Cite this article as: BMJ, doi:10.1136/bmj.38959.650903.7C (published 29 September 2006)

Research

BMJ

Comparison of academic performance of twins and singletons in adolescence: follow-up study

Kaare Christensen, Inge Petersen, Axel Skytthe, Anne Maria Herskind, Matt McGue, Paul Bingley

Abstract

Objectives To determine whether twins in recent cohorts show similar academic performance in adolescence to singletons and to test the effect of birth weight on academic performance in twins and singletons.
Design Follow-up study.
Setting Denmark.
Participants All twins (n=3411) and a 5% random sample of singletons (n=7796) born in Denmark during 1986-8.
Main outcome measures Test scores in ninth grade (age 15 or 16), birth weight, gestational age at birth, parents' age, and parents' education.
Results Ninth grade test scores were normally distributed, with almost identical mean and standard deviations for twins and singletons (8.02 *v* 8.02 and 1.05 *v* 1.06) despite the twins weighing on average 908 g (95% confidence interval 886 to 930 g) less than the singletons at birth. Controlling for birth weight, gestational age at birth, age at test, and parents' age and education confirmed the similarity of test scores for twins and singletons (difference 0.04, 95% confidence interval −0.03 to 0.10). A significant, positive association between test score and birth weight was observed in both twins and singletons, but the size of the effect was small: 0.06-0.12 standard deviations for every kilogram increase in birth weight.
Conclusions Although older cohorts of twins have been found to have lower mean IQ scores than singletons, twins in recent Danish cohorts show similar academic performance in adolescence to that of singletons. Birth weight has a minimal effect on academic performance in recent cohorts; for twins this effect is best judged relative to what is a normal birth weight for twins and not for singletons.

Introduction

Infertility treatment has doubled the twinning rate in many Western countries to about 2% of births.[1] The resulting increased incidence of twins with low birth weight has substantially attenuated decreasing trends in infant mortality.[2] Children of extremely low birth weight have considerable long term health and educational needs,[3] and twins compared with singletons are about four times more likely to have cerebral palsy[4] and are at increased risk of other congenital malformations.[5] Even within its normal range, birth weight is positively associated with IQ in children,[6] and large scale studies on twins from the mid-20th century show that they score four or five IQ points lower than singletons.[7 8] Although newer and smaller studies have questioned this result,[9] a recent study concluded that twins born in the 1950s continue to be cognitively disadvantaged compared with singletons.[10] None the less, it remains unclear whether an intellectual disadvantage characterises twins in recent birth cohorts, and, if it does exist, whether it is due to a small group of severely affected twins or a shift in the whole distribution of scores for twins towards lower performance. We compared the performance of twins and singletons and the effect of birth weight on academic performance, using nationwide registers of academic performance in ninth graders born in Denmark during 1986-8.

Methods

The Danish civil registration system identifies individuals by unique social security numbers, which can be linked through Statistics Denmark to several thematically organised population databases, or registers. We used information from three registers: the Danish demographic database, which includes information on parents' identities, deaths, migrations, adoptions, and education[11]; the national hospital discharge register, which includes information on overnight hospital stays for non-psychiatric illnesses[12]; and the register of compulsory school completion assessments and test scores compiled by the Ministry of Education from school reports.[13]

The Danish twin registry is a population based register comprising more than 65 000 twin pairs born in Denmark since 1870,[14] including all twins born since 1973 as identified through the medical birth registry. Zygosity of same sexed twin pairs has been classified by means of four standard questions, a method with less than 5% misclassification.[15] We did not have information on whether the twins were born as a result of assisted conception, but in recent Danish cohorts the risk of neurological sequelae is similar in assisted and naturally conceived twins.[16]

Danish students in ninth grade (age 15 or 16) are required to complete a general test of academic achievement, which is scored on a scale of 0-13, with average performance rated as 8. The tests cover major domains of academic achievement, including Danish and foreign languages, mathematics, hard science, and social science. These test scores are supplemented by teacher ratings, also on a 0-13 point scale. Reporting of test scores and teacher evaluations is a legal requirement for all schools except special schools for those with learning disabilities. Some private schools do not test, and a small proportion of children in public schools choose not to take the test. We used the average test score for each child and the average of the teacher evaluations completed through ninth grade, as well as test scores for single topics—namely, mathematics and Danish. The test scores were available for the years 2002-4 corresponding to the 1986-8 birth cohorts. The present study is based on all twins and a 5% random sample of singletons born in Denmark during

Table 1 Characteristics of twins and singletons born in Denmark during 1986-8. Values are numbers (percentages) unless stated otherwise

Characteristics	Singletons*	Twins
No of live births	8280	3652
Deaths (days after birth):	90 (1.1)	97 (2.7)
1-28	34 (0.4)	72 (2.0)
≥29†	56 (0.7)	25 (0.7)
Emigrated†	394 (4.8)	144 (3.9)
Study base‡	7796 (94.2)	3411 (93.4)
Mean (SD) median No of days in hospital (age <1 year)	6.6 (9.2) 5	16.0 (18.4) 10
Mean (SD) median No of days in hospital (age 1-14 years)	3.5 (14.1) 0	3.6 (12.5) 1
Hospital stay (days) age 1-14 years:		
None	4064 (52.1)	1673 (49.0)
1-2	1730 (22.2)	827 (24.2)
3-30	1863 (23.9)	841 (24.7)
31-60	86 (1.1)	46 (1.3)
≥61	53 (0.7)	24 (0.7)
Male	4030 (51.7)	1715 (50.3)
Mean (SD) birth weight	3449 (537); n=7771	2541 (547); n=3406
Mean (SD) gestational age	39.7 (1.7); n=7759	37.0 (2.5); n=3406
Mean (SD) maternal age	27.8 (4.8); n=7795	29.0 (4.6); n=3411
Mean (SD) paternal age	30.8 (5.8); n=7738	31.9 (5.7); n=3402
Mean (SD) maternal education§	1.67 (1.72); n=7629	1.72 (1.77); n=3318
Mean (SD) paternal education§	1.58 (1.76); n=7330	1.68 (1.83); n=3233
School performance:		
Test score available	6575 (84.3)	2866 (84.0)
Mean (SD) test score	8.02 (1.06)	8.02 (1.05)
Mean (SD) age at test	16.0 (0.3)	16.0 (0.3)
Teacher score available	6572 (84.3)	2851 (83.6)
Mean (SD) teacher score	8.05 (1.08)	8.09 (1.06)
Mean (SD) age at test	16.0 (0.3)	16.0 (0.3)
Information on all variables	6018 (77.2)	2611 (76.5)

Denominators vary owing to missing values.
*5% random sample of Danish birth cohorts, 1986-8.
†Before 1 January 2003.
‡Rest of table gives percentage of study base.
§0=basic school 8th-10th form; 1=vocational main course; 2=upper secondary education; 3=short cycle higher education; 4=medium cycle higher education; 5=bachelors degree; 6=masters degree and PhD.

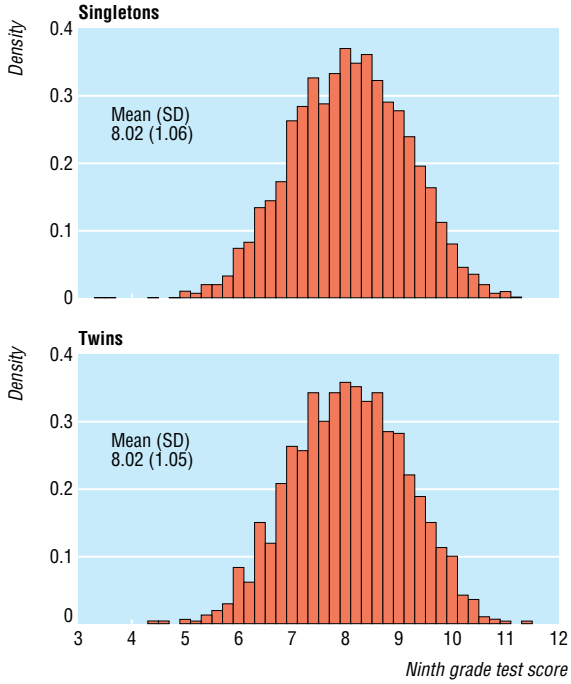
1986-8. The mean (SD) age at test was 16.0 (0.3) years, for both twins and singletons.

To correct for the correlated nature of the twin data we used the Stata "cluster" option (release 9) based on generalised estimating equations.[17]

Results

A total of 3652 twin individuals were live born in Denmark during 1986-8, and a 5% random sample of all liveborn singletons in each of these three years yielded 8280 additional individuals. The study base included those who survived to 1 January 2003 and had not emigrated. Mortality in this period was significantly higher among twins than among singletons: 2.7% *v* 1.1% (95% confidence interval of the difference 1.0% to 2.1%). The excess in twin mortality was limited to the period from birth to 28 days (table 1). More singletons than twins emigrated (4.8% *v* 3.9%), therefore 93.4% of the twins (n=3411) and 94.2% of the singletons (n=7796) constituted the study base for all subsequent analyses.

During their first year, twins spent more days in hospital than singletons: 16.0 *v* 6.6 days (95% confidence interval of difference 8.9 to 9.9 days), whereas only small differences were shown for hospital stays from age 1 to 14 years (table 1). The percentage of twins and singletons spending more than two months in hospital during their lifetime was the same (0.7%).



Distribution of ninth grade mean test scores for Danish twins (n=2866) and a 5% random sample (n=6575) of Danish singletons, born 1986-8

The birth weight and gestational age of twins was significantly lower than that of singletons: 2541 g *v* 3449 g (mean difference 908 g, 95% confidence interval 886 to 930 g) and 37.0 *v* 39.7 weeks (95% confidence interval of the difference 2.7 to 2.8 weeks). Consistent with the increased prevalence of dizygotic twinning with maternal age, mothers of twins were significantly older than those of singletons (29.0 *v* 27.8 years), and a similar pattern was observed in fathers (31.9 *v* 30.8). The educational level of mothers and fathers was similar for twins and singletons.

Academic performance

Twins and singletons showed almost identical academic performance (figure).

Further multivariate analyses confirmed that twins have similar academic performance to singletons, even after controlling for sex, age at test, birth weight (in grams or centiles), gestational age, and parents' age and education. Overall, the results and pattern of the teachers' evaluations as well as the topic specific tests were similar to that for the overall average score—that is, no differences were found between twins and singletons except that twins did slightly better in mathematics than singletons (difference 0.13, 95% confidence interval 0.03 to 0.23).

Twins and singletons with missing test scores

The same proportion of twins and singletons (84%) had a test score: a proportion similar to previous Danish studies.[18] Similar proportions of complete test scores for twins and singletons were found in mathematics, Danish, and English.

Health and social indicators for children with and without test scores (table 2) showed minimal differences that were similar for twins and singletons: individuals without a test score spent more days in hospital and had lower birth weight, younger mothers, and parents of a lower mean educational level. The percentage with birth weights less than 1500 g was higher among twins with a test score than without (9.7% *v* 3.5%), suggesting that extremely low birth weight is associated with non-completion of the ninth grade test. A similar pattern was seen in singletons: 1.4% with a test score and 0.3% without a test

Table 2 Basic descriptive characteristics of twins and singletons born in Denmark during 1986-8 stratified for presence of ninth grade test score. Values are numbers (percentages) unless stated otherwise

Characteristics	Singletons*		Twins	
	Test score missing	Test score available	Test score missing	Test score available
No in sample	1221	6575	545	2866
Mean (SD) median No of days in hospital (age <1 year)	9.0 (16.5) 5	6.2 (6.9) 5	22.8 (26.7) 13	14.8 (16.1) 9
Mean (SD) median No of days in hospital (age 1-14 years)	6.6 (24.3) 1	2.9 (11.2) 0	7.4 (23.9) 1	2.9 (8.5) 0
Hospital stay (days) age 1-14 years:				
None	524 (42.9)	3540 (53.8)	192 (35.2)	1481 (51.7)
1-2	277 (22.7)	1453 (22.1)	153 (28.1)	674 (23.5)
3-30	369 (30.2)	1494 (22.7)	172 (31.6)	669 (23.3)
31-60	30 (2.5)	56 (0.9)	15 (2.8)	31 (1.1)
≥61	21 (1.7)	32 (0.5)	13 (2.4)	11 (0.4)
Male	738 (60.4)	3292 (50.1)	306 (56.1)	1409 (49.2)
Birth weight:				
Mean (SD) birth weight (g)	3372 (603); n=1214	3463 (523); n=6557	2369 (600); n=545	2574 (530); n=2861
≤1500	1.4; n=17	0.3; n=18	9.7; n=53	3.5; n=100
1500-2000	1.3; n=16	0.7; n=48	16.1; n=88	11.1; n=318
2000-2500	3.9; n=47	2.6; n=172	31.7; n=173	27.9; n=799
2500-3000	16.8; n=204	14.1; n=926	29.4; n=160	37.8; n=1082
3000-3500	36.4; n=442	36.9; n=2420	12.1; n=66	16.6; n=474
3500-4000	27.8; n=337	32.0; n=2098	0.9; n=5	3.0; n=85
>4000	12.4; n=151	13.3; n=875	0; n=0	0.1; n=3
Mean (SD) gestational age (weeks)	39.5 (2.0); n=1214	39.7 (1.6); n=6545	36.2 (3.0); n=545	37.1 (2.3); n=2861
Mean (SD) maternal age	27.1 (5.0); n=1221	28.0 (4.7); n=6574	28.5 (4.6); n=545	29.1 (4.5); n=2866
Mean (SD) paternal age	30.2 (6.2); n=1207	30.9 (5.7); n=6531	31.6 (5.7); n=544	31.9 (5.7); n=2858
Mean (SD) maternal education†	1.24 (1.59); n=1183	1.74 (1.73); n=6446	1.26 (1.69); n=528	1.81 (1.78); n=2790
Mean (SD) paternal education†	1.14 (1.47); n=1115	1.66 (1.79); n=6215	1.30 (1.72); n=508	1.75 (1.84); n=2725

Denominators vary owing to missing values.
*5% random sample of Danish birth cohorts, 1986-8.
†See footnote to table 1.

score. The percentage of test takers is lower for the 1988 cohort than for the earlier cohorts because some from this cohort had not yet advanced to ninth grade at the time test data were obtained but again the pattern was the same for twins and singletons.

Birth weight

Birth weight had a significant but modest effect on test scores (test performance increased 6% of a standard deviation per kilogram increase in birth weight for singletons and 12% for twins). The significant but small influence of birth weight is confirmed in trend analyses[19] and in intrapair analysis, where regression of differences in test score on differences in birth weight within twin pairs shows a difference of one sixth of a standard deviation in test performance per kilogram difference in birth weight. In 1256 pairs of twins with different birth weights (mean difference 309 g), the mean test score was 8.05 for the lighter twin at birth and 8.08 for the heavier twin at birth—a difference of only 3% of a standard deviation. In the 102 pairs where the twins had identical birth weight, the mean test score was 7.99.

Recent results[3] suggest that children of extremely low birth weight might be especially at risk for several adverse health outcomes and functional limitations. The strongest evidence for an influence of birth weight on later functioning is the over-representation of children of extremely low birth weight in the 15% of the birth cohorts that did not have a test score in the register.

The failure to find twin-singleton differences in light of the observed, albeit modest, effects of birth weight on test scores may seem anomalous. Table 3 gives mean test performance as a function of birth weight centile separately for twins and singletons. Twins and singletons in the same birthweight centile scored virtually identically, suggesting that relative rather than absolute birth weight is most prognostic.

Single twins

The 43 twins with a deceased cotwin scored significantly lower than the 2823 twins with a living cotwin: mean (SD) 7.69 (1.20) *v* 8.03 (1.05); P = 0.04.

Discussion

A large national sample of Danish adolescent twins and singletons showed similar performance in the ninth grade test.

Table 3 Mean test scores for birthweight centiles for twins and singletons born in Denmark during 1986-8

Birthweight centiles (%)	Singletons*			Twins		
	No	Mean (SD) birth weight (g)	Mean (SD) test score	No	Mean (SD) birth weight (g)	Mean (SD) test score
0-10	694	2524 (354)	7.85 (1.04)	288	1565 (256)	7.84 (1.10)
11-25	1014	3026 (84)	7.93 (1.08)	458	2093 (108)	7.90 (1.02)
26-50	1586	3325 (89)	8.02 (1.06)	692	2451 (98)	8.03 (1.05)
51-75	1731	3635 (100)	8.10 (1.02)	755	2780 (96)	8.04 (1.03)
76-90	911	3962 (85)	8.07 (1.08)	389	3079 (75)	8.17 (1.04)
91-100	620	4375 (236)	8.08 (1.04)	279	3450 (192)	8.12 (1.07)

*5% random sample of Danish birth cohorts, 1986-8.

Birth weight had a minimal effect on performance except for twins of very low birth weight, who were more likely not to have a ninth grade test score. This suggests that a minority of twins—and among them many twins of very low birth weight—have severe physical or cognitive problems whereas most twins perform cognitively similar to singletons.

Our findings run counter to the consistent finding of poorer IQ performance among twins in studies of older cohorts and in particular to findings from a recently published study.[10] Although the latter study was based on cohorts born in the 1950s, it was interpreted as showing that twins continue to be at a cognitive disadvantage, possibly because of shorter gestation or impaired foetal growth. Our study questions the validity of this generalisation to recent cohorts of twins.

We interpret our findings as indicating that improvements in obstetric and paediatric practices over the past 50 years have largely ameliorated the cognitive disadvantage identified in twins by earlier research,[7 8 10] despite more twins of extremely low birth weight now surviving the first year of life. It is possible that our findings differ from those of earlier research because of country specific factors or differences in measurement. Our research is based on measures of academic achievement rather than IQ. These differences are not likely to be a major factor in accounting for the differences in findings. A recent review[20] found that the correlation between IQ and standardised achievement tests is high (average 0.70 to 0.74). The correlation between IQ and national achievement tests, such as the test used here, seem almost this high.[21] The high correlation between the two types of assessments suggests that they would produce similar results. In any case, assessments of achievement have a pragmatic advantage over measures of IQ as parents are likely to be more interested in how their twins will do in school than in how they will do in a test of intelligence.

The strength of the study is that it is nationwide, large, and register based, and the important covariates, such as parents' education, were available for almost all participants. The expected associations with covariates, such as a strong correlation between test scores and parents' education, were observed in our sample, suggesting that the quality of the data is high. The major weakness of the study is that we had no information on why test data were missing for about 15% of the population. Missing data can arise because children are too mentally or physically handicapped to participate in a test, and because some schools do not report test scores. None the less, the equal representation of twins and non-twins in the study (84% had scores identified in both groups) makes bias from this source unlikely.

Record et al[7] showed that the four or five IQ point disadvantage found in twins from cohorts born in the 1950s did not exist among the subgroup of twins who lost their cotwin early in life, suggesting that social competition may be the cause of the twin disadvantage. We found the opposite pattern in the current sample—namely, that twins with a deceased cotwin scored significantly lower on the academic tests than twins with a living cotwin.

Our study indicates that twins and singletons of extremely low birth weight have lower academic achievement in adolescence than children of average birth weight, and we were able to retrieve reported associations between birth weight and school achievement, although the size of the effect was modest. When we analysed birth weight as centiles separately for twins and singletons, we found no meaningful differences in test scores between twins and singletons in any centile stratum.[22] The shift in distribution of birth weight for twins therefore seems to have no effect on cognition in recent twin cohorts. This finding also suggests that the association of birth weight with academic achievement may not be causal, at least within the range of birth weights studied here—that is, a birth weight of 2500 g is associated with mild cognitive deficits in singletons, where it corresponds to the 10th centile, but no cognitive deficits in twins, where it approximately equals the median score.

Contributors: KC initiated the study, obtained funding, supervised the analyses, and was mainly responsible for writing the manuscript. He is guarantor. PB and IP helped develop the protocol, were responsible for creating and analysing the dataset, and helped write the manuscript. MMcG, AMH, and AS assisted with the protocol design, analysis, and writing of the manuscript.

Funding: University of Southern Denmark.

Competing interests: None declared.

Ethical approval: This study was approved by the Danish Data Protection Agency (case No 2000-54-0047).

1 Herskind AM, Basso O, Olsen J, Skytthe A, Christensen K. Is the natural twinning rate still declining? *Epidemiology* 2005;16:591-2.
2 Westergaard T, Wohlfahrt J, Aaby P, Melbye M. Population based study of rates of multiple pregnancies in Denmark, 1980-94. *BMJ* 1997;314:775-9.
3 Hack M, Taylor HG, Drotar D, Schluchter M, Cartar L, Andreias L, et al. Chronic conditions, functional limitations, and special health care needs of school-aged children born with extremely low-birth-weight in the 1990s. *JAMA* 2005;294:318-25.
4 Scher AI, Petterson B, Blair E, Ellenberg JH, Grether JK, Haan E, et al. The risk of mortality or cerebral palsy in twins: a collaborative population-based study. *Pediatr Res* 2002;52:671-81.
5 Myrianthopoulos NC. Congenital malformations in twins: epidemiological survey. *Birth Defects Orig Artic Ser* 1975;11:1-39.
6 Shenkin SD, Starr JM, Deary IJ. Birth weight and cognitive ability in childhood: a systematic review. *Psychol Bull* 2004;130:989-1013.
7 Record RG, McKeown T, Edwards JH. An investigation of the difference in measured intelligence between twins and single births. *Ann Hum Genet* 1970;34:11-20.
8 Deary I, Pattie A, Wilson V, Whalley L. The cognitive cost of being a twin: two whole-population surveys. *Twin Res Hum Genet* 2005;8:376-83.
9 Posthuma D, De Geus EJ, Bleichrodt N, Boomsma DI. Twin-singleton differences in intelligence? *Twin Res* 2000;3:83-7.
10 Ronalds GA, De Stavola BL, Leon DA. The cognitive cost of being a twin: evidence from comparisons within families in the Aberdeen children of the 1950s cohort study. *BMJ* 2005;doi:10.1136/bmj.38633.594387.3A (published 18 Nov 2005).
11 Petersen JK. *The Danish demographic database: longitudinal data for advanced demographic methods*. Research Report 15. Odense: Danish Center for Demographic Research, University of Southern Denmark; 2000.
12 Andersen TF, Madsen M, Joergensen J, Mellemkjaer L, Olsen JH. The Danish national hospital register: a valuable source for modern health sciences. *Dan Med Bull* 1999;(46):263-8.
13 Danish Ministry of Education. *Tests, assessment and teaching: an overall evaluation of compulsory school completion assessment and test scores May-June 2004* [in Danish]. Copenhagen: Danish Ministry of Education, 2000.
14 Skytthe A, Kyvik K, Holm NV, Vaupel JW, Christensen K. The Danish twin registry: 127 birth cohorts of twins. *Twin Res* 2002;5:352-7.
15 Christiansen L, Frederiksen H, Schousboe K, Skytthe A, Wurmb-Schwark N, Christensen K, et al. Age- and sex-differences in the validity of questionnaire-based zygosity in twins. *Twin Res* 2003;6:275-8.
16 Pinborg A, Loft A, Schmidt L, Greisen G, Rasmussen S, Nyboe Andersen A. Neurological sequelae in twins born after assisted conception: controlled national cohort study. *BMJ* 2004;329:311.
17 Pickles A. Generalized estimating equations. In: Armitage PCT, ed. *Encyclopedia of biostatistics vol 2*. Chichester: Wiley, 1998:1626-37.

What is already known on this topic

In older cohorts twins have mean IQ scores considerably lower than singletons

Previous studies show a positive association between birth weight and IQ in children

What this study adds

Twins in recent cohorts have school performance in adolescence similar to singletons

Birth weight has a minimal effect on school performance in recent cohorts and for twins this is best judged relative to what is a normal birth weight for twins not singletons

18 Bingley P, Jensen VM, Walker I. *School resources, curriculum design and test scores at the end of compulsory schooling in Denmark*. Working paper. Aarhus: Aarhus School of Business, Economics Department, 2005.
19 Cuzick J. A Wilcoxon-type test for trend. *Stat Med* 1985;4:87-90.
20 Naglieri JA, Bornstein BT. Intelligence and achievement: just how correlated are they? *J Psychoeduc Assess* 2003;21:244-60.
21 Bartels M, Rietveld MJH, van Baal GCM, Boomsma DI. Heritability of educational achievement in 12-year-olds and the overlap with cognitive ability. *Twin Res* 2002;5:544-53.
22 Wilcox AJ. Invited commentary: the perils of birth weight—a lesson from directed acyclic graphs. *Am J Epidemiol* 2006 Aug 24; (Epub ahead of print).

(Accepted 23 August 2006)

doi 10.1136/bmj.38959.650903.7C

Danish Twin Registry, Institute of Public Health, University of Southern Denmark
Kaare Christensen *professor*
Inge Petersen *mathematician*
Axel Skytthe *associate professor*

Paediatric Department, Odense University Hospital, Denmark
Anne Maria Herskind *paediatrician*

Department of Psychology, University of Minnesota, USA
Matt McGue *professor*

Department of Economics, Aarhus School of Business, Denmark
Paul Bingley *associate professor*

Correspondence to: K Christensen, Epidemiology, Institute of Health Sciences, University of Southern Denmark, DK-5000 Odense C, Denmark
kchristensen@health.sdu.dk