, Andres-Pueyo A. The generational intelligence gains are caused by decreasing variance in the lower half of the distribution: supporting evidence for the nutrition hypothesis. *Intelligence*. 2005;33(1):83–91.
36. Christensen K, Doblhammer G, Rau R, et al. Ageing populations: the challenges ahead. *Lancet*. 2009;374 (9696):1196–1208.
37. Oeppen J, Vaupel JW. Broken limits to life expectancy. *Science*. 2002;296(5570):1029–1031.