Personality and Individual Differences 149 (2019) 100–107

Contents lists available at ScienceDirect

Personality and Individual Differences

journal homepage: www.elsevier.com/locate/paid

The influence of familial factors on the association between IQ and educational and occupational achievement: A sibling approach

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ARTICLE INFO

Keywords:
Intelligence
Educational achievement
Occupational achievement
Family
Siblings
Denmark

ABSTRACT

The present register-based study investigated the influence of familial factors on the association of IQ with educational and occupational achievement among young men in Denmark. The study population comprised all men with at least one full brother where both the individual and his brothers were born from 1950 and appeared before a draft board in 1968–1984 and 1987–2015 (N = 364,193 individuals). Intelligence was measured by Børge Priens Prøve at age 18. Educational and occupational achievement were measured by grade point average (GPA) in lower secondary school, time to receiving social benefits at ages 18–30, and gross income at age 30. The statistical analyses comprised two distinct statistical analyses of the investigated associations: A conventional cohort analysis and a within-sibship analysis in which the association under investigation was analysed within siblings while keeping familial factors shared by siblings fixed. The results showed that an appreciable part of the associations of IQ with educational and occupational achievement could be attributed to familial factors shared by siblings. However, only the within sibling association between IQ and GPA in lower secondary school clearly differed from the association observed in the cohort analysis after covariates had been taken into account.

1. Introduction

Intelligence test scores have been shown to correlate positively with educational and occupational achievement in numerous observational studies (Gottfredson, 2003; Neisser et al., 1996; Strenze, 2007). The strongest correlations are typically found for educational achievement with correlation coefficients of 0.5–0.6 (Deary & Johnson, 2010; Roth et al., 2015; Strenze, 2007), followed by occupational level and income with correlation coefficients of 0.4–0.5 and 0.2–0.4, respectively (Gottfredson, 2003; Schmidt & Hunter, 2004; Strenze, 2007). However, because of the observational study designs, it cannot be ruled out that part of the observed associations between intelligence and educational and occupational achievement is explained by unmeasured familial factors operating in childhood. Some of these familial factors are possible to measure and to take into account in statistical analyses. For instance, parental socioeconomic position is often included as a confounder due to its association with offspring intelligence and educational and occupational achievement (Hegelund, Flensborg-Madsen, Dammeyer, & Mortensen, 2018). Other relevant factors, such as parental intelligence and parental psychiatric history, are not taken into account because information on these factors are not available. Additionally, unknown factors might also explain some of the observed associations.

Studies of twins and non-twin sibling pairs have shown that both shared genetic factors and shared environmental factors are in fact responsible for part of the observed associations between intelligence and educational and occupational achievement (Johnson, McGue, & Iacono, 2007; Lichtenstein & Pedersen, 1997; Rowe, Vesterdal, & Rodgers, 1998). However, the study findings' generalizability to the general population is uncertain because the study populations are restricted to samples of twins or samples of biological and adoptive sibling pairs. It is therefore an interesting question how much of the associations between intelligence and educational and occupational achievement can be attributed to familial factors operating in childhood in study populations that are more representative of the general population.

One way to investigate this is to compare the findings from statistical analyses based on the traditional cohort design and the sibling comparison design (Strully & Mishra, 2009). In the sibling comparison design, siblings with different intelligence test scores are compared whereby all factors shared by the siblings are matched out including

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https://doi.org/10.1016/j.paid.2019.05.045
Received 12 February 2019; Received in revised form 5 May 2019; Accepted 27 May 2019
Available online 04 June 2019
0191-8869/

both genetic and family environmental factors (Strully & Mishra, 2009). Thus, all familial factors shared by the siblings will be matched out by design, including factors that are unknown, unmeasured or measured with considerable measurement error. This is not to suggest that the observed associations in the sibling comparison design will be completely unconfounded, since this design only matches out factors that are shared by siblings. However, it might be a new and useful step towards understanding how much of the associations between intelligence and educational and occupational achievement can be attributed to familial factors operating in childhood because this study design includes all siblings in a sibship and therefore can be based on large representative samples of the general population.

The aim of this study was therefore to investigate the influence of familial factors shared by siblings on the association between IQ and educational and occupational achievement in young adulthood in a large cohort consisting of nearly 365,000 Danish siblings within > 170,000 sibships.

2. Materials and methods

2.1. Study population

A register-based cohort study was conducted including all Danish men with at least one full brother where both the individual and his brothers were born from 1950 and appeared before a draft board during the periods from 1968 to 1984 and from 1987 to 2015 (N = 364,193 individuals & 171,037 sibships). Men who appeared before a draft board in 1985–1986 were not included, because draft board information from these two years still have not been digitized.

It is compulsory for all male Danish citizens with residence in the country to appear before a draft board when they turn 18 years. However, if the men are undergoing education the draft board examination can be postponed until the end of the year in which they turn 25 years. At the draft board examination, it is determined whether each of the men are eligible, limitedly eligible or unfit for military service based on the results of an intelligence test and a medical examination. During the period from 1995 to 2015, the proportion of men who were classified as eligible, limitedly eligible or unfit for military service corresponded to 53%, 8% and 39%, respectively (The Defence Command, 2017). About half of the men who are classified as unfit for military service never come up before a draft board because their military service is cancelled due to documentation of existing health issues forwarded to the draft board (personal communication with Mogens Rosenlund Nielsen, the Danish Defence Personnel Organization). Further, men who volunteer for the military forces before the age of conscription do also not come up before a draft board, but this group only counts a few hundred in total.

According to Danish legislation, no ethics approval is needed for register-based studies. The present study is covered by permissions from the Danish Data Protection Agency to the authors.

2.2. Variables

2.2.1. Intelligence

The exposure of interest was intelligence, which was measured by Børge Priens Prøve (BPP) (Teasdale, 2009) when the study population came up before a draft board.

The BPP is a group-administered intelligence test in paper-and-pencil format, which consists of 78 items within the following domains: Letter Matrices, Verbal Analogies, Number Series and Geometric Figures. The intelligence test takes 45 min after which the number of correct answers is summed to a total score (range: 0–78). A previous study has found a correlation coefficient of 0.82 between the BPP and the full-scale Wechsler Adult Intelligence Scale (Mortensen, Reinisch, & Teasdale, 1989).

Information on intelligence test scores was available from four national conscription databases covering different periods of time: The Danish Conscription Database, the Danish National Archives' database, the Danish Defence Personnel Organization's database, and the Conscription Register. However, in the Danish National Archives' database the BPP total score has been recoded into 5 categories (Teasdale, 2009).

To make the results of this study easier to interpret, the BPP total score was converted to an IQ score with a mean of 100 and a standard deviation of 15. A detailed description of this procedure can be found in Hegelund et al. (2018).

2.2.2. Educational achievement

The first outcome of interest was the study population's educational achievement in young adulthood. Educational achievement was measured by grade point average (GPA) in lower secondary school at approximately 15 years of age. In Denmark, a 7-point grading scale ranging from 12 to −3 has been used since 2007. The Danish grading scale is directly comparable with the European Credit Transfer System grading scale ranging from A to F. GPAs obtained before the introduction of the 7-point grading scale has been converted to this scale using the conversion table from the Danish Ministry of Education (Ministry of Education, 2017). Information on grades in lower secondary school was available from Statistics Denmark's registers since the school year 2001/2002, for this reason the statistical analyses of the association between IQ and GPA in lower secondary school were based on a subsample of the study population including individuals who had left lower secondary school since 2002 (N = 93,458 individuals & 44,677 sibships).

2.2.3. Occupational achievement

The second outcome of interest was the study population's occupational achievement in young adulthood. Occupational achievement was measured by time to receiving social benefits (sickness benefits, welfare benefits and disability pension) at ages 18–30 and by gross income at age 30, respectively. Sickness benefits are granted to individuals who are unable to work due to sickness, but who have had some attachment to the labour market until the sick note. Welfare benefits are granted to individuals who are unable to provide for themselves and their families. Disability pensions are granted to individuals with a substantially and permanently reduced work capacity. Information on the two indicators of occupational achievement was available from the Danish Register for Evaluation of Marginalisation since 1991 and Statistics Denmark's registers since 1980, respectively. For this reason the statistical analyses of social benefits at ages 18–30 were based on a subsample of the study population including individuals born during the period from 1973 to 1986 (N = 108,855 individuals & 52,211 sibships), whereas the statistical analyses of gross income at age 30 were based on a subsample including individuals born during the period from 1950 to 1985 (N = 228,817 individuals & 108,552 sibships).

2.2.4. Covariates

Covariates included the study population's year of birth, ethnicity (Danish, non-Danish), birth region (Capital Region of Denmark, Region Zealand, North Denmark Region, Central Denmark Region, Region of Southern Denmark), binary indicators of out-of-home care in childhood, psychiatric diagnoses in childhood, neurological diagnoses in childhood, perinatal diagnoses and congenital deformities (see Supplementary Material 1 for the specific ICD codes), and parental socioeconomic position at birth measured by the highest completed education of either mother or father (low, medium-low, medium-high, high).

Year of birth was included due to the secular trends in IQ and educational and occupational achievement and ethnicity and birth region due to ethnic and geographical differences with regard to educational and occupational achievement in Denmark, respectively

Table 1
Characteristics of the study population (N = 364,193)[a].

	IQ score			Missing (N = 106,399)
	≤85 (N = 35,754)	86–115 (N = 181,709)	> 115 (N = 40,331)	
Year of birth				
Mean (SD)	1978 (15.4)	1979 (13.4)	1979 (13.5)	1974 (4.9)
Ethnicity, N (%)				
Danish	30,892 (86.4)	173,649 (95.6)	39,891 (98.9)	102,357 (96.2)
Non-Danish	4860 (13.6)	8059 (4.4)	440 (1.1)	4042 (3.8)
Missing	2 (–)	1 (–)	0 (–)	0 (–)
Birth region, N (%)				
Capital Region of Denmark	5758 (26.0)	31,696 (24.7)	7984 (27.4)	7201 (24.6)
Region Zealand	3396 (15.3)	16,867 (13.2)	3383 (11.6)	3640 (12.4)
North Denmark Region	2300 (10.4)	13,561 (10.6)	2903 (10.0)	3283 (11.2)
Central Denmark Region	4859 (21.9)	31,939 (24.9)	7738 (26.6)	7431 (25.3)
Region of Southern Denmark	5863 (26.4)	34,169 (26.7)	7112 (24.4)	7765 (26.5)
Missing	1319 (–)	2488 (–)	221 (–)	1344 (–)
Not available	12,259 (–)	50,989 (–)	10,990 (–)	75,735 (–)
Parental education at birth[b], N (%)				
Low	4900 (28.7)	11,941 (13.3)	1144 (5.5)	2632 (27.8)
Medium-low	9331 (54.7)	46,526 (51.7)	8286 (40.2)	4599 (48.5)
Medium-high	2361 (13.8)	23,973 (26.6)	7380 (35.8)	1704 (18.0)
High	478 (2.8)	7612 (8.5)	3825 (18.5)	549 (5.8)
Missing	1721 (–)	2761 (–)	207 (–)	802 (–)
Not available	16,963 (–)	88,896 (–)	19,489 (–)	96,113 (–)
Out-of-home care in childhood, N (%)				
Yes	1440 (6.5)	2504 (2.1)	179 (0.7)	1500 (7.4)
No	20,579 (93.5)	116,391 (97.9)	26,799 (99.3)	18,850 (92.6)
Not available	13,735 (–)	62,814 (–)	13,353 (–)	86,049 (–)
Psychiatric diagnoses in childhood, N (%)				
Yes	303 (1.4)	670 (0.6)	87 (0.3)	266 (1.3)
No	21,716 (98.6)	118,225 (99.4)	26,891 (99.7)	20,084 (98.7)
Not available	13,735 (–)	62,814 (–)	13,353 (–)	86,049 (–)
Neurological diagnoses in childhood, N (%)				
Yes	2444 (11.1)	9689 (8.2)	1745 (6.5)	1033 (5.1)
No	19,575 (88.9)	109,206 (91.9)	25,233 (93.5)	19,317 (94.9)
Not available	13,735 (–)	62,814 (–)	13,353 (–)	86,049 (–)
Perinatal diagnoses and congenital deformities, N (%)				
Yes	1727 (7.8)	7568 (6.4)	1400 (5.2)	1387 (6.8)
No	20,292 (92.2)	111,327 (93.6)	25,578 (94.8)	18,963 (93.2)
Not available	13,735 (–)	62,814 (–)	13,353 (–)	86,049 (–)
GPA in lower secondary school				
Mean (SD)	3.3 (1.7)	6.1 (2.1)	8.4 (1.8)	4.9 (2.6)
Missing, N	2999	2828	316	461
Not available, N	22,005	117,895	26,369	104,466
Social benefits at ages 18–30, N (%)				
Yes	3220 (51.1)	18,167 (34.1)	2691 (22.1)	15,555 (42.0)
No	3088 (49.0)	35,140 (65.9)	9513 (78.0)	21,481 (58.0)
Not available	29,446 (–)	128,402 (–)	28,127 (–)	69,363 (–)
Gross income at age 30				
Mean (SD)	296,020 (156,901)	336,636 (330,384)	361,746 (238,753)	337,146 (207,490)
Missing, N	311	1355	323	2093
Not available, N	18,751	89,066	19,662	9990

Abbreviations: GPA, grade point average.

[a] All characteristics differ statistically significantly according to the three categories of IQ scores ($p < 0.001$). Categorical variables were tested by use of χ^2 tests and continuous variables were tested by use of ANOVA tests.

[b] Parental education at birth is categorized as 'low' (primary education), 'medium-low' (upper secondary education, vocational education and training), 'medium-high' (short cycle higher education, vocational bachelor's programmes, bachelor's programmes), and 'high' (master's programmes, PhD programmes).

(Nørskov, Jarl, Thomsen, Sørensen, & Bilde, 2010; Teasdale & Owen, 1987; Teasdale, Owen, & Sørensen, 1988).

2.3. Statistical methods

Descriptive statistics were used to show the characteristics of the study population according to three categories of IQ. Tests for marginal associations between IQ and each of the characteristics were conducted – categorical variables were tested by means of χ^2 tests and continuous variables were tested by means of ANOVA tests.

The missing data frequency was < 3% for all variables, except for parental education at birth, GPA in lower secondary school and IQ for which the missing data frequency was 3.9%, 7.1% and 29.2%, respectively. However, the missing IQ data was mainly due to administrative circumstances because the Danish National Archives had recoded the BPP total scores into 5 categories and only stored this variable. To handle missing data, our statistical analyses were conducted using multiple imputation. This made it possible to include the large proportion of individuals with missing IQ or other missing data in our statistical analyses. A detailed description of the multiple imputation procedure can be found in Hegelund et al. (2018).

The main analyses comprised two distinct statistical analyses of all the investigated associations: A conventional cohort analysis and a within-sibship analysis in which the association under investigation was analysed within siblings while keeping familial factors shared by siblings fixed. The findings of the conventional cohort analysis and the

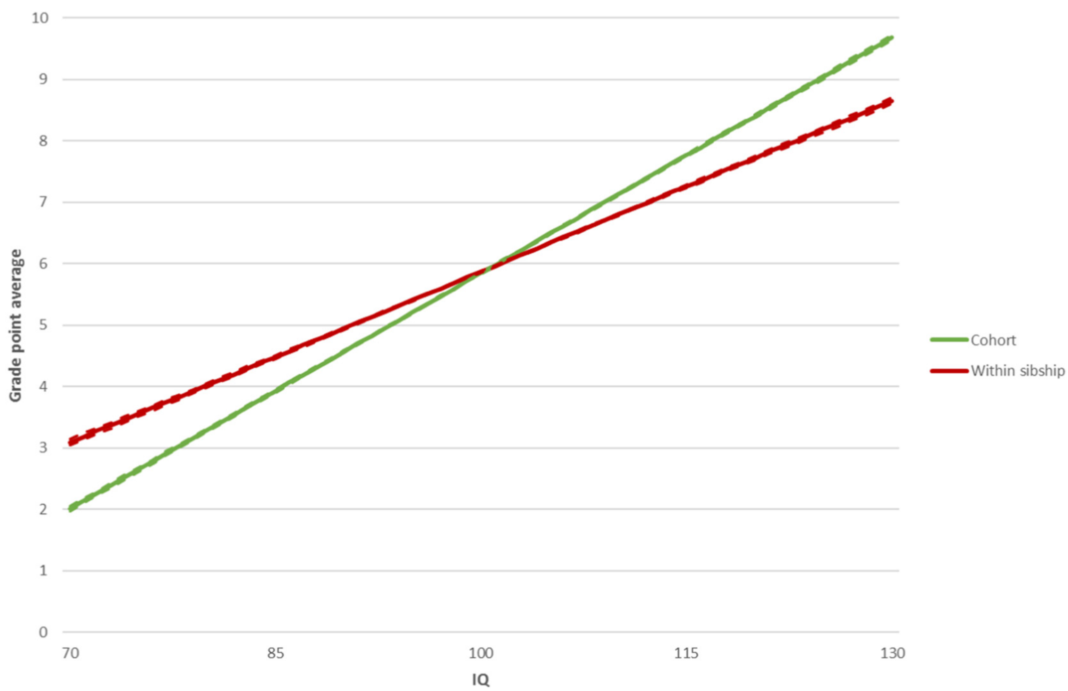

Fig. 1. Grade point average according to IQ.

within-sibship analysis were later compared by visual inspection of the confidence intervals to determine the importance of confounding from unmeasured familial factors operating in childhood.

With regard to the two continuous outcomes – 'GPA' and 'gross income' – the associations of IQ with educational and occupational achievement were analysed by means of general linear regression. To fulfil the assumptions of the general linear regression model, gross income was log transformed. In the conventional cohort analyses, the association under investigation was analysed in the usual way taking clustering of observations into account by correcting for intra-cluster dependency. In the within-sibship analyses, the association under investigation was analysed within siblings by including a sibling group ID variable as a fixed effect.

With regard to the time-to-event outcome – 'time to social benefits' – the association of IQ with occupational achievement was analysed by means of Cox regression with calendar time as the underlying time scale. Thus, the study population was followed from the date when they were first in employment, education or training after they had turned 18 years until the first registration of social benefits, attrition or the date of their 30th birthday, whichever came first. The hazard of social benefits was estimated by the product of the baseline hazard and the exponential function of a linear combination of the independent variables. In the conventional cohort analysis, the association was investigated in the usual way taking clustering of observations into account by correcting for intra-cluster dependency. In the within-sibship analysis, the association was investigated within siblings by including a sibling group ID variable as a stratum variable.

For all statistical analyses, we used an IQ of 100 as the reference and tested whether a linear, quadratic or cubic IQ term best described the association under consideration. On the basis of these tests, the associations of IQ with GPA in lower secondary school were presented by cubic IQ terms, the associations of IQ with social benefits at ages 18–30 were presented by a quadratic IQ term in the conventional cohort analysis and by a linear IQ term in the within-sibship analysis, while the associations of IQ with gross income at age 30 were presented by quadratic IQ terms. All statistical models were adjusted for year of birth (centred linear, quadratic or cubic term depending on the association under consideration), ethnicity, birth region, parental education at birth, out-of-home care in childhood, psychiatric diagnoses in childhood, neurological diagnoses in childhood, and perinatal diagnoses and congenital deformities. Relevant model assumptions were evaluated, but no violations were observed.

In sensitivity analyses, the statistical analyses were conducted among Danish men who were born since 1950 and appeared before a draft board during the periods from 1968 to 1984 and from 1987 to 2015, but who were not registered with at least one full brother – that is, among the individuals we had to exclude from our study population. This made it possible to determine whether our findings might be generalizable to males without male siblings. Further, our statistical analyses were conducted using non-imputed data on all available cases to investigate the robustness of the results.

All statistical analyses were carried out using STATA version 15.

3. Results

The characteristics of the 364,193 men comprising the study population are shown in Table 1. Individuals who differed in IQ score were found to differ with regard to all characteristics – thus, low IQ seemed to be associated with belonging to the older birth cohorts, non-Danish ethnicity, being born in Region Zealand or Region of Southern Denmark, parents with lower educational attainment, out-of-home care in childhood, psychiatric diagnoses in childhood, neurological diagnoses in childhood, perinatal diagnoses and congenital deformities as well as lower GPA in lower secondary school, social benefits at ages 18–30 and lower gross income at age 30. The far right column of Table 1 shows the characteristics of individuals with missing IQ scores, including individuals with BPP scores recoded into 5 categories.

Within the 171,037 sibships comprising the study population, the mean age difference between siblings was 3.9 years (standard deviation: 2.8), but the age difference ranged from 0 to 27 years. However, only 10% of the siblings in the study population were > 7 years apart in age from the other siblings in their sibship.

The crude analyses showed that an appreciable part of the associations between IQ and educational and occupational achievement could be attributed to familial factors shared by siblings (Figs. 1–3 & Supplementary Table 1). Thus, the associations of IQ with GPA in lower

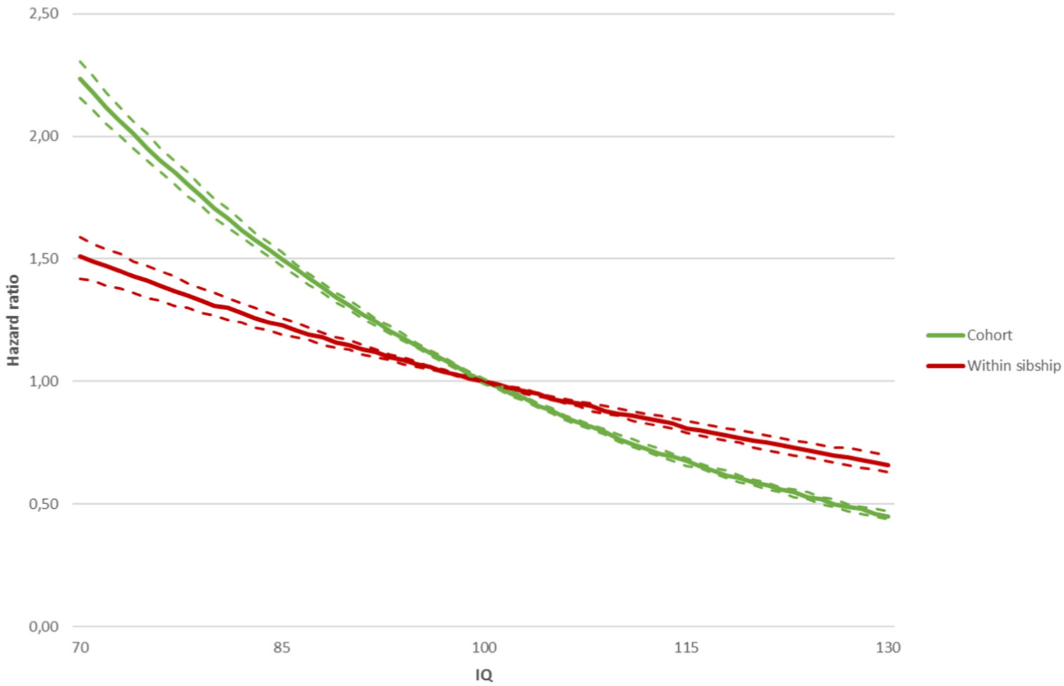

Fig. 2. Hazard ratio for social benefits according to IQ.

secondary school, risk of social benefits at ages 18–30 and gross income at age 30 within siblings were all notably weaker than the associations observed in the cohort analyses. However, with regard to the association between IQ and gross income at age 30 the confidence intervals of the two models were overlapping.

After adjustment for covariates, familial factors shared by siblings still seemed to explain parts of the associations of IQ with GPA in lower secondary school and risk of social benefits at ages 18–30 (Figs. 4–5 & Supplementary Table 1). However, familial factors did not seem to influence the association between IQ and gross income at age 30 (Fig. 6 & Supplementary Table 1). With regard to GPA in lower secondary school, Fig. 4 shows that the association within siblings still was notably weaker than the association observed in the cohort analysis after covariates had been taken into account. Whereas individuals with an IQ of 70 were found to have a 2.9 times lower GPA than individuals with an IQ of 130 in the within-sibship analysis, individuals with an IQ of 70 were found to have a 4.0 times lower GPA than individuals with an IQ of 130 in the conventional cohort analysis. Interestingly, the within-sibship analysis also showed that individuals with IQs in the range of 70–130 meet the new admission requirements to upper secondary education in Denmark, which require a GPA in lower secondary school of minimum three. With regard to risk of social benefits at ages 18–30, Fig. 5 shows that the association within siblings still was weaker than the association observed in the cohort analysis after covariates had

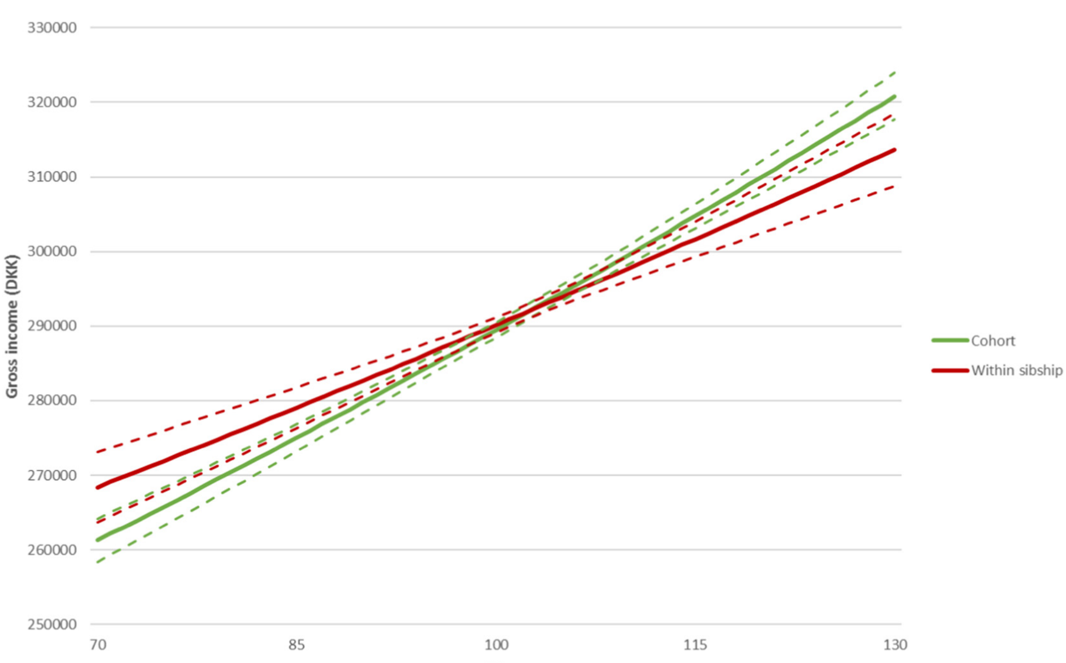

Fig. 3. Gross income according to IQ.

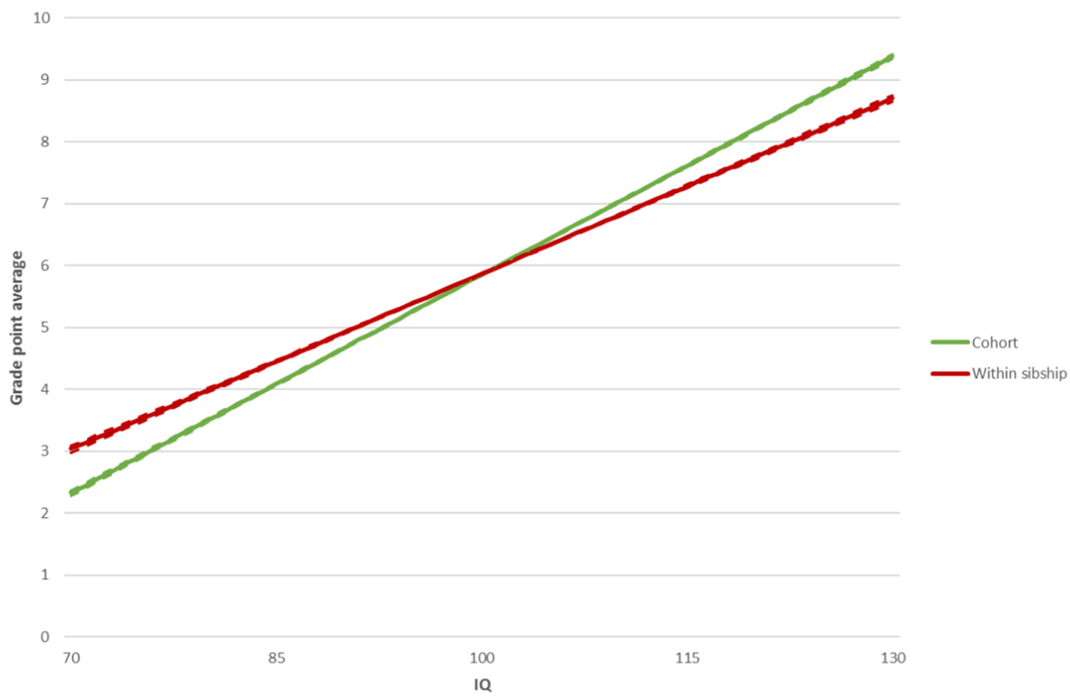

Fig. 4. Grade point average according to IQ.
Association is adjusted for year of birth, ethnicity, birth region, parental education at birth, out-of-home care in childhood, psychiatric diagnoses in childhood, neurological diagnoses in childhood, and perinatal diagnoses and congenital deformities.

been taken into account. Whereas individuals with an IQ of 70 were found to have a 1.4 times higher hazard of social benefits than individuals with an IQ of 100 in the within-sibship analysis, individuals with an IQ of 70 were found to have a 1.7 times higher hazard of social benefits than individuals with an IQ of 100 in the conventional cohort analysis. However, the confidence intervals of the two models were now overlapping.

Sensitivity analyses showed that the associations of IQ with GPA in lower secondary school and risk of social benefits at ages 18–30 were essentially the same among individuals included in our study population and individuals excluded from our study population due to no registered full brothers. However, the association between IQ and gross income at age 30 was notably weaker among individuals included in our study population compared with the excluded individuals (Supplementary Figs. 1–3 & Supplementary Table 2). There were no notable changes in the associations of IQ with educational and

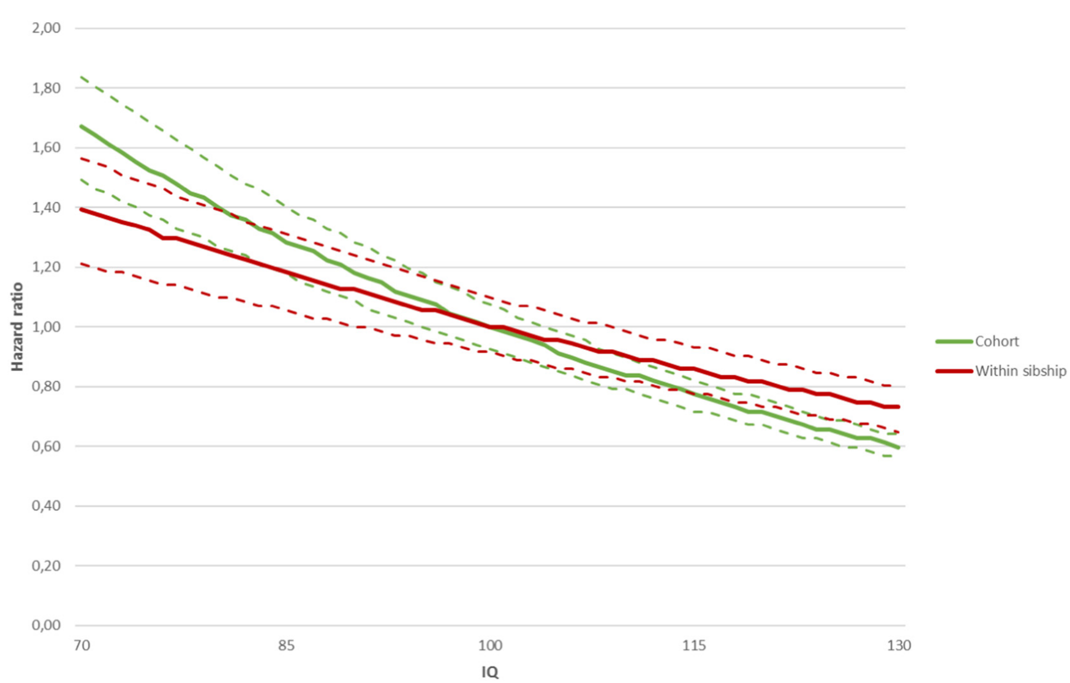

Fig. 5. Hazard ratio for social benefits according to IQ.
Association is adjusted for year of birth, ethnicity, birth region, parental education at birth, out-of-home care in childhood, psychiatric diagnoses in childhood, neurological diagnoses in childhood, and perinatal diagnoses and congenital deformities.

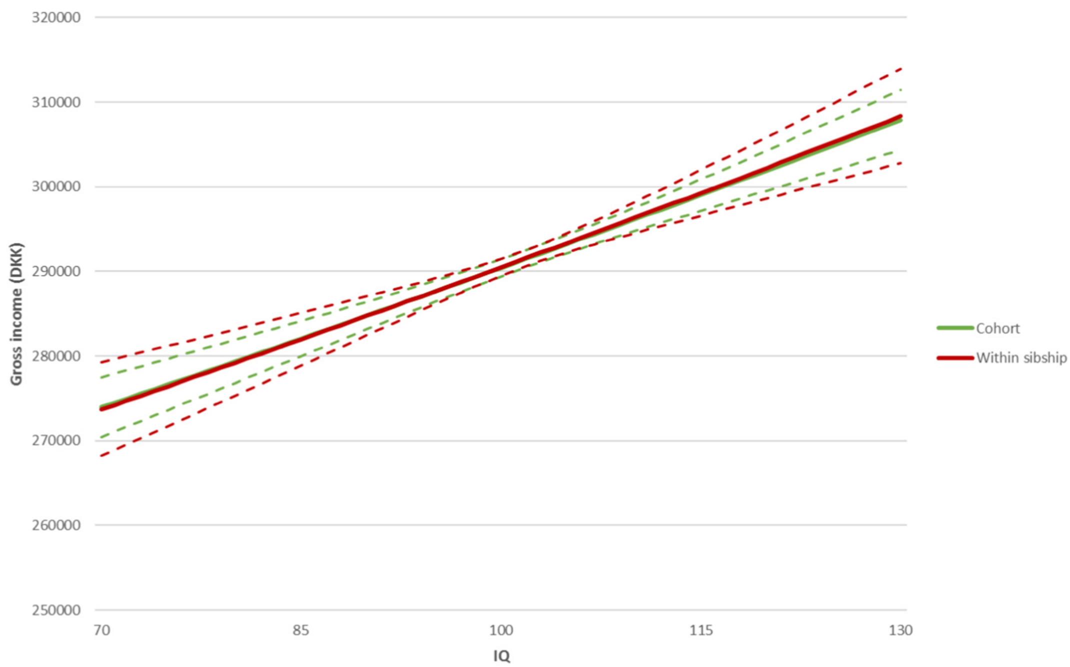

Fig. 6. Gross income according to IQ.
Association is adjusted for year of birth, ethnicity, birth region, parental education at birth, out-of-home care in childhood, psychiatric diagnoses in childhood, neurological diagnoses in childhood, and perinatal diagnoses and congenital deformities.

occupational achievement by use of available case analyses.

4. Discussion

4.1. Main findings

The results showed that an appreciable part of the associations of IQ with GPA in lower secondary school, risk of social benefits at ages 18–30 and gross income at age 30 could be attributed to familial factors shared by siblings. However, most of the associations were not attributable to such familial factors. In fact, only the association between IQ and GPA in lower secondary school within siblings clearly differed from the association observed in the cohort analysis after covariates had been taken into account.

4.2. Comparison with the existing literature

The finding that IQ is positively associated with educational and occupational achievement is consistent with the existing literature, including a large meta-analysis of 65 studies (Strenze, 2007). No previous studies have investigated the influence of familial factors shared by siblings on the associations between IQ and educational and occupational achievement by use of the sibling comparison design. However, twin and non-twin sibling studies have found that shared genetic factors and shared environmental factors are responsible for part of the associations (Johnson et al., 2007; Lichtenstein & Pedersen, 1997; Rowe et al., 1998), which is in accordance with this study's findings that the investigated associations within siblings were weaker than the crude associations observed in the cohort analyses. Future studies are encouraged to corroborate our findings with regard to the strength of the associations in large representative samples of the general population.

That the investigated associations within siblings were weaker than the crude associations observed in the cohort analyses suggests that familial factors shared by siblings influence educational and occupational achievement beyond the influence of IQ. With regard to the association between IQ and GPA in lower secondary school, our included covariates seemed to constitute only a minor part of these familial factors. Other familial factors influencing GPA in lower secondary school beyond the influence of IQ might be shared genetic factors or shared environmental factors, for which we have no information available. For example, parenting practices such as creating a school-oriented family environment and allowing the children to make decisions, as well as the consistency of parental warmth during childhood and adolescence, have all been found to influence the educational and occupational achievement of young people (Mandara, Varner, Greene, & Richman, 2009; Sun, McHale, & Updegraff, 2017). With regard to the associations of IQ with risk of social benefits at ages 18–30 and gross income at age 30, our included covariates seemed to represent all familial factors influencing these two outcome variables beyond the influence of IQ. This might be because some of our included covariates, e.g. psychiatric diagnoses in childhood, neurological diagnoses in childhood and perinatal diagnoses and congenital deformities, have a larger influence on the risk of social benefits at ages 18–30 and gross income at age 30 than on GPA in lower secondary school. However, it might also be because proximal family factors, for which we have no information available, only influence educational achievement during upbringing or because these factors have a much smaller influence on later educational and occupational achievement.

4.3. Strengths and limitations

The major strength of this study is its large study population comprising 364,193 full brothers born since 1950 and appearing before a draft board during the periods 1968–1984 and 1987–2015. Another strength is the use of information from Danish registers because of their high validity and completeness. The use of information from Danish registers has also made it possible to link individuals with their mothers and fathers, which allowed for investigating the influence of familial factors shared by siblings on the association between IQ and educational and occupational achievement. Another strength of the study is the use of the BPP as a measure of intelligence, since a previous study has found a high correlation between the BPP and the full-scale Wechsler Adult Intelligence Scale (Mortensen et al., 1989). Finally, the prospective nature of the data collection reduces the risk of reverse causality.

However, since the study population's intelligence has been measured after they have left lower secondary school, it is possible that the association of IQ with GPA in lower secondary school is due to reverse causality given that education has been shown to have a small beneficial effect on intelligence (Ritchie & Tucker-Drob, 2018). But since previous studies have found that intelligence is relatively stable from childhood until middle age, this is most likely not a major concern (Deary, Whalley, Lemmon, Crawford, & Starr, 2000; Deary, Whiteman, Starr, Whalley, & Fox, 2004; Osler, Avlund, & Mortensen, 2013). Nevertheless, what might be a concern is the possible influence of confounding from factors that are not shared by siblings. Bias from non-shared confounding can be exacerbated by sibling comparisons, which condition on discordance between the siblings (Frisell, Öberg, Kuja-Halkola, & Sjölander, 2012). The bias would occur when the causes of discordance between brothers in IQ also affect the outcomes. We have adjusted all our statistical analyses for psychiatric diagnoses in childhood, neurological diagnoses in childhood, and perinatal diagnoses and congenital deformities, which may affect discordance in IQ between brothers. However, we cannot rule out that non-shared confounding from factors like the brothers' social relations, school environmental factors, and serious illnesses or injuries in childhood still confound the investigated associations because our study is based on existing register data and we have had no influence on the data collection. Finally, with regard to the generalizability of our study results it is important to note that the association between IQ and gross income at age 30 was notably weaker among individuals included in our study population compared with the excluded only children. The weaker association might be due to the smaller variance in gross income at age 30 among the males included in our study population, but whether this explains the entire discrepancy is not known, calling into question the generalizability of this association to males without male siblings. Further, since this study is the first to investigate the influence of familial factors shared by siblings on the associations between IQ and educational and occupational achievement using the sibling comparison design the generalizability of our study results with regard to the strength of the associations within siblings should be further determined. In other words, we cannot be sure that the associations between IQ and educational and occupational achievement found in this study will be consistent with the findings of studies including females and studies in other countries where the influence of familial factors shared by siblings might differ from a Danish context.

5. Conclusions

The study found that an appreciable part of the associations of IQ with GPA in lower secondary school, risk of social benefits at ages 18–30 and gross income at age 30 could be attributed to familial factors shared by siblings. However, most of the associations were not attributable to such familial factors. In fact, only the association between IQ and GPA in lower secondary school within siblings clearly differed from the association observed in the cohort analysis after covariates had been taken into account. This might either suggest that proximal family factors, for which we have no information available, only influence educational achievement during upbringing or that these factors have a much smaller influence on later educational and occupational achievement in young adulthood. Whatever the case, future studies are encouraged to investigate further the influence of familial factors shared by siblings on the associations between IQ and educational and occupational achievement. With other information available, it might be possible to identify modifiable familial factors influencing educational and occupational achievement beyond the influence of IQ.

Supplementary data to this article can be found online at https://doi.org/10.1016/j.paid.2019.05.045.

Funding

This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors.

Declaration of Competing Interest

None.

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