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TWIN SPECIFIC RISK FACTORS IN PRIMARY SCHOOL ACHIEVEMENTS

Based on Eveline L. de Zeeuw, Catherina E. M. van Beijsterveldt, Eco J. C. de Geus and Dorret I. Boomsma (2011). Twin Specific Risk Factors in Primary School Achievements. *Twin Research and Human Genetics, 15 (1),* p. 107-115.

The main aim of this study was to examine twin specific risk factors that influence educational achievement in primary school. We included prenatal factors that are not unique to twins, except for zygosity, but show a higher prevalence in twins than in singletons. In addition, educational achievement was compared between twins and their non-twin siblings in a within-family design. Data were obtained from parents and teachers of approximately 10,000 twins and their non-twin siblings registered with the Netherlands Twin Register. Teachers rated the proficiency of the children on arithmetic, language, reading, and physical education, and reported a national educational achievement test score. Structural equation modeling showed that gestational age, birth weight, and sex were significant predictors of educational achievement, even after correction for socioeconomic status. Mode of delivery and zygosity did not have an effect, while parental age only influenced arithmetic. Mode of conception, incubator time, and birth complications negatively affected achievement in physical education. The comparison of educational achievement of twins and singletons showed significantly lower ratings on arithmetic, reading, and language in twins, compared to their older siblings, but not compared to their younger siblings. Low birth weight and small for gestational age were the most important risk factors for lower educational achievement of twins in primary school. It seems that the differences observed between twins and their non-twin siblings in educational achievement can largely be explained by birth order within the family.

INTRODUCTION

In the last decade, the twin birth rate was more than 32 per 1000 live births and twins are currently estimated to make up almost 2 per cent of the world population (Martin et al., 2010). Sharing the womb with another fetus can influence prenatal as well as perinatal conditions and outcomes. Fetuses have to compete for nutrition and, near the end of the pregnancy, for the best position in the uterus (Powers & Kiely, 1994). Crowding is a major risk factor for early birth and, as a consequence, twins are born, on average, 3 weeks earlier and with lower birth weights than singletons (Gielen et al., 2010). Second-born twins seem to suffer more from the sharing of the womb (Prins, 1994). For example, they have even lower mean birth weights than first-born twins (van Baal & Boomsma, 1998). After birth, most parents of twins perceive the first years when caring for two newborns as stressful and exhausting (Hay & O'Brien, 1984). As a consequence, twins may become each other's competitor when parents have to divide their attention between them. For example, it appears that mothers speak less often directly to one of the twins as an individual (Rutter & Redshaw, 1991). The difference in intrauterine environment and the limited resources in the family environment could influence the development of twins. Twin status is associated with several other potential risk factors for cognitive development, including assisted conception, prematurity, low birth weight, cesarean section, time spent in an incubator, and birth complications. These factors are not unique to twins, but are more prevalent in twins than in singletons, while risks associated with zygosity are specific to twins.

Almost 16 per cent of twins are born after assisted reproductive therapies (ART), compared to approximately 1 per cent of singletons (Wright et al., 2008). This difference is due to both the fertility drugs that increase the chance of several eggs being released at the same time and the practice of implanting more than one embryo, which was common in the early years of in vitro fertilization (IVF). A review of studies about the outcomes of children born after ART concluded that their cognitive development is comparable to that of naturally conceived children (Wilson et al., 2011). Another review also concluded that there is no evidence for differences in educational achievement between children born after assisted conception and children born after natural conception (Wagenaar et al., 2008).

More than half of all twins are born premature (gestational age of less than 37 weeks) and have low birth weight, according to the definition of the World Health Organization (less than 2500 grams), compared to less than 10 per cent of singletons (Martin et al., 2010). As a consequence, twins are placed in an incubator more often and for a longer period of time. However, the average difference in birth weight between twins and singletons is over 1000 grams (De Geus et al., 2001), and whether growth retardation is the same in twins as in singletons is still unknown (Phillips, Davies & Robinson, 2001). It seems that, for academic performance, the relative birth weight of twins is more important than their absolute birth weight (Christensen et al., 2006). However, after correcting for several potential confounders, a relationship between low birth weight and lower IQ (Aylward, 2005; Matte et al., 2001; Shenkin, Starr & Deary, 2004) and poorer educational achievement (Lundgren & Tuvemo, 2008) has been found in singletons as well as in twins.

Complications occur more frequently during the birth of twins and a cesarean section is more common than for singletons. While the pressure on the brain of children born through vaginal delivery might have a negative effect on the child’s brain, it has also been suggested that the exposure of the developing brain to anesthesia during cesarean delivery has a negative influence on cognitive development (Khadem & Khadivzadeh, 2010). Yet, learning disabilities occur just as often in children born after cesarean section as in children born after vaginal delivery (Sprung et al., 2009), and there appears to be no association between intelligence and mode of delivery (Khadem & Khadivzadeh, 2010).

Finally, some adverse effects occur more often in monozygotic twins than in dizygotic twins. For example, monozygotic twins were more likely to have low birth weight or to be born preterm (Gielen et al., 2010; Hoskins, 1995). However, according to a meta-analysis, the difference in intelligence between twins and singletons was not influenced by zygosity status (Voracek & Haubner, 2008). Whether this also applies to educational achievement has not yet been determined. The question of whether twins differ from singletons in their cognitive abilities due to the risk factors associated with their twin status has been the focus of research for a long time (Hay & O'Brien, 1984; Record, McKeown & Edwards, 1970; Vandenberg, 1984). A recent meta-analysis of studies on differences in intelligence between twins and singletons concluded that, on average, twins seem to have lower IQs than singletons (Voracek & Haubner, 2008). The estimates of the difference in intelligence range from 5.1 to only 0.5 IQ points in studies from different countries, populations, and birth cohorts. Several studies based on birth cohorts from many years ago found a lower intelligence in twins (Deary et al., 2005; Record, McKeown & Edwards, 1970; Ronalds, de Stavola & Leon, 2005). However, prenatal and perinatal care has improved in the past decades, which may have reduced this difference in cognitive ability between twins and singletons. A study from the Netherlands found no evidence of differences in cognitive performance between adult twins and their non-twin siblings (Posthuma et al., 2000). A longitudinal study measured IQ scores in a large sample of singletons and approximately 6000 twins who went to primary school between 1994 and 2003. The study found that there was only a small difference (less than 1 IQ point) at ages 6 and 8 years, which disappeared at age 12 years (Webbink et al., 2008).

Intelligence is the single best predictor of educational achievement and correlates approximately 0.5 with school grades (Bartels et al., 2002). Therefore, when a difference in IQ is found between twins and singletons, the educational achievement of twins will probably be affected as well. Only a few studies have looked at the differences in educational achievement between twins and singletons. A 1983–1985 birth cohort study from Taiwan found that twins had lower scores and were less likely to attend college, even when the data were adjusted for birth weight, gestational age, birth order within the family, sex, and socioeconomic status (Tsou et al., 2008). The scores of Dutch female twins on an educational achievement test were also lower than those of singleton controls from the same grade and those of an older brother or sister. However, the twins performed just as well as the total Dutch female population and the difference found between twins and singletons was attributed to a bias in the selection of the control group (Cohen et al., 2002).

As with any phenotype, controlling for differences between twin and singleton families has been a problem in these studies. Selection bias, differences in social background, and family composition may explain differences between twins and singletons. Furthermore, most studies on the difference in educational achievement between twins and singletons have not corrected for the possible confounding influence of birth order within a family, which has been suggested to have an effect on intelligence. One study reported IQ to be approximately two IQ points lower in children with one older sibling (Bjerkedal et al., 2007). Another study found little effect of the number of older siblings on the difference in IQ between singletons and twins (Ronalds, De Stavola & Leon, 2005).

The present study used teacher ratings of different school subjects for twins in primary school from twin families on the Netherlands Twin Register. The data from teacher surveys on non-twin siblings of these twins provided a perfect match on social and family background. The first objective of our study was to determine the influence of several risk factors associated with twin birth on the educational achievement of twins. The second objective was to investigate whether the difference in intelligence found between twins and singletons also exists for educational achievement, taking into account the possibility that the birth or der of twins within a family may explain part of the difference in educational achievement between twins and singletons.

METHODS

PARTICIPANTS

The Netherlands Twin Register (NTR), established in 1987 by the Department of Biological Psychology at the VU University in Amsterdam, registers approximately 40 per cent of all multiple births in the Netherlands. The parents of these twins receive a survey about the development of their children every two years until the twins are 12 years old. At ages 7, 9, and 12 years, when the twins are attending primary school, parents are asked consent to approach the teacher(s) of their children with a survey. Since 2005, the siblings of twins in primary school are also included in the database (Bartels et al., 2007; Boomsma et al., 2002; Boomsma et al., 2006).

Information about the birth of the twins was obtained with the first survey sent to the parents shortly after registration of the newborns. This survey asks mothers to report on several birth characteristics, including maternal and paternal age at birth, mode of conception, gestational age, birth weight, time in an incubator, mode of delivery, birth complications, and sex. The educational achievement data were obtained with a survey sent to the primary school teachers. Teachers and parents were asked to report the scores of a national educational achievement test administered in the last grade of primary school (Cito, 2002).

The present study analyzed data from 7-year-old twins (*M* = 7.5, *SD* = .5) from birth cohorts 1992–2003 to determine the influence of twin and family risk factors on educational achievement in primary school (*N* = 9917). Questionnaires of children attending specialized education (*N* = 127) and questionnaires missing educational achievement data (*N* = 374) were excluded from this sample. The sample included data of children from 4272 complete twin pairs (*N* = 8544) and 872 twins from incomplete pairs. Incomplete data were due to one of the teachers not returning the questionnaire when the twins were in different classes or schools.

Because not all twins in the sample had reached the last grade of primary school yet, scores on the national test of educational achievement were not yet available for some of the twins. The data available in this sample included both teacher ratings and national educational achievement test score (*N* = 3262), only teacher ratings (*N* = 5944), or only a national educational achievement test score (*N* = 210). In this sample, 3012 twins belonged to an opposite-sex twin pair. For the twins belonging to a same-sex twin pair, determination of zygosity status was based on DNA polymorphisms (*N* = 603), on the first survey sent to the mother (*N* = 215), or on a parental questionnaire with 10 items about resemblance in appearance and frequency of mistaking the children for each other (*N* = 5530). With this last method, zygosity can be established with an accuracy of almost 93 per cent (Rietveld et al., 2000). Zygosity data was missing for 56 twins from 34 families. Information on the country of birth showed that 95.0% of mothers and 93.3% of fathers were born in the Netherlands, 1.4% and 1.9% in another Western country, and 1.5% and 2.3% in a non-Western country. For 1.9% of the mothers and 2.5% of the fathers, the country of birth was unknown.

For the analysis of the difference between twins (*M* = 9.1 years, *SD* = 1.8) and their non-twin siblings (*M* = 9.8 years, *SD* = 2.1), data from teacher surveys of 7, 9, and 12-year olds were analyzed. All twins for whom a teacher's survey of an additional non-twin sibling was available were included in the sample (*N* = 1375). This sample included 613 complete twin pairs (*N* = 1226), each pair matched with the non-twin sibling, as well as 149 twins from incomplete pairs and their non-twin siblings. Data on birth order within the family was available for 577 of the included families.

MEASURES

Educational achievement was assessed by the evaluation of several school subjects with two versions of a teacher's survey. In the first version of the survey (birth cohorts 1992–1998), teachers could choose up to six subjects and rated the proficiency of the students in these subjects on a five-point scale from 1 (*insufficient*) to 5 (*[very] good*). In the second version (birth cohorts 1997–2003), teachers rated the proficiency of the students in four predefined school subjects (arithmetic, language, reading, and physical education) on a similar five-point scale. Due to the free choice of school subjects in the first version and differences in missing data on the twin risk factors, the number of teacher ratings varies between the different comparison tests. The teacher survey also included questions about the type of education (regular or special) a child was attending, and whether he or she had ever had to repeat a grade.

The national test of educational achievement consists of multiple choice items in four different subjects (arithmetic, language, world studies [optional], and study skills), and is administered in the last grade of primary school. In this paper, the total score on the national educational achievement test, a standardized measure that ranges from 500 to 550, is used. The questions concerning world studies are not included in the total score since administration of these questions is optional.

Socioeconomic status (SES) was based on a full description of the occupations of both parents, and was coded according to the system of Statistics Netherlands (CBS Statistics, 2001), or an EPG-classification combined with information on parental education (Erikson, Goldthorpe & Portocarero, 2010). The SES score was classified on a five-point scale from 1 (*lower job*) to 5 (*scientific profession*), and the highest SES score of the parents determined the family SES. The SES score of the family when the twins were aged 3 or 10 years was used when the SES at age 7 years was not available, because these scores are highly correlated over time.

Assisted conception included in vitro fertilization (IVF) or intra cytoplasmic sperm injection (ICSI), and natural conception excluded conception after the prescription of ovulation-inducing drugs. Preterm birth was defined as born before 37 weeks gestation, and low birth weight was defined as less than 2500 grams. Birth complications were considered present when parents indicated that a child had experienced health problems directly after the delivery. Incubator time was defined as the number of days a child had spent in an incubator after delivery. Birth order within a family of twins and their non-twin sibling was determined on the basis of the order of the date of births in the families.

STATISTICAL ANALYSES

Data were analyzed by independent sample *t* tests to compare educational achievement between groups of twins that differed in mode of conception, gestational age, birth weight, incubator time, mode of delivery, birth complications, sex, and zygosity. Paired sample *t* tests were used to analyze the difference in educational achievement between twins and their non-twin siblings. A chi-square test was used to compare the number of grade repeaters amongst twins and their non-twin siblings. Data were checked and analyzed using the Statistical Package for the Social Sciences (SPSS 17.0) (2011). The tests were done in the statistical program Stata 9.0 (StataCorp, 2005) to correct for the influence of the family cluster effect. For all analyses, two-tailed *p* values of < .05 indicated statistical significance.

A linear structural equation model was estimated in Lisrel 8 (Jöreskog & Sörbom, 2002) to simultaneously investigate the influence of twin and family risk factors on educational achievement. The model included all twin and family risk factors as independent latent variables, and the teacher rating for the four school subjects as dependent variables. Correlations between the dependent variables were estimated. The analyses were based on the full information likelihood maximization. To correct for the family cluster effect, the data were divided into two groups. The first-born and second-born twins of every twin pair were randomly assigned to the first or second group. The Lisrel model was fitted to the data of both groups to determine whether the results found in the first group could be replicated in the second group.

TABLE 1 Twin and family risk factors

	N	(out of N families)	%
Socioeconomic Status			
1 Low	130	(75)	1.4
2	1113	(601)	11.8
3	4112	(2231)	43.7
4	2299	(1239)	24.4
5 High	1234	(681)	13.1
missing	*528*	*(300)*	*5.6*
Mode of Conception			
Natural	6828	(3715)	76.5
IVF/ICSI	1339	(733)	15.0
Ovulation Inducing Drugs	766	(415)	8.1
missing	*483*	*(268)*	*5.1*
Maternal Age			
<25 years	243	(111)	2.6
25-30 years	2564	(1383)	27.2
30-35 years	4430	(2419)	47.0
>35 years	2108	(1156)	22.4
missing	*71*	*(41)*	*0.8*
Paternal Age			
<25 years	76	(41)	0.8
25-35 years	5349	(2916)	56.8
35-45 years	3536	(1932)	37.6
>45 years	220	(121)	2.3
missing	*235*	*(132)*	*2.5*
Zygosity			
Monozygotic	3246	(1751)	34.5
Dizygotic	6114	(3346)	64.9
missing	*56*	*(34)*	*0.6*
Gestational Age			
>37 weeks	5570	(3030)	59.2
32-37 weeks	2988	(1624)	31.7
<32 weeks	660	(365)	7.0
missing	*198*	*(112)*	*2.1*

Birth Weight		
<1500 grams	414	4.4
1500-2500 grams	3840	40.8
>2500 grams	4881	51.8
missing	*281*	*3.0*
Incubator Time		
0 days	4638	49.3
1-7 days	2570	27.3
8-14 days	727	7.7
>14 days	942	10.0
missing	*539*	*5.7*
Mode of Delivery		
Vaginal	6442	68.4
Cesarean Section	2786	29.6
missing	*188*	*2.0*
Birth Complications		
No	7043	74.8
Yes	2086	22.2
missing	*287*	*3.0*
Sex		
Boy	4634	49.2
Girl	4782	50.8

RESULTS

Table 1 shows the summary statistics of the twin and family risk factors of the 7-year-old twins, and Table 2 displays the means of educational achievement for each risk factor. The analysis of several twin birth risk factors showed that twins born after assisted conception had significantly higher teacher ratings for reading and significantly lower performance in physical education, compared to twins born after natural conception. However, when matched on the possible confounders SES, maternal age at birth, and birth order within a family, twins born after assisted conception were no longer better at reading ($t = -0.55$, $p = .585$). Their achievement in physical education remained lower ($t = 2.14$, $p = .033$). Preterm twins, twins who had to be placed in an incubator, and twins with complications after delivery had poorer performance in physical education. Low birth weight twins received lower ratings for arithmetic and physical education and scored lower on the national educational achievement test. Mode of delivery had no effect on any of the school subjects. There were significant sex differences: boys performed better at arithmetic and obtained higher scores for the educational achievement test, while girls received higher ratings for language, reading, and physical education. No significant differences were found between the educational achievement of monozygotic and dizygotic twins.

TABLE 2 Means of educational achievement for the twin risk factors

	N	Mean	N	Mean	t	p
Mode of Conception	**Natural**		**Assisted**			
Arithmetic	6504	3.76	1274	3.81	-1.28	.202
Language	4615	3.67	950	3.65	.47	.639
Reading	5640	3.49	1109	3.58	-2.05	.041*
Physical Education	3401	3.85	745	3.76	2.24	.025*
Educational Achievement	2576	537.6	458	538.3	-1.48	.139
Gestational Age	**Full Term**		**Preterm**			
Arithmetic	5288	3.80	3483	3.76	1.35	.178
Language	3823	3.69	2459	3.67	.63	.528
Reading	4593	3.52	3012	3.52	.08	.940
Physical Education	2776	3.86	1891	3.77	3.04	.002**
Educational Achievement	2113	537.5	1346	538.0	-1.27	.205
Birth Weight	**Normal**		**Low**			
Arithmetic	4655	3.84	4037	3.72	-4.69	<.001**
Language	3359	3.70	2851	3.66	-1.40	.161
Reading	4034	3.54	3498	3.50	-1.21	.227
Physical Education	2460	3.87	2169	3.77	-3.66	<.001**
Educational Achievement	1871	538.1	1563	537.2	-2.88	.004**
Incubator	**No**		**Yes**			
Arithmetic	4430	3.81	4320	3.76	1.89	.059
Language	3251	3.69	3002	3.67	.80	.421
Reading	3855	3.53	3725	3.52	.52	.604
Physical Education	2385	3.87	2269	3.78	3.17	.002**
Educational Achievement	1686	538.0	1757	537.4	1.87	.061
Mode of Delivery	**Vaginal**		**Cesarean Section**			
Arithmetic	6146	3.79	2636	3.77	.76	.445
Language	4343	3.68	1949	3.68	-.11	.916
Reading	5310	3.51	2304	3.56	-1.54	.124
Physical Education	3139	3.83	1534	3.81	.76	.450
Educational Achievement	2501	537.5	950	538.1	-1.57	.117

Birth Complications	**No**		**Yes**			
Arithmetic	6702	3.78	1983	3.80	-1.02	.308
Language	4823	3.68	1391	3.71	-.90	.370
Reading	5826	3.52	1699	3.53	-.22	.826
Physical Education	3514	3.87	1103	3.70	5.26	<.001**
Educational Achievement	2645	537.6	781	537.7	-.22	.826
Sex	**Boy**		**Girl**			
Arithmetic	4422	3.89	4539	3.66	9.47	<.001**
Language	3154	3.59	3300	3.77	-6.55	<.001**
Reading	3817	3.42	3952	3.62	-6.27	<.001**
Physical Education	2453	3.80	2380	3.86	-2.45	.015*
Educational Achievement	1638	538.3	1834	537.1	3.89	<.001**
Zygosity	**Dizygotic**		**Monozygotic**			
Arithmetic	5842	3.79	3066	3.75	1.44	.149
Language	4233	3.68	2170	3.67	.31	.754
Reading	5003	3.52	2721	3.51	.28	.783
Physical Education	3144	3.82	1637	3.85	-1.13	.259
Educational Achievement	2211	537.6	1261	537.8	-.43	.667

* p<0.05; ** p<0.01

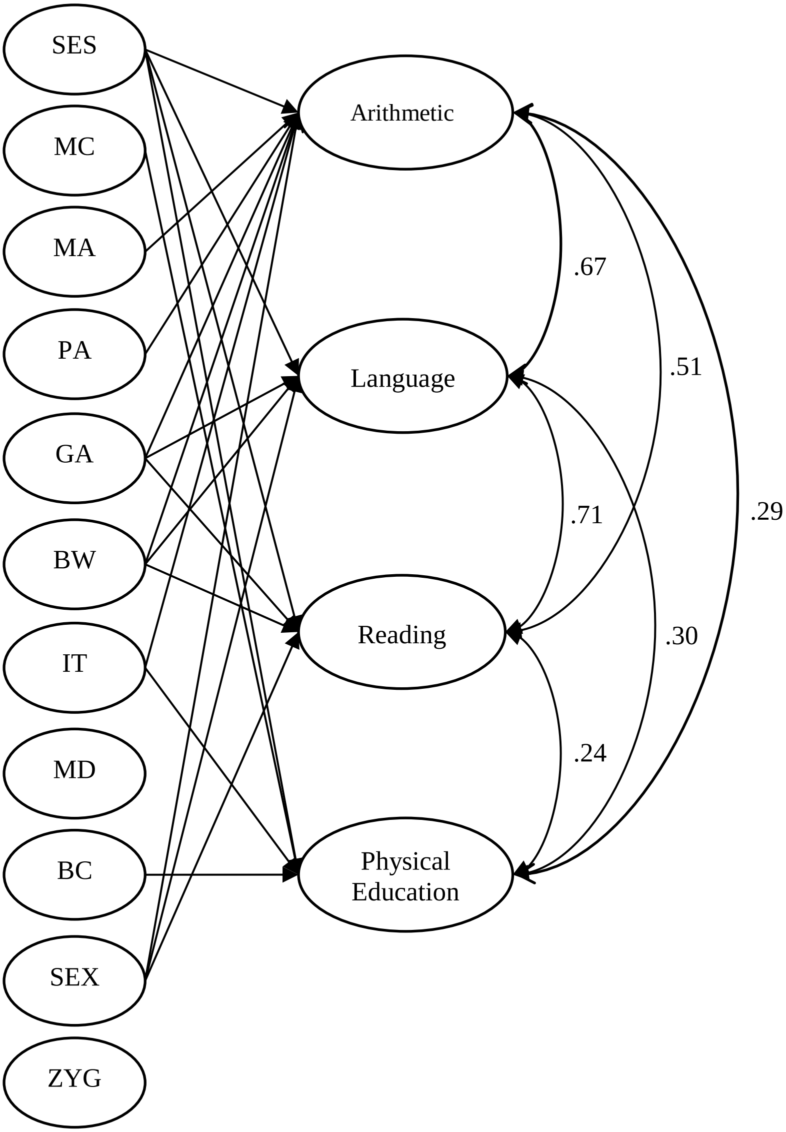
Figure 1 depicts the Lisrel model, with the eleven variables that represent the twin and family risk factors on the left and, on the right, the four school subjects as dependent factors. The twin and family risk factors together explained 3.8, 3.3, 2.7, and 2.5 (Group 1) per cent and 4.2, 2.9, 2.7, and 1.6 (Group 2) per cent of the variance, in arithmetic, language, reading, and physical education, respectively. Table 3 shows the parameter estimates and standard errors for the linear relationships between those independent and dependent variables. Socioeconomic status had a significant influence on the ratings of all four school subjects, and there were sex differences for arithmetic, language, and reading. Maternal age had a positive influence on the performance in arithmetic, while paternal age had a negative influence on this subject. Birth weight and gestational age influenced the ratings of all school subjects, except for physical education. Physical education was affected by mode of conception, incubator time, and birth complications. Mode of delivery and zygosity did not have an effect on educational achievement.

TABLE 3 Parameter estimates of the linear relationships between twin and family risk factors and educational achievement

	Arithmetic		Language		Reading		Physical Education	
	Parameter Estimate	SE	Parameter Estimate	SE	Parameter Estimate	SE	Parameter Estimate	SE
Socioeconomic status (SES)	.107**[1]	.011	.108**[1]	.012	.111**[1]	.014	.037**	.012
Mode of conception (MC)	.037	.048	.011	.050	.078	.059	-.106*	.052
Maternal age (MA)	.013*[1]	.013	.005	.006	-.001	.007	.003	.006
Paternal age (PA)	-.008[2]	.004	-.006	.005	-.003	.005	-.001	.005
Gestational age (GA)	-.014[2]	.011	-.022*	.011	-.035**	.013	.002	.011
Birth weight (BW)	.090*[1]	.044	.108*[1]	.047	.163**	.054	-.033	.048
Incubator time (IT)	-.004[2]	.002	-.001	.003	.001	.003	-.007**	.003
Mode of delivery (MD)	-.019	.034	-.004	.035	.047	.041	-.030	.036
Birth complications (BC)	.068	.039	.034	.040	-.026	.047	-.147**	.042
Sex (SEX)	-.202**[1]	.031	.200**[1]	.032	.215**[1]	.038	.058	.033
Zygosity (ZYG)	.025	.034	.031	.036	.036	.042	-.021	.037

note: [1] significance replicated in second group; [2] relationship significant in second group
* $p<0.05$; ** $p<0.01$

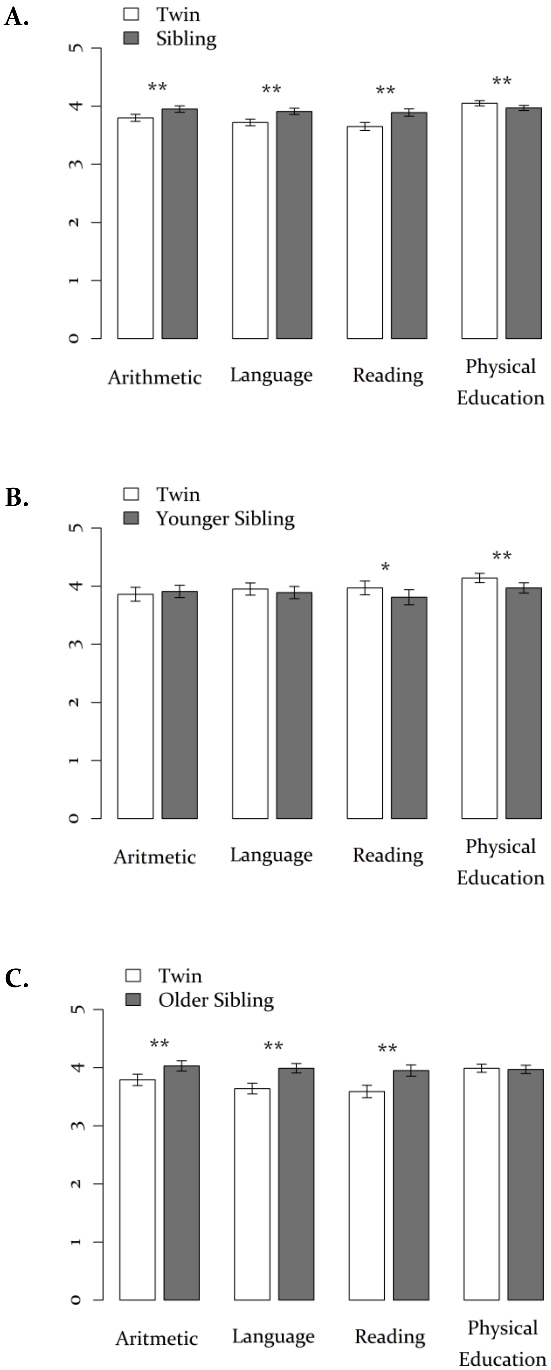
FIGURE 1 Structural equation model with the significant linear relationships between twin and family risk factors and educational achievement



SES = socioeconomic status; MC = mode of conception; MA = maternal age; PA = paternal age; GA = gestational age; BW = birth weight; IT = incubator time; MD = mode of delivery; BC = birth complications; SEX = sex; ZYG = zygosity

Twins were matched with a non-twin sibling to determine the difference in educational achievement between twins and singletons ($N = 1375$). The results show that singletons had significantly higher ratings in arithmetic ($M_{twin} = 3.80$, $M_{sib} = 3.95$, $t = -4.08$, $p < .001$), language ($M_{twin} = 3.72$, $M_{sib} = 3.91$, $t = -5.60$, $p < .001$), and reading ($M_{twin} = 3.65$, $M_{sib} = 3.89$, $t = -5.77$, $p < .001$) (Figure 2a). However, 148 of 1367 (10.8%) twins were held back a year at some point in their school career, compared to 67 of 747 (10.1%) singletons ($\chi2 = 1.82$, $p = .177$). In order to test whether the difference in educational achievement could be explained by the birth order of the twins within the family, separate analyses were performed on a group of twins who were first-born and a group of twins for whom the non-twin sibling was the first-born within the family. The results showed that twins with a younger sibling had the same, or even higher, ratings on arithmetic, language, and reading as their non-twin sibling (Figure 2b). In contrast, twins with an older sibling had significantly lower ratings than their non-twin sibling for these school subjects (Figure 2c). Physical education was an exception because all twins received higher ratings for this school subject than their non-twin sibling ($M_{twin} = 4.05$, $M_{sib} = 3.97$, $t = 2.74$, $p = .007$).

FIGURE 2 Differences in educational achievement between twins and their non-twin siblings



DISCUSSION

This study showed that gestational age and birth weight were the most important risk factors in twins. Twins with lower birth weight and small for gestational age performed more poorly in arithmetic, language, reading, and a national educational achievement test. Incubator time and paternal age had a negative effect on the ratings in arithmetic, while maternal age had a positive influence on this school subject. Achievement in physical education was negatively affected by mode of conception, incubator time, and birth complications, even after correction for gestational age and birth weight. The other risk factors, mode of delivery and zygosity, had no effect on educational achievement.

In agreement with IQ studies amongst preterm and low birth weight singletons and twins (Kirkegaard et al., 2006; Shenkin, Starr & Deary, 2004), birth weight had a negative effect on the educational achievement of twins in primary school. Assisted conception does not affect the educational achievement of twins once SES, maternal age at birth, and birth order are taken into account. This is in agreement with a study that found that children born after IVF scored even higher than matched controls on an achievement test (Mains et al., 2010). However, achievement in physical education was lower in children born after IVF/ICSI, compared to children born after natural conception. Our study is the first to investigate whether mode of delivery has an influence on educational achievement, and found that twins born after cesarean section have the same ratings on all school subjects as twins born after vaginal delivery. Finally, in agreement with studies that found that zygosity status does not influence intelligence (Voracek & Haubner, 2008), our study also shows that educational achievement did not differ between monozygotic and dizygotic twins.

When interpreting these results, one must keep in mind that the twin and family factors included in the Lisrel model explained only a small amount of the variance in educational achievement. The control variables socioeconomic status and sex had the greatest influence on the teacher ratings of the different school subjects. In addition, not all significant linear relationships between the independent and dependent variables in the Lisrel model were replicated in the second group. Of note, socioeconomic status and sex, here used as covariates, had a much greater influence on the teacher ratings of the different school subjects than the twin-specific risk factors of interest.

A difference between twins and singletons in educational achievement in primary school seems to exist in this sample. Singletons received higher ratings from their teachers for arithmetic and language, as well as for reading. However, an important observation is that birth order within the family can largely account for the lower educational achievement of twins found in this sample: twins who were first in birth order within the family had the same, or even higher, ratings as their non-twin sibling, while twins with a sibling who was first in birth order within the family had lower ratings than their non-twin siblings. Remarkably, all twins had a somewhat higher score on physical education, compared to their non-twin siblings.

Regarding the difference in educational achievement between twins and singletons, the results in the literature are mixed. One study also reported a difference in educational achievement of twins compared to singletons (Tsou et al., 2008). In contrast, a study from Denmark in birth cohorts from 1986 to 1988 showed that, although twins had, on average, a lower birth weight than singletons, their mean scores on a test of general academic achievement were as high as scores from singletons (Christensen et al., 2006). However, the study in Denmark used a random sample of singletons from the general population as a control group, while our study compared the twins with their non-twin siblings. The lower educational achievement of twins compared to singletons found in this study is also in accordance with a meta-analysis that concluded that an IQ difference exists between twins and singletons for multiple birth cohorts from various countries (Voracek & Haubner, 2008).The finding that birth order within the family could explain part of the differences in educational achievement between twins and their non-twin siblings is in agreement with another study in a group of twins. This study showed that intelligence was negatively associated with birth order within the family. Twins without older siblings had the highest IQs, while twins with two or more older siblings had the lowest IQs (Boomsma et al., 2008).

To conclude, our study is the first to give an overview of the influence of several risk factors associated with twin birth, including mode of conception, gestational age, birth weight, incubator time, mode of delivery, birth complications, and zygosity, on the educational achievement of a very large sample of 7-year-old twins in primary school. Low birth weight is the most important risk factor for the educational achievement of twins in primary school. The differences in educational achievement observed between 7, 9, and 12-year-old twins and their non-twin siblings can largely be explained by birth order within the family.

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