Education in twins and their parents across birth cohorts over 100 years: an individual-level pooled analysis of 42 twin cohorts

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Running title: Zygosity difference in education

Abstract

Whether monozygotic (MZ) and dizygotic (DZ) twins differ from each other in a variety of phenotypes is important for genetic twin modeling and for inferences made from twin studies in general. We analyzed whether there were differences in individual, maternal and paternal education between MZ and DZ twins in a large pooled dataset. Information was gathered on individual education for 218,362 adult twins from 27 twin cohorts (53% females; 39% MZ twins), and on maternal and paternal education for 147,315 and 143,056 twins, respectively, from 28 twin cohorts (52% females; 38% MZ twins). Together, we had information on individual or parental education from 42 twin cohorts representing 19 countries. The original education classifications were transformed to education years and analyzed using linear regression models. Overall, MZ males had 0.26 (95% confidence interval (CI) 0.21-0.31) years and MZ females 0.17 (95% CI 0.12-0.21) years longer education than DZ twins. The zygosity difference became smaller in more recent birth cohorts for both males and females. Parental education was somewhat longer for fathers of DZ twins in cohorts born in 1990-1999 (0.16 years, 95% CI 0.08-0.25) and 2000 or later (0.11 years, 95% CI 0.00-0.22), compared with fathers of MZ twins. The results show that the years of both individual and parental education are largely similar in MZ and DZ twins. We suggest that the socio-economic differences between MZ and DZ twins are so small that inferences based upon genetic modeling of twin data are not affected.

Understanding how monozygotic (MZ) and dizygotic (DZ) twins differ from each other has important methodological and possible public health implications. Quantitative genetic twin models assume that MZ and DZ twins are representative of the same background population (Posthuma et al. 2003). If they are not, this may be seen as differences in the means and variances between the two zygosity groups. Zygosity differences in anthropometric measures, especially in early life, are well documented: MZ twins are lighter and shorter at birth than DZ twins (Hur et al. 2005). Furthermore, DZ twins were taller and had a somewhat higher body mass index (BMI) than MZ twins in a large international twin study based on the same database also used in the present study. The differences were largest in childhood and decreased in adulthood, where differences were less than 1 cm in height and 0.1 kg/m^2 in BMI (Jelenkovic et al. 2015). A Swedish study of young adult men also found that MZ twins had slightly less muscle strength than DZ twins (Silventoinen et al. 2008).

Socio-economic status (SES) is an important determinant of health (Mackenbach et al. 2008), and education is one of the most important dimensions of SES in modern societies (Hout and DiPrete 2006). Thus, the evaluation of the representativeness of SES in twins is important when generalizing the results from twin studies to the general population. One aspect of that validity assessment is to examine educational differences between MZ and DZ twins. There are at least three possible origins of differences between these two types of twins in terms of individual and parental education. First, because MZ twins tend to be shorter and lighter at birth than DZ twins (Hur et al. 2005) and these birth-related factors may be associated with slower cognitive development (Broekman et al. 2009), it is possible that differences in IQ can be found between MZ and DZ twins that could lead to differences in academic performance in later life. This is supported by findings that twins have, in general, slightly lower IQs than singletons (Voracek and Haubner 2008), and this difference is even more pronounced in triplets suggesting that there is a dose-response relationship between the birth-related anthropometrics

of multiple pregnancies and later IQ (Silventoinen et al. 2013). However, this effect can at least partially be explained by birth order as found in a Dutch study (de Zeeuw et al. 2012). There is also evidence that the multiple-birth effect on IQ has diminished over time (Voracek and Haubner 2008, Silventoinen et al. 2013), and it may not exist anymore in the most recent birth cohorts (Webbink et al. 2008, Calvin et al. 2009). Previous studies on the zygosity differences in IQ from childhood through early adulthood have shown mixed results with higher, similar and lower IQ in MZ twins as compared with DZ twins without a clear age pattern (Silventoinen et al. 2006, Haworth et al. 2009, Keller et al. 2013, Modig et al. 2011). Furthermore, the IQ difference between MZ and DZ twins was small (i.e., less than three IQ points) in the reviewed studies and thus is not likely to strongly affect academic performance.

Second, DZ twin births have become more common during the last decades in many countries because of the increasing use of in-vitro fertilization and other infertility treatments (Imaizumi 2003). A US study found that mothers who have used fertility treatments, in-vitro fertilization in particular, tend to be older, better educated and are less likely to be smokers than those mothers who have not used these treatments (Tong et al. 2016). Higher maternal age and lower smoking rate, but not higher maternal education, were also found in a Dutch study of mothers that used in-vitro fertilization (van Beijsterveldt et al. 2011), which may indicate differences in the access to in-vitro fertilization procedures between countries. It is thus possible, especially in societies where fertility treatments are not publicly funded, that the socio-economic background of parents of DZ twins has improved relative to the parents of MZ twins since the 1980s, when in-vitro fertilization first became publicly available (Steptoe and Edwards 1976).

Third, it is possible that different social dynamics between MZ and DZ co-twins may lead to different educational outcomes. A Finnish study of adolescent twins found that MZ twins reported more dependency on their co-twin, and they spend more time together than DZ twins (Penninkilampi-Kerola et al. 2005). In that study, co-twin dependence was found to be associated with less ambitious academic careers after primary education, but otherwise it is poorly known whether this would affect educational differences between MZ and DZ twins.

The previous literature reviewed above suggests that both individual and parental education may differ between MZ and DZ twins and that these differences may have changed over time. We explored these potential differences in the present study by comparing MZ and DZ twins in a very large pooled twin database that contained information on individual, maternal and paternal education from twin birth cohorts from the late 19th century through to the early 21st century.

Data and methods

The data were derived from the CODATwins (COllaborative project of Development of Anthropometrical Measures in Twins) database described in detail previously (Silventoinen et al. 2015). The project aimed to combine height and weight data from all twin projects in the world. In addition to the anthropometric measures, the collaborators were asked to provide data on individual education for adults and parental education for children. Together, we had information on individual education from 218,482 twin individuals from 27 twin cohorts representing 15 countries. Since we were interested how the zygosity differences changed over birth cohorts, we removed those without information on birth year (104 individuals), those born before 1890 (7 individuals) and those born after 2000 (9 individuals). Thus, in the analyses, we had 218,362 twin individuals with information on

education (53% females; 39% MZ twins) including 95,208 twin pairs with information on education from both co-twins. Information on maternal education was available in 147,315 and paternal education in 143,056 twin individuals after excluding those without information on birth year (91 individuals for maternal and 89 individuals for paternal education) which came from 28 twin cohorts representing 15 countries (52% females; 38% MZ twins). These twins come from 78,748 twin families for maternal and 76,024 twin families for paternal education.

Education classifications were transformed into education years using the average length of educational level in each country. The classifications for individual education for each cohort are presented in Appendix table 1 and for maternal and paternal education in Appendix table 2. Those who reported individual (2 cases), maternal (10 cases) or paternal (7 cases) education more than 22 years were coded to have 22 years of education (i.e., equivalent of PhD education).

The data were analyzed using linear regression models with individual or parental education as the dependent variable and zygosity and twin cohort as the independent variables. We stratified the analyses by 10-year birth cohorts from 1890-1899 to 1990-1999 when analyzing individual education and to 2000 or later when analyzing maternal and paternal education. We first tested the main effect of zygosity on individual and parental education. In the analyses pooling all birth cohorts together, the results were additionally adjusted for 10-year birth cohort by including it as a classified independent variable in the regression model to also take into account possible non-linear effects of birth cohort on individual or parental education. After that we tested whether the association between zygosity and individual education is similar in males and females and whether the associations between zygosity and individual, maternal and paternal education have changed over the birth cohorts by fitting interaction terms between zygosity and sex as well as zygosity and birth cohort into the regression model. Thus, in

total, we tested four interaction effects. When individual education was analyzed, we used twin individuals after taking into account the effect of sampling twin pairs rather than unrelated individuals on standard errors by using the cluster option of Stata/SE statistical software, version 13.1 for Windows (StataCorp, College Station, TX, USA). We also replicated the analyses for 172,970 twin individuals with information on education at 30 years of age or older to confirm that the results are similar if studying completed education. Furthermore, we analyzed this between same-sex and opposite-sex DZ twins using 201,949 twin individuals for whom we knew the sex of the co-twin. When we analyzed maternal and paternal education, only one twin from each family was selected since both co-twins have the same parental education.

Since we had fewer families with information on paternal education than maternal education, we studied the representativeness of paternal education. We found that the maternal education was 0.56 (95% CI 0.47-0.66) years higher in families with information also available on paternal education as compared to families without information on paternal education, when adjusting the results for twin cohorts and 10-year birth cohorts. This suggests that in families of lower socioeconomic position, it may be more likely that we did not have information on paternal education.

Results

Figure 1 presents the mean individual, maternal and paternal education by birth cohort. The educational years increased over the birth cohorts and were higher for individual than for parental education indicating the general educational transition in the world. An exception was the cohort born 1990-1999, because in this cohort twins were generally younger and had not yet finalized their education.

Figure 1 about here

We started the analyses by studying the zygosity difference in individual education. Among both men and women, MZ twins had slightly higher education levels than DZ twins (Table 1). This difference was seen in all birth cohorts except 1890-1899 in men and 1910-1909 and 1990-1999 in women, but according to linear regression, in some birth cohorts the zygosity difference was not statistically significant because of small sample size. When data pooled according to birth year were analyzed, a statistically significant interaction effect between sex and zygosity was found ($p<0.0001$): in men, MZ twins had 0.26 (95% CI 0.21-0.31) years more education, whereas for women this difference was 0.17 (95% CI 0.12-0.21) education years when the results were also additionally adjusted for birth cohort. However, there was also an interaction effect between zygosity and birth cohort ($p<0.0001$ in both men and women): the education difference between twin types decreased, on average, by 0.09 years (95% CI 0.06-0.11) in men and by 0.10 years (95% CI 0.08-0.13) in women per 10-year birth cohort between 1890-99 and 1990-99. The comparisons between opposite-sex and same-sex DZ twins revealed no systematic differences, and in most of the birth cohorts the difference was non-significant (Appendix table 3). The analyses were repeated for participants 30 years of age or older using the pooled data to determine whether unfinished education affected the results. However, we found only slight changes (0.29, 95%CI 0.24-0.35 education years difference in males and 0.19, 95%CI 0.14-0.23 education years difference in females when comparing MZ and DZ twins) as compared to the results using all twins. Furthermore, birth cohort-specific results were very similar except in the two latest birth cohorts for which there were not enough participants aged 30 or older to conduct the analyses (results not shown, but are available from the corresponding author).

Table 1 about here

We then conducted similar analyses for parental education (Table 2). When data from all birth cohorts were pooled together and the results were additionally adjusted for birth cohorts, no zygosity effect was seen for either maternal (0.01, 95% CI -0.03-0.06 years more education in MZ twins) or paternal education (0.01, 95% CI -0.04-0.05 years more education in MZ twins). We found some evidence of an interaction effect between zygosity and birth cohort both for maternal (p=0.001) and paternal education (p<0.0001): the interaction term suggested that the zygosity difference in maternal education had changed 0.03 (95% CI 0.01-0.04) years and paternal education 0.05 (95% CI 0.03-0.07) years per 10-year birth cohort. In the earliest birth cohorts, there was some evidence of higher maternal and paternal education in MZ twins, and the difference was statistically significant in the cohort born 1920-1929 (0.31, 95% CI 0.13-0.48 years for maternal and 0.31, 95% CI 0.10-0.52 years for paternal education). However, this was no longer evident in the cohorts born after the 1950s. Instead, the fathers of DZ twins had higher education levels in the most recent cohorts born in 1990-1999 (0.16 95% CI 0.08-0.25 years) and 2000 or later (0.11 95% CI 0.00-0.22 years), but for maternal education we did not find a statistically significant difference.

Table 2 about here

Discussion

In this very large pooled twin study, we found that the education level of MZ twins was slightly higher than that of DZ twins. The difference was more pronounced in men and in the earliest birth cohorts, but even in these groups, the difference was quite small (less than 0.5 education years). We found some evidence of higher maternal and paternal education in MZ twins in the cohorts born in the 1950s or

earlier, but paternal education was higher in DZ twins in the latest birth cohorts (1990-1999 and 2000 or later). The higher paternal education in these birth cohorts may be associated with the increased use of fertility treatments, in-vitro fertilization in particular. US mothers using in-vitro fertilization tend to be older and better educated than other mothers (Tong et al. 2016), and this, in turn, may also have affected paternal education because of educational homogamy, which is well known in many societies (Blossfeld 2009). Also, the fertility treatment is expensive and a husband's income determinates the social position of the family in many societies, which may explain why the effect is particularly evident in paternal education.

The observation that MZ twins had slightly higher education than DZ twins is puzzling. We found some evidence of higher parental education in the earliest birth cohorts, but this effect disappeared in the later birth cohorts and even reversed for paternal education, thus not supporting the idea that the difference in individual education would be caused by socioeconomic background. It is also not very likely that physiological features related to twin pregnancies would be the explanation. MZ twins are somewhat lighter at birth (Hur et al. 2005) and slightly shorter in adolescence and adulthood than DZ twins (Jelenkovic et al. 2015). Low birthweight has been found to be associated with slower cognitive development (Broekman et al. 2009) and short stature in adulthood with lower IQ (Silventoinen et al. 2006) and less education (Magnusson et al. 2006). Thus, the zygosity differences in birth size and later height would predict an effect in the opposite direction of what was found.

One explanation for the slightly higher education in MZ as compared with DZ twins could be different social dynamics within MZ and DZ co-twins. In a Finnish study, MZ twins reported more dependence on the co-twin than did DZ twins, but this was related to selecting a vocational rather than an academic educational path after the compulsory primary education (Penninkilampi-Kerola et al. 2005). There is

also some evidence that cooperation is more common in MZ than in DZ twin pairs (Segal and Hershberger 1999, Segal 2002). More cooperation and a greater similarity in intelligence in MZ than DZ twins might help MZ twins continue schooling together. However, it is clear that more research is needed to find out whether this could explain the observed zygosity difference in education years.

Still another possible explanation of the differences in education between MZ and DZ twins could be differences in maternal age also affecting birth order. It is well known that older maternal age not only increases DZ births because of the increasing use of in-vitro fertilization but also natural DZ twinning rates (Derom et al. 2011). Thus, it is also likely that DZ twins more often have later parity than MZ twins. Older maternal age has been found to be associated with slightly lower IQ when adjusted for birth cohort effect (Myrskylä et al. 2013), and the number of older siblings also has a negative effect on education (Black et al. 2005, Brooth and Kee 2009). Because fertility has decreased during the 20th century (Lesthaeghe 2010), this effect may have become weaker as the average family size has decreased, which parallels our result on the decreasing difference in education between MZ and DZ twins over the birth cohorts.

It is also possible that selective participation may have affected our results. Higher than expected proportions of MZ twins have been found in many twin cohorts suggesting that participation rates have been higher in MZ than DZ twins (Silventoinen et al. 2015), and those in higher socioeconomic positions tend to more actively take part in surveys in general (Laaksonen et al. 2008). This may have led to the situation that DZ twins in the surveys are more socially selected than MZ twins. Selective participation due to differential mortality or disease occurrence could also explain these findings. Monochorionic twins, who are always MZ, have higher perinatal mortality than dichorionic twins (Oldenburg et al. 2012). Thus, we can speculate that the MZ twins who have both survived are more

robust and may obtain higher education levels. This may also explain the higher parental education in MZ twins born before the Second World War. Self-selection in the participating twin surveys has probably also affected our results in another way. It is unlikely that twins suffering from serious birth-related effects, such as cerebral palsy, took part in the surveys. These defects are much more common in monochorionic than in dichorionic twins (Pharoah and Dundar 2009), and the likely lower participation rates of these twins are thus more likely to create bias for MZ than DZ twins. Our results should thus be generalized primarily to the healthy twin populations without any serious birth-related complications affecting school performance.

Our data do not include information on singletons, and thus we cannot study whether twins differ from singletons according to their educational achievement. Previous studies on this issue have produced somewhat conflicting results. A Taiwanese study found that both test scores and the probability to attend college were lower in twins than singletons (Tsou et al. 2008). On the other hand, studies from Denmark (Christensen et al. 2006) and the Netherlands (de Zeeuw et al. 2012) did not find differences in educational achievement between twins and singletons, and a Swedish study found that twins had slightly better educational achievement than singletons (Hjern et al. 2012). It is thus likely that twins do not have poorer academic achievement in Western countries, but it is too early to argue whether this also applies to East Asia. Furthermore, in all of these previous studies the participants were born in the 1970s or later. Since there is clear evidence of the trend of lower IQs in twins compared to singletons in the earlier birth cohorts diminishing in the more recent birth cohorts (Voracek and Haubner 2008, Silventoinen et al. 2013), it is possible that twins have also been behind singletons in school performance in the earlier birth cohorts.

Our data have both strengths and weaknesses. Our main strength is the very large sample size allowing us to convincingly demonstrate even the very small difference in education levels between MZ and DZ twins. Such small differences would be difficult to find in any of the existing twin cohorts alone. We also had information on the maternal and paternal education of twins. It is also an advantage that we have twin birth cohorts over a period of more than 100 years, allowing us to study temporal changes of the zygosity differences. One limitation is that we do not have information on the academic performance of the twins at school; so, we do not know whether the difference in education is due to better school performance or rather continuing education with lower grades. Also, we do not have information on singletons and thus cannot say how the education of MZ and DZ twins compares to the general population. Furthermore, we do not have any information on maternal age and the number of older siblings, which may affect educational differences between MZ and DZ twins. We also found some evidence that paternal education may be selective since maternal education was higher in families where we also had information on paternal education than in families where this information was missing. Finally, pooling data from twin cohorts representing different countries and birth cohorts creates challenges when harmonizing education classifications. This is partly related to different ways to ask about education in the surveys – some cohorts have used only a few education levels, whereas others have used the exact years of education – but also reflects large differences in educational systems between countries and over time. Thus, we have focused only on education adjusted by twin cohort and birth cohort and consequently relative rather than absolute education.

In conclusion, MZ twins have slightly but systematically higher education than DZ twins, and this difference is more pronounced in men and in earlier birth cohorts. The difference is, however, so small that it is not likely to affect the comparability of MZ and DZ twins when studying the heritability of education or applying the twin design to other research questions. If this difference is regarded as a

problem, then special care should be paid to make MZ and DZ twins comparable for parity, family size, maternal age and other factors which may differ between MZ and DZ twins and in turn affect education. For parental education, we found only minor and unsystematic differences between MZ and DZ twins. Thus, our results suggest that the social background of MZ and DZ twins is largely comparable.

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Conflict of interest

None

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Figure legends.

Figure 1. Mean individual, maternal and paternal education years by birth cohort.

Table 1. Number of twin individuals and means, standard deviations (SD) and the regression coefficients (β) with 95% confidence intervals (CI) of individual education by sex, zygosity and birth cohort.

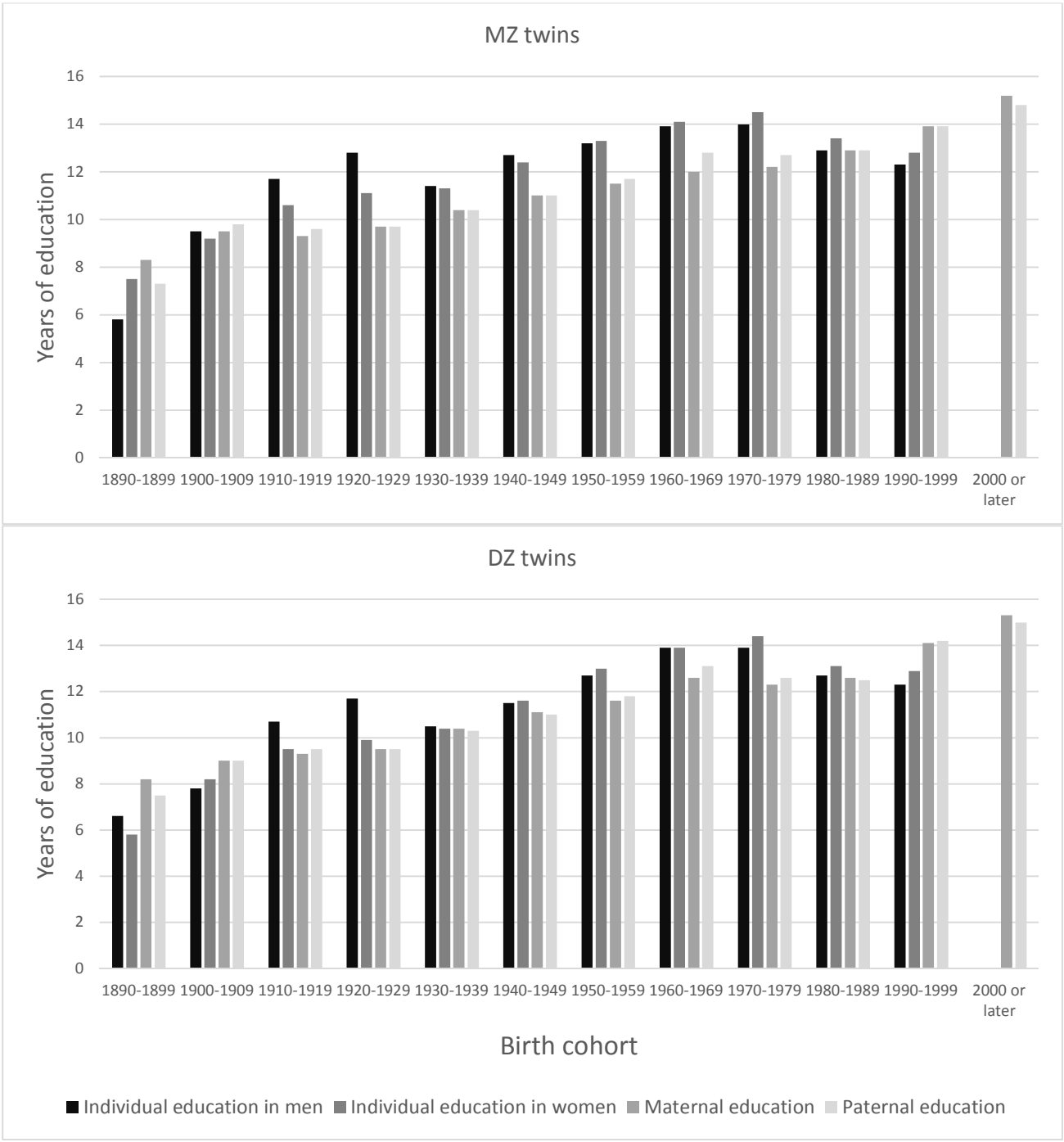
Birth cohort	MZ twins			DZ twins			Regression coefficient[1]	
	N	mean	SD	N	mean	SD	β	95% CI
Men								
1890-1899	27	5.8	3.94	41	6.6	3.81	0.32	-2.24, 2.89
1900-1909	216	9.5	4.88	353	7.8	4.41	-0.52	-1.09, 0.05
1910-1919	1585	11.7	4.16	2286	10.7	4.28	-0.41	-0.67, -0.15
1920-1929	6294	12.8	3.79	8988	11.7	4.15	-0.25	-0.39, -0.12
1930-1939	3139	11.4	4.35	7417	10.5	4.46	-0.12	-0.30, 0.07
1940-1949	6087	12.7	4.21	14297	11.5	4.40	-0.46	-0.59, -0.33
1950-1959	7496	13.2	3.64	14077	12.7	3.76	-0.26	-0.37, -0.16
1960-1969	3567	13.9	2.92	5077	13.9	2.87	-0.01	-0.15, 0.12
1970-1979	4900	14.0	2.71	5683	13.9	2.58	-0.18	-0.30, -0.06
1980-1989	3948	12.9	2.54	5117	12.7	2.47	-0.13	-0.25, -0.02
1990-1999	593	12.3	1.96	665	12.3	2.21	-0.15	-0.43, 0.12
Women								
1890-1899	57	7.5	4.15	75	5.8	2.88	-0.05	-1.39, 1.30
1900-1909	403	9.2	4.62	622	8.2	4.36	-0.17	-0.62, 0.27
1910-1919	1528	10.6	4.03	2378	9.5	4.09	0.01	-0.23, 0.24
1920-1929	3159	11.1	3.96	5428	9.9	4.02	-0.21	-0.38, -0.04
1930-1939	3988	11.3	3.95	7640	10.4	4.16	-0.24	-0.40, -0.07
1940-1949	7669	12.4	3.84	15727	11.6	4.12	-0.20	-0.31, -0.09
1950-1959	10294	13.3	3.45	15476	13.0	3.62	-0.14	-0.23, -0.05
1960-1969	6615	14.1	2.87	6948	13.9	2.85	-0.13	-0.24, -0.03
1970-1979	7124	14.5	2.88	6875	14.4	2.71	-0.13	-0.24, -0.03
1980-1989	6485	13.4	2.52	6271	13.1	2.39	-0.14	-0.24, -0.05
1990-1999	988	12.8	2.22	759	12.9	2.02	0.23	0.00, 0.47

[1]Adjusted for twin cohort; MZ twins used as the reference category

Table 2. Number of twin families and means, standard deviations and regression coefficients (β) with 95% confidence intervals (CI) of maternal and paternal education by zygosity and birth cohort.

Birth cohort	MZ twins			DZ twins			Regression coefficient[1]	
	N	mean	SD	N	mean	SD	β	95% CI
Maternal education								
1890-1899	8	8.3	2.49	5	8.2	3.90	-0.05	-3.91, 3.81
1900-1909	75	9.5	2.94	96	9.0	3.03	-0.44	-1.36, 0.47
1910-1919	713	9.3	3.07	826	9.3	2.91	-0.03	-0.33, 0.26
1920-1929	2095	9.7	3.05	2459	9.5	3.00	-0.31	-0.48, -0.13
1930-1939	1267	10.4	2.69	1864	10.4	2.75	-0.08	-0.27, 0.11
1940-1949	2794	11.0	2.62	4763	11.1	2.72	-0.11	-0.22, 0.01
1950-1959	4427	11.5	2.82	6375	11.6	2.66	-0.12	-0.22, -0.03
1960-1969	1956	12.0	3.35	2478	12.6	3.00	0.10	-0.06, 0.27
1970-1979	2451	12.2	3.37	2997	12.3	3.17	0.10	-0.06, 0.26
1980-1989	3164	12.9	3.26	4319	12.6	3.50	0.06	-0.09, 0.21
1990-1999	7009	13.9	2.90	12909	14.1	2.92	0.06	-0.01, 0.14
2000 or later	4280	15.2	3.04	9418	15.3	3.18	0.06	-0.04, 0.16
Paternal education								
1890-1899	9	7.3	2.00	4	7.5	1.91	0.17	-2.44, 2.78
1900-1909	67	9.8	3.69	89	9.0	3.37	-0.82	-1.95, 0.31
1910-1919	675	9.6	3.49	800	9.5	3.47	-0.05	-0.40, 0.31
1920-1929	2018	9.7	3.65	2378	9.5	3.42	-0.31	-0.52, -0.10
1930-1939	1219	10.4	3.08	1781	10.3	3.06	-0.08	-0.30, 0.14
1940-1949	2724	11.0	3.07	4626	11.0	3.19	-0.06	-0.21, 0.08
1950-1959	4290	11.7	3.34	6224	11.8	3.24	-0.18	-0.30, -0.06
1960-1969	1869	12.8	3.66	2365	13.1	3.36	-0.05	-0.25, 0.16
1970-1979	2308	12.7	3.48	2765	12.6	3.35	0.07	-0.11, 0.24
1980-1989	2980	12.9	3.60	4090	12.5	3.88	0.08	-0.08, 0.24
1990-1999	6875	13.9	3.03	12665	14.2	3.06	0.16	0.08, 0.25
2000 or later	4114	14.8	3.34	9089	15.0	3.34	0.11	0.00, 0.22

[1]Adjusted for twin cohort; MZ twins used as the reference category


MZ twins
Years of education
16
14
12
10
8
6
4
2
0
1890-1899
1900-1909
1910-1919
1920-1929
1930-1939
1940-1949
1950-1959
1960-1969
1970-1979
1980-1989
1990-1999
2000 or later
DZ twins
Years of education
16
14
12
10
8
6
4
2
0
1890-1899
1900-1909
1910-1919
1920-1929
1930-1939
1940-1949
1950-1959
1960-1969
1970-1979
1980-1989
1990-1999
2000 or later
Birth cohort
Individual education in men
Individual education in women
Maternal education
Paternal education

Twin Research and Human Genetics

Education in twins and their parents across birth cohorts over 100 years: an individual-level pooled analysis of 42 twin cohorts

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Supplementary table S1. Original classifications of individual education, the corresponding numbers of education years and the proportions of twin individuals by education categories and zygosity by twin cohort.[1]

Original label	Number of years	Males (%)			Females (%)		
		MZ	SSDZ	OSDZ	MZ	SSDZ	OSDZ
Australian Twin Registry							
Did not go to school	4	0	0	0	0	0	0
8 years or below	8	0	0	1	1	1	0
9 years or equivalent	9	1	0	0	3	2	3
10 years or equivalent	10	2	3	4	8	10	6
11 years or equivalent	11	3	4	3	3	3	3
12 years or equivalent	12	6	15	10	8	8	6
VET certificate I or II	13	2	0	0	3	3	5
VET certificate III or IV or trade certificate	14	14	19	20	10	8	6
VET Diploma or advanced diploma	15	10	10	7	8	7	16
Bachelor degree	16	30	25	23	26	22	23
Graduate diploma or graduate certificate	17	17	14	15	18	20	25
Postgraduate degree (masters / PhD)	18	16	11	17	14	16	8
N of twin individuals		352	80	109	1361	374	110
Berlin Twin Register Health TwiSt							
9 years of below	8	13	15	8	8	0	8
10 years	10	43	46	62	43	64	62
13 years	13	14	8	15	22	29	15
Professional School	14	10	31	8	11	7	8
College/University	18	20	0	8	16	0	8
N of twin individuals		84	13	13	76	14	13
Bielefeld Longitudinal Study of Adult Twins							
None	0	3	0	6	4	1	4
Elementary school	4	5	4	6	10	7	1
Secondary school I	9	5	7	9	8	9	7
Secondary school II	10	17	15	17	29	25	32
High school or	13	38	41	34	32	36	31

Technical high school							
Technical college	17	12	15	14	7	8	8
University	18	21	18	14	11	15	17
N of twin individuals		213	68	65	823	307	75
California Twin Program							
8 years or less	8	0	0	0	0	0	0
9-11 years	10	3	4	5	2	3	3
12 years	12	20	21	22	21	22	24
13-15 years	14	31	32	33	37	36	37
16 years	16	17	16	15	15	15	14
17 years or more	18	29	25	25	24	24	22
N of twin individuals		4052	3809	3425	6200	5683	3428
Carolina African American Twin Study of Aging[2]							
9 years or less	exact years	15	7	3	13	5	2
10 years	10	2	3	6	1	3	3
11 years	11	11	8	6	4	7	5
12 years	12	40	32	36	27	36	39
13 years	13	3	3	5	4	3	8
14 years	14	10	14	14	13	15	9
15 years	15	3	9	3	2	2	8
16 years	16	15	15	15	20	15	20
17 years	17	0	0	6	2	0	0
18 years	18	2	3	3	7	8	8
19 years	19	0	4	0	1	3	0
20 years	20	0	3	3	6	3	0
N of twin individuals		62	72	66	111	118	66
Colorado Twin Registry							
None	0	0	0	0	0	0	0
Elementary/Junior High School	9	1	1	0	1	2	1
GED or High School Diploma	12	47	51	36	39	43	28
Vocational or Technical Diploma	13	3	2	8	5	8	7
Associate degree or R.N. Diploma	14	9	10	8	9	9	7
Bachelor Degree	16	34	33	40	40	34	48
Master’s Degree	18	5	3	8	5	4	8
Doctorate: M.D.,	20	1	1	0	1	1	1

Ph.D., J.D., etc.							
N of twin individuals		507	370	237	686	412	241
Finnish Older Twin Cohort							
Less than Primary School	3	3	3	1	3	4	0
Primary School	6	40	44	70	40	42	62
Primary School and at least 1 year of education such as vocational training	7	31	30	5	22	24	4
Upper Primary School	9	4	4	10	8	7	16
Junior High School and at least 1 year of education such as vocational training	10	9	9	2	11	10	3
High School graduate	12	1	1	13	2	2	15
High School graduate and at least 1 year of education	13	5	4	0	9	7	0
University degree	18	7	6	0	5	5	0
N of twin individuals		3378	8022	1445	4082	8380	1455
FinnTwin12							
No Primary School	6	0	0	1	0	0	0
Primary School	9	6	8	6	4	5	6
Vocational School	11	39	35	38	24	26	23
Matriculation examination	12	43	46	39	52	42	43
Diploma from University of Applied Sciences	16	7	7	7	12	17	19
University Graduate	18	5	4	8	9	11	9
N of twin individuals		478	443	462	658	551	577
FinnTwin16							
Primary School	9	4	3	4	2	2	3
Vocational School	11	23	32	31	15	18	17
Community College degree or matriculation examination	12	19	20	22	24	21	23
Diploma from University of Applied Sciences	16	26	22	20	29	27	27
University graduate	18	29	23	23	30	31	30

N of twin individuals		506	611	621	794	671	765
East Flanders Prospective Twin Survey							
No diploma	3	0	0	0	0	0	0
Primary education or special primary education	6	1	0	2	1	0	2
Special secondary education or lower secondary general or lower secondary technical	9	8	7	12	5	3	7
Lower secondary professionals or higher secondary general or higher secondary technical or higher secondary professionals	12	57	59	60	54	50	51
Non-university higher education: short type	14	17	16	16	25	34	33
Non-university higher education: long type	16	8	7	5	5	4	2
University and post-university	18	10	12	5	9	9	5
N of twin individuals		226	92	43	256	98	43
Hungarian Twin Registry							
Less than 8 years (below lower secondary, no vocational education)	6	6	6	13	9	8	12
9-10 years (lower secondary, no vocational education)	9	15	6	6	12	14	0
11-12 years (lower secondary plus vocational school)	11	19	44	25	14	28	35
13-16 years (upper secondary, vocational college)	14	20	0	19	17	20	6
University level or equivalent (e.g.	18	41	44	38	48	30	47

university of applied sciences)							
Doctoral degree	20	0	0	0	0	0	0
N of twin individuals		18	16	146	50	17	54
Italian Twin Registry							
None	0	0	0	0	0	0	0
Elementary School (5 years)	5	3	3	3	3	3	4
Middle School (3 years)	8	18	21	20	13	14	15
High School (5 years)	13	65	64	64	66	69	67
University (4/5 years)	16	14	12	13	18	14	14
N of twin individuals		2054	1271	1377	3421	1910	1381
Korean Twin-Family Register							
Did not go to school	0	0	0	0	0	0	0
Dropped out of Elementary School	3	0	0	0	1	0	0
Graduated Elementary School or dropped out of Middle School	6	5	8	0	4	9	0
Graduated Middle School or dropped out of High School	9	8	8	0	6	5	0
Graduated High School	12	28	27	0	37	46	0
Graduated Community College	13	11	13	0	8	10	0
Dropped out of University	14	3	3	0	3	2	0
Graduated University	18	35	34	0	34	27	0
Graduate School or more	20	11	6	0	7	2	0
N of twin individuals		397	106	0	699	133	0
Mid-Atlantic Twin Registry							
Elementary School (0-7 years)	6	1	2	2	1	1	0
Elementary School (8 years)	8	2	3	3	3	3	3
High School (1-3 years)	10	7	7	10	8	9	8
High School (4 years)	12	27	29	29	36	36	36
College (1-3 years)	15	24	25	24	28	27	25

College (4+ years)	18	39	36	33	25	24	27
N of twin individuals		1537	1142	1317	3643	2316	1322
Minnesota Twin Family Study[2]							
9 years or less	exact years	16	20	13	18	21	14
10 years	10	1	1	1	0	1	1
11 years	11	1	2	1	1	1	1
12 years	12	25	27	30	33	32	35
13 years	13	7	5	7	11	11	13
14 years	14	13	12	11	9	8	9
15 years	15	3	4	4	4	4	5
16 years	16	18	17	18	15	15	16
17 years	17	6	5	5	3	3	3
18 years	18	5	4	4	3	3	3
19 years	19	3	2	2	1	1	1
20 years	20	2	1	2	1	1	0
21 years	21	2	1	2	1	1	1
N of twin individuals		1145	979	815	1530	1393	794
Murcia Twin Registry							
Illiterate	0	0	0	0	0	0	0
No studies (just reading and writing)	3	0	2	1	0	0	2
Primary studies	4	4	3	9	9	13	10
General secondary education	6	26	33	34	31	39	40
Professional education (FP1)	7	28	27	24	27	26	22
Superior secondary education	9	9	7	4	12	7	6
Professional education (FP2) or	12	20	17	15	10	8	12
University – medium degree	15	6	7	5	8	4	3
University – high degree	17	6	4	8	3	3	4
N of twin individuals		250	315	269	431	435	267
NASC-NRC Twin Cohort[2]							
9 years or less	exact years	8	10	0	0	0	0
10 years	10	5	5	0	0	0	0
11 years	11	4	4	0	0	0	0

12 years	12	30	29	0	0	0	0
13 years	13	11	11	0	0	0	0
14 years	14	7	9	0	0	0	0
15 years	15	3	3	0	0	0	0
16 years	16	17	15	0	0	0	0
17 years	17	3	2	0	0	0	0
18 years	18	6	5	0	0	0	0
19 years	19	2	2	0	0	0	0
20 years	20	5	5	0	0	0	0
N of twin individuals		4885	4965	0	0	0	0
Netherlands Twin cohort							
Primary School only	9	2	3	3	2	2	2
Lower Vocational School or Lower Secondary School	11	14	13	10	14	16	12
Intermediate Vocational School or Intermediate/Higher Secondary School	13	37	50	47	25	34	46
Higher Vocational School	14	25	23	26	31	28	26
University	18	22	11	14	29	20	14
N of twin individuals		851	540	655	2064	1061	655
Norwegian Twin Registry							
Compulsory School	9	30	32	0	32	31	0
Secondary School, low level	11	37	38	0	45	43	0
Secondary School, high level	14	12	12	0	13	14	0
University	18	21	19	0	10	11	0
N of twin individuals		1893	2262	0	2480	2786	0
Osaka University Aged Twin Registry[2]							
12 years or less	12	49	64	20	33	38	40
13	13	8	2	0	1	8	0
14	14	3	5	20	18	31	0
15	15	0	0	0	9	10	20
16	16	26	19	40	29	12	40
17	17	1	0	0	3	2	0
18 years more	18	13	10	20	7	0	0
N of twin individuals		86	42	5	234	52	5
Qingdao Cohort of							

Adults							
Illiteracy or half-illiteracy	0	2	2	1	2	1	4
Primary School	6	14	19	10	11	8	22
Junior High School	9	50	48	50	38	43	34
Senior High School	12	20	18	20	24	24	22
Bachelor or diploma	16	14	11	19	26	25	17
Master degree and above	18	0	2	0	0	0	0
N of twin individuals		292	96	94	328	102	94
Queensland Twin Register							
Pre-primary education	6	0	0	0	0	0	0
Primary education or first stage of basic education	9	2	2	3	4	4	2
Lower secondary or second stage of basic education	12	13	14	14	20	19	16
Upper secondary education	13	16	20	20	21	21	22
Post-secondary non-tertiary education	14	30	30	29	23	24	25
First stage of tertiary education	16	23	19	19	21	21	22
Second stage of tertiary education	18	15	15	15	11	11	11
N of twin individuals		3028	2200	2213	5489	3830	2240
Sri Lanka Twin Study							
Not had school education	0	1	0	1	1	1	2
From grade 1 up to grade 5	5	4	6	5	5	8	4
From grade 6 up to O/LS	9	42	50	49	43	42	45
Passed O/LS	12	17	17	14	16	15	15
Up to A/LS or passed A/L	14	27	19	27	27	26	25
University or higher	18	10	8	4	8	8	9
N of twin individuals		344	212	253	487	302	253
Swedish Twin Cohort							
Elementary school	9	81	84	36	81	85	37

Secondary School	12	12	10	40	10	9	35
Bachelor degree	14	2	2	8	3	2	9
Master degree	18	5	4	16	5	4	19
N of twin individuals		4311	6664	5374	5159	7420	5177
Swedish Young Male Twins Study							
Primary School < 9 years	7	0	0	0	0	0	0
Primary School 9 years	9	4	4	0	0	0	0
Secondary School 10-11 years	11	10	9	0	0	0	0
Secondary School >= 12 years	13	36	39	0	0	0	0
Post-secondary School < 15 years	14	17	16	0	0	0	0
Post-secondary School >= 15 years	16	34	31	0	0	0	0
PhD >= 19 years	19	1	1	0	0	0	0
N of twin individuals		1218	912	0	0	0	0
Vietnam Era Twin Study of Aging[2]							
9 years or less	exact years	0	1	0	0	0	0
10 years	10	1	1	0	0	0	0
11 years	11	2	1	0	0	0	0
12 years	12	38	40	0	0	0	0
13 years	13	5	7	0	0	0	0
14 years	14	22	20	0	0	0	0
15 years	15	3	2	0	0	0	0
16 years	16	21	18	0	0	0	0
17 years	17	2	1	0	0	0	0
18 years	18	5	7	0	0	0	0
19 years	19	1	0	0	0	0	0
20 years	20	1	2	0	0	0	0
N of twin individuals		698	530	0	0	0	0
Washington State Twin Registry							
Never attended school or only attended kindergarten	0	0	0	0	0	0	0
Grade 1-8	7	5	4	5	5	4	5
Grade 9-11	10	8	8	8	5	4	5
Grade 12/ High School	12	24	26	25	21	24	24

Graduate/GED							
Some College	13	22	21	24	25	25	26
Associate's degree	14	7	8	7	9	9	8
Bachelor's degree	16	20	19	19	21	20	19
Graduate or professional degree	18	15	15	12	14	14	13
N of twin individuals		3057	1394	1770	5372	2441	1772

[1]Only twin individuals with information on the sex of co-twins are included to separate same-sex and opposite sex pairs.

[2]Education reported as exact number of years

Supplementary table S2. Original classifications of maternal and paternal education, the corresponding number of education years and the proportions of twin individuals by parental education categories and zygosity in participating twin cohorts.

Original label	Number of years	Maternal education (%)		Paternal education (%)	
		MZ twins	DZ twins	MZ twins	DZ twins
Australian Twin Registry[1]					
11 years or less	exact years	48	48	43	44
12	12	10	12	10	11
13	13	4	4	2	3
13	14	5	3	8	6
15	15	9	6	9	7
16	16	12	12	14	15
17	17	8	9	7	8
18	18	4	4	7	5
N of twin individuals		1577	602	1554	594
Boston University Twin Project					
Less than 7th grade	6	0	0	0	1
Junior High School	9	1	1	1	1
Some High School (10th/11th grade)	10	0	1	2	2
High School graduate	12	8	2	10	7
Trade School	13	3	2	4	1
Some College	14	9	14	14	16
College graduate	16	36	45	36	40
Some graduate study	17	8	5	5	6
Graduate degree	18	36	32	29	26
N of twin individuals		284	326	280	319
California Twin Program					
8 years or less	8	8	8	11	13
9-11 years	10	9	9	9	10
12 years	12	38	38	29	30
13-15 years	14	25	24	22	21
16 years	16	10	10	12	11
17 years of more	18	10	10	16	15
N of twin individuals		10202	16205	9935	15884
Carolina African American Twin Study of Aging[1]					
11 years or less	exact	42	44	56	52

	years				
12 years	12	40	34	25	29
13 years	13	2	1	1	3
14 years	14	5	4	5	2
15 years	15	1	0	1	1
16 years	16	6	11	8	9
18 years	18	2	4	2	2
19 years	19	1	0	1	0
20 years or more	exact years	0	1	2	1
N of twin individuals		139	276	117	217
Child and Adolescent Twin Study in Sweden					
Basic education (year 0-9) or equivalent	9	4	5	12	11
High School or equivalent	12	48	44	52	52
University or college level	18	48	51	36	37
N of twin individuals		1040	1921	1018	1874
Colorado Twin Registry[1]					
11 years or less	exact years	2	3	4	2
12 years	12	24	21	21	18
13 years	13	15	12	14	9
14 years	14	17	13	13	15
15 years	15	5	5	5	4
16 years	16	24	28	26	30
17 years	17	1	4	3	3
18 years	18	9	12	9	13
19 years	19	1	1	2	2
20 years or more	exact years	1	1	4	3
N of twin individuals		1018	982	901	884
East Flanders Prospective Twin Survey					
No diploma	3	6	6	4	3
Primary or special primary education	6	19	21	12	15
Special secondary or lower secondary general or lower secondary	9	14	13	15	21

technical education					
Lower secondary professional or higher secondary general or higher secondary technical or higher secondary professional education	12	33	32	32	25
Non-university higher education: short type	14	25	21	18	12
Non-university higher education: long type	16	0	1	6	6
University and post-university education	18	4	5	12	19
N of twin individuals		447	300	432	291
FinnTwin12					
Less than Lower Primary School	3	0	0	0	0
Less than Lower Primary School+ maximum of two years of vocational training	4	0	0	0	0
Less than Lower Primary School+ more than two years of vocational training	5	0	0	0	0
Lower Primary School	6	12	15	22	26
Lower Primary School+ maximum of two years of vocational training	7	8	8	12	12
Lower Primary School+ more than two years of vocational training	8	7	9	14	14
Primary School	9	10	7	7	5
Primary School+ maximum of two years of vocational training	10	9	11	7	6
Primary School+ more than two years of vocational training	11	17	14	13	13
Matriculation examination	12	3	3	2	1
Matriculation examination + maximum of two years of vocational training	13	0	0	0	0

Matriculation examination + more than two years of vocational training	14	8	6	2	2
Matriculation examination + more than two years of vocational training	16	11	11	7	8
University degree	18	13	15	14	14
N of twin individuals		1646	3153	1464	2838
FinnTwin16					
Primary education or other education	9	26	25	22	20
Primary education and at least one year of high school or vocational school	10	44	50	55	57
Matriculation examination	12	4	4	4	5
Matriculation examination and one year or education	13	23	18	15	14
University degree	18	2	3	5	4
N of twin individuals		914	1908	844	1736
Gemini study					
No qualification	4	3	5	10	8
CSE, GCSE, O level	9	15	13	22	19
Vocational qualification (GNVQ, BTEC	10	16	13	15	15
A or AS level	12	13	10	7	8
HNC or HND	14	11	10	10	10
Undergraduate	16	28	29	26	24
Postgraduate	18	14	19	11	18
N of twin individuals		1160	2335	1112	2249
Italian Twin Registry					
None	0	0	0	0	0
Elementary School (5 years)	5	2	2	3	2
Middle School (3 years)	8	19	18	25	19
High School (5 years)	13	50	49	45	45
University (4/5 years)	18	29	32	28	34
N of twin individuals		2009	3758	1985	3701
Korean Twin-Family Register					
Did not go to school	0	12	20	5	10

Dropped out of elementary school	3	12	10	6	8
Graduated elementary school or dropped out of middle school.	6	32	36	29	25
Graduated middle school or dropped out of high school	9	12	8	11	14
Graduated high school	12	25	18	26	19
Graduated community college	13	1	0	1	3
Dropped out of university	14	1	0	4	5
Graduated university	18	6	7	14	14
Graduate school or more	20	0	0	3	2
N of twin individuals		771	155	771	155
Longitudinal Israeli Study of Twins[1]					
11 years or less	exact years	0	1	1	4
12 years	12	24	17	28	26
13 years	13	3	4	4	5
14 years	14	3	8	9	9
15 years	15	10	18	16	13
16 years	16	17	22	13	17
17 years	17	17	8	6	8
18 years	18	16	12	9	8
19 years	19	2	2	3	3
20 years or more	exact years	7	8	11	8
N of twin individuals		175	568	159	519
Michigan Twins Study					
8th grade or less	8	1	0	1	1
9th grade	10	0	1	1	1
10th grade	11	1	1	1	1
11th grade	12	1	1	2	2
12th grade	13	17	14	24	21
1 year of college	14	11	10	10	9
2 years of college	15	15	15	13	14
3 years of college	16	7	7	4	4
4 years of college	17	22	23	20	20
5 years of college	18	7	6	4	4
6 years of college	19	6	7	6	6
Post graduate	22	14	16	14	17
N of twin individuals		5228	12155	5082	11877

Mid-Atlantic Twin Registry					
Elementary School (0-7 years)	6	12	13	16	18
Elementary School (8 years)	8	16	16	19	18
High School (1-3 years)	10	14	13	14	14
High School (4 years)	12	32	30	23	21
College (1-3 years)	15	15	16	13	13
College (4+ years)	18	10	12	16	17
N of twin individuals		4553	5303	4372	5118
Minnesota Twin Family Study (adults)[1]					
9 years or less	exact years	22	28	38	45
10 years	10	4	4	4	4
11 years	11	3	3	2	2
12 years	12	38	37	27	26
13 years	13	7	6	4	3
14 years	14	11	9	7	6
15 years	15	3	3	2	1
16 years	16	11	9	10	8
17 years	17	1	1	1	1
18 years	18	1	1	2	1
19 years	19	0	0	1	0
20 years	20	0	0	3	2
N of twin individuals		2324	4177	2326	4138
NAS-NRC Twin Cohort					
11 years or less	exact years	51	57	63	64
12	12	34	26	20	19
13	13	2	3	2	1
14	14	5	6	4	3
15	15	1	1	1	1
16	16	6	8	7	7
17	17	0	0	0	1
18 or more	exact years	0	1	3	4
N of twin individuals		1962	1815	1969	1846
Netherlands Twin cohort (children)					
Primary education	9	4	5	6	6
Pre-vocational secondary education	12	29	30	29	28

Secondary vocational education	14	42	41	35	35
Higher professional education	16	18	16	17	18
University	18	7	7	13	13
N of twin individuals		11453	22885	11168	22356
Norwegian Twin Registry					
Compulsory School	9	75	76	72	72
Secondary School, low level	11	19	18	17	17
Secondary School, high level	14	4	4	5	6
University	18	2	2	6	6
N of twin individuals		4743	6177	4648	6084
Portugal Twin Cohort					
Incomplete Primary School	3	2	5	6	7
1st cycle	6	47	36	45	37
2nd cycle	9	9	19	15	20
3rd cycle	12	14	11	15	10
Secondary education	14	22	14	13	21
Bachelor's or equivalent level	16	0	4	1	2
Master's or equivalent level	18	6	10	4	3
Doctoral or equivalent level	20	0	1	0	0
N of twin individuals		172	258	168	250
Qingdao Twin Cohort of Children					
Illiteracy	3	4	4	1	1
Primary School	6	17	20	9	7
Junior School	9	46	44	44	54
Senior School	12	16	15	25	19
Secondary School	13	6	7	8	6
Junior College	14	7	5	9	6
College	18	4	5	5	8
N of twin individuals		500	443	470	399
Southern California Twin Register					
Less than 7th grade	6	0	0	0	0
Junior high school	9	0	0	0	0
Partial high school 10th or 11th grade	10	19	13	22	16

High school graduate	12	18	17	26	24
Partial college, at least one year of specialized training	14	30	32	19	25
Standard college or university graduation	16	23	25	21	23
Graduate/professional training	18	10	13	12	13
N of twin individuals		665	858	640	822
South Korea Twin Registry					
Elementary School	6	3	2	2	2
Junior High School	9	5	5	4	4
Senior High School	12	56	48	46	31
University	16	32	42	41	53
Graduate level and above	18	3	4	6	9
N of twin individuals		1337	932	1337	932
TCHAD-study					
Compulsory (9-year comprehensive) school	9	16	13	22	20
2 years in upper secondary school	11	46	42	37	35
3-4 years in upper secondary school	13	9	13	17	16
University degree	18	29	32	24	29
N of twin individuals		962	1387	878	1216
Texas Twin Project[1]					
11 years or less	exact years	9	4	5	4
12 years	12	1	1	3	1
13 years	13	5	7	11	11
14 years	14	1	2	0	2
15 years	15	3	6	2	2
16 years	16	18	15	15	17
17 years	17	2	6	4	5
18 years	18	30	28	37	30
19 years	19	5	5	3	5
20 years or more	exact years	25	27	19	24
N of twin individuals		185	344	185	336
Turkish Twin Study					
Illiterate	3	15	20	5	3
Primary	6	47	53	30	45
Secondary	9	11	12	12	19

High	12	18	8	28	22
University	16	8	6	21	11
Graduate	18	1	0	3	1
N of twin individuals		213	371	211	371
Vietnam Era Twin Registry[1]					
11 years or less	exact years	29	32	44	48
12	12	51	55	34	36
13	13	7	5	6	6
14	14	4	3	5	3
15	15	1	2	1	2
16	16	5	2	5	3
17	17	1	0	1	1
18 years or more	exact years	1	1	3	1
N of twin individuals		693	528	679	524
West Japan Twins and Higher Order Multiple Births Registry					
Junior High School	9	0	0	1	0
Senior High School	12	23	15	23	14
Junior College	14	21	29	1	1
Technical School	15	15	14	9	4
University	16	36	37	55	66
Graduate School	18	4	5	10	14
N of twin individuals		414	407	414	407

[1]Education reported as exact number of years

Supplementary table S3. The regression coefficients of individual education for same-sex and opposite-sex dizygotic twins as compared to monozygotic twins by sex and birth year.

Birth year	Same-sex DZ twins[1]		Opposite-sex DZ twins[1]		P-value of zygosity[1]
	β	95% CI	β	95% CI	
Men					
1890-1899	-0.15	-3.71, 3.41	-3.29	-7.69, 1.10	0.1707
1900-1909	-0.39	-1.10, 0.31	-1.57	-2.93, -0.20	0.0563
1910-1919	-0.36	-0.64, -0.07	-0.55	-1.03, -.06	0.0144
1920-1929	-0.25	-0.39, -0.11	-0.27	-0.55, 0.01	0.0013
1930-1939	-0.11	-0.32, 0.11	-0.09	-0.33, 0.15	0.6013
1940-1949	-0.37	-0.53, -0.22	-0.60	-0.75, -0.45	<0.0001
1950-1959	-0.29	-0.42, -0.18	-0.24	-0.36, -0.11	<0.0001
1960-1969	0.03	-0.13, 0.20	-0.06	-0.21, 0.10	0.5065
1970-1979	-0.16	-0.29, -0.02	-0.25	-0.40, -0.10	0.0026
1980-1989	-0.13	-0.27, 0.01	-0.13	-0.26, 0.00	0.0885
1990-1999	-0.40	-0.78, -0.02	0.14	-0.14, 0.43	0.0178
Women					
1890-1899	-0.56	-2.28, 1.16	-1.71	-4.11, 0.68	0.3399
1900-1909	-0.05	-0.54, 0.45	-0.59	-1.70, 0.52	0.5784
1910-1919	-0.06	-0.33, 0.20	0.24	-0.16, 0.65	0.3447
1920-1929	-0.22	-0.41, -0.02	-0.03	-0.30, 0.25	0.0774
1930-1939	-0.26	-0.45, -0.07	-0.09	-0.32, 0.13	0.0241
1940-1949	-0.13	-0.26, 0.00	-0.22	-0.36, -0.08	0.0067
1950-1959	-0.17	-0.27, -0.06	-0.02	-0.13, 0.10	0.0028
1960-1969	-0.14	-0.26, -0.01	-0.13	-0.26, 0.00	0.0459
1970-1979	-0.12	-0.24, 0.01	-0.15	-0.28, -0.01	0.0585
1980-1989	-0.15	-0.27, -0.03	-0.14	-0.26, -0.03	0.0142
1990-1999	0.33	0.05, 0.62	0.10	-0.16, 0.36	0.0642

[1]Adjusted for twin cohort