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The health-schooling relationship: evidence from Swedish twins

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Abstract Health and education are known to be highly correlated, but the mechanisms behind the relationship are not well understood. In particular, there is sparse evidence on whether adolescent health may influence educational attainment. Using a large registry dataset of twins, including comprehensive information on health status at the age of 18 and later educational attainment, we investigate whether health predicts final education within monozygotic (identical) twin pairs. We find no evidence of this and conclude that health in adolescence may not have an influence on the level of schooling. Instead, raw correlations between adolescent health and schooling appear to be driven by genes and twin-pair-specific environmental factors.

Keywords Twins · Twin-fixed effects · Education · Health · Specific conditions

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1 Introduction

The existence of an education-health gradient is one of the most well-established findings of social and medical science (see, for example, Adler et al. 1994; Adler and Ostrove 1999; Smith 1999; Deaton and Paxson 2001; Cutler and Lleras-Muney 2006; Marmot and Wilkinson 2006; Currie 2009 or Conti et al. 2010). However, the mechanisms behind this relationship are not well understood. Medical scientists tend to believe that the relationship mostly represents a causal effect of socioeconomic status (SES) on health, generated by factors such as worse adult health behaviors and more psychological stress in the lower educated. Economists have often been more agnostic, also pointing out the possibility of causal mechanisms running in the opposite direction (e.g., that health early in life affects cognitive development or days of school sick leave) as well as noncausal mechanisms (genetic or environmental factors influencing both health and socioeconomic achievement).

In the past decade or so, a number of studies in the economics literature have considered the influence of infant health as measured by birth weight, or fetal growth,[1] on schooling outcomes. Some of these studies used monozygotic (MZ) twins to sort out the influence of confounders such as genes and family environment. The results are rather mixed. Studies including Behrman and Rosenzweig (2004) and Black et al. (2007) have found evidence of a rather strong effect of fetal growth on educational attainment as well as earnings. For example, the study by Behrman and Rosenzweig (2004) suggests that an increase in fetal growth by 1 oz (28 g) per week implies an increase in educational attainment by as much as 0.66 years. Other studies including Bonjour et al. (2003) and Miller et al. (2005) found no significant effect at all.

However, many dimensions of child health do not manifest themselves in a lower birth weight and many childhood health problems do not show up until long after birth. But to date, no twin study has examined whether health status after birth has an influence on individuals' educational attainment.[2] If, in fact, better health in childhood or adolescence causes individuals to obtain more education, then there are additional payoffs to investments in health and health care to individuals before adulthood. Moreover, child or adolescent health could then be a mechanism whereby socioeconomic disadvantage is transmitted across generations (see Currie 2009).

If health and educational attainment are related within twin pairs, this also has implications for the literature estimating the returns to schooling. One of the main approaches in this literature has been to compare outcomes of (MZ) twins (e.g., Ashenfelter and Krueger 1994; Isacsson 2004). The validity of this approach relies on the assumption that twins are similar in other characteristics or abilities, including health. If, however, a more healthy twin tends to obtain more years of schooling,

[1] Birth weight divided by gestation.

[2] A few studies, including Smith (2009) and Currie et al. (2010), have examined the role of childhood health using sibling comparisons, thus not fully accounting for potential genetic confounders. As will be shown, accounting for genetic confounders is important for the interpretation of the relationship.

studies in this literature may have produced biased estimates, partly reflecting the returns to health rather than the returns to schooling.[3]

The possibility that MZ twins differ in ability has always been known (see Card 1999), and a few studies have examined the relationship between education and ability, in terms of cognition. In their study, Ashenfelter and Rouse (1998) asked MZ twins differing in educational attainment for reasons why one twin obtained more schooling. Only 11 % of the responses included explanations such as "one twin was better at books," leading the authors to conclude that ability differences was not an important issue. On the other hand, a recent study using Swedish data (Sandewall et al. 2014) found that differences in cognitive ability test scores between MZ twins are significantly related to differences in educational attainment. The authors suggest that estimates of the returns to schooling are upward biased by 15 % unless cognitive ability is taken into account.

This study sets out to examine the mechanisms behind the relationship between adolescent health and educational attainment, using a unique dataset, including rich information on health, schooling, and other characteristics. In particular, we are able to sort out whether an individual is a twin and, if so, whether he is MZ or dizygotic (DZ). As MZ twins share exactly the same genes and largely the same childhood environment, by comparing these, we are able to sort out most potential confounders. Comparing DZ twins, we sort out any common family environmental factor but only partly genes, thus allowing us to evaluate the importance of genes by contrasting results to those obtained based on MZ twins. In contrast to most datasets with information on health, we have information on cognitive and noncognitive ability, allowing us to assess whether these play a role in determining the health-education relationship. The data include almost all Swedish men born between 1950 and 1979, and in particular a large majority of all male twins.[4]

In contrast to most other twin-based studies in economics, we have access to data on objective health conditions. These are reported by physicians based on obligatory assessments of individuals' health, taking place at military enlistment. While these assessments must inevitably to some extent rely on self-reports, measurement errors for example originating from differences in health-seeking behaviors or in health awareness, which may be present in sources like hospital and insurance records or in standard self-evaluations, are less of an issue. This is potentially important in light of the criticism of Bound and Solon (1999), Griliches (1979), and others, that fixed effects estimation may exacerbate measurement errors.

We first run ordinary least squares (OLS) regressions, in order to obtain some "baseline" results. In agreement with many previous studies, we then find a significant relationship between health status and educational attainment for both the overall male population and MZ twins. However, when applying fixed-effects estimators to the MZ twin sample, our results in general point to the absence of a health-education relationship, as coefficients approach zero and become insignificant. Given that male MZ twins are representative of the population at large, our study provides no evidence of health

[3] This has previously been pointed out by Miller et al. (2005).

[4] We have used these military enlistment records in several other studies. For example, Lundborg et al. (2014b) showed the existence of a relationship between health and earnings both within families and twin pairs. Our data source is the same as the one used by Sandewall et al. (2014).

problems in adolescence influencing educational attainment.[5] We also provide an answer to this discrepancy in results, suggesting that a substantial part of the raw association is due to genes related to skill differences.

2 Data and method

2.1 Data

Our dataset links data on native Swedish male twins born in 1950–1979 from surveys run by the Swedish Twin Registry to data on educational attainment from Statistics Sweden (Statistiska centralbyrån) from 2007 and to data from tests and medical examinations performed at military enlistment 1969–1997, as provided by the Swedish National Service Administration (Pliktverket). We also have parental labor market incomes as of 1970.

During the time period of study, young Swedish males were obliged by law to undergo the military enlistment procedure, with exemptions only granted for institutionalized individuals, prisoners, and individuals living abroad. The procedure lasted for 2 days and individuals usually took the tests at age 18.[6] Individuals refusing to enlist could be punished with a fine and eventually imprisonment, which implies that attrition is very low. Only around 3 % of individuals in each cohort did not enlist.

Zygosity has been determined for 83 % of all individuals in the data, based on survey questions regarding co-twin similarity. The method used to classify individuals with respect to zygosity has been estimated to have an accuracy of 95 % or more (Lichtenstein et al. 2002). In total, 4868 individuals that are (classified as) MZ are available in the data. There are 5763 individuals who are (classified) as DZ and also have a male co-twin.

In our data, educational attainment is expressed in terms of the highest degree attained as of 2007, that is, when the men in the data were at least 28 years old. There is also information on parents' educational attainment, as of 1999. In our analysis, we use a measure of years of schooling, which is assigned based on the standard number of years of schooling associated with the degree obtained.

Several different types of health examinations were performed at military enlistment. The order of these examinations was different for different individuals. Every individual had to undergo an examination by a physician, lasting for about 20 min. Any condition (physical or mental) that would interfere with the individual's ability to undergo military education was to be recorded, whereas conditions not interfering with this ability were not recorded. Inevitably, the determination of diagnoses to some extent had to rely on self-reports, but the individual was required to bring any doctor's certificate, health record, drug prescription, or similar, to prove that he suffered from the conditions he claimed to have.

In addition to this, the individual visited different testing stations, where physical tests were carried out. Different tests were administered by different staff members (not physicians). At one testing station, staff members examined the maximum number of watts

[5] Although we use the term "adolescent" throughout, it should be noted that health is a process from birth up to the current age and that our measure will reflect a sum of health shocks up to the age of 18.

[6] Up until 1972, individuals were usually called to undergo the military enlistment test at age 19, whereas in later years most individuals underwent the enlistment test at age 18.

attained by the individual when riding a stationary bike for a certain time period. The individual was here instructed to maintain a pedal cadence between 60 and 70 rpm. The test was initiated with 5 min of exercise at work rates of 75 to 175 W, depending on expected fitness. After this, the work rate was continuously increased by 25 W/min until volitional exhaustion. The maximum number of watts attained can then be transformed into a measure of physical capacity (which is related to oxygen consumption) by dividing by the individual's weight in kilograms (e.g., Worme et al. 1991; Booth et al. 1996).

At another test station, the individual's muscular strength was determined. This was measured as the maximum pressure exerted when squeezing a dynamometer, using the strongest hand. Handgrip strength is a valid indicator of, and is commonly used to assess, overall muscle strength (e.g., Metter et al. 2002; Gale et al. 2007).

At further test stations, the individual's (systolic and diastolic) blood pressure, visual acuity, and hearing acuity were measured. Visual acuity was determined by having the individual read letters of different sizes from a screen, and visual acuity by listening to tones of different loudness, at a number of frequencies (500, 1000, 2000, 3000, 4000, and 6000 Hz). Moreover, the individual's weight and height were recorded.[7]

Our analysis uses three different types of health measures. First and most importantly, we make use of a global measure of health. This was assigned by the National Service Administration based on the individual's diagnoses (both physical and mental) and the severeness of these. The measure is expressed with letters from A to M (except "I") or "U," "Y," or "Z." The closer to the start of the alphabet the letter assigned to the individual is, the better his general health status is considered. "A" thus represents more or less perfect health, which is necessary for "high mobility positions" (such as light infantry or pilot) and has been assigned to about 60 % of all individuals for which there is nonmissing data. For combat positions, individuals must have been assigned at least a "D," and individuals with a "G" or lower are only allowed to function in "shielded positions." Individuals that have been assigned a "Y" or "Z" (in total 8 % of the individuals) are not allowed to undergo education within the military. "U" (assigned to less than 1 % of all individuals) indicates that global health status has not been decided, and we treat this as missing. We focus on a linear measure of global health in our main analysis and transform "A" into 0, "B" into 1, etc., "Y" into 12 and "Z" into 13.

We also consider five variables for health conditions, which basically represent the five most prevalent categories of health conditions in the data, according to the ICD classification.[8] However, because the category of diseases of the respiratory system includes many short-term and temporary conditions such as common cold, we do not use this category. Instead, we create a category of respiratory conditions including only asthma, hay fever, and hypertrophy of tonsils and adenoids. This leaves us with the following health condition variables: mental conditions (which

[7] A number of studies suggest that childhood disease burden has strong effects on the growth of a person (e.g., Bozzoli et al. 2009), and a number of recent studies have used indicators of height or stunted growth to proxy for health early in life (e.g., Case and Paxson 2008; Bhalotra and Rawlings 2011). Bozzoli et al. (2009) suggest that height is related to rates of postneonatal mortality due to pneumonia and possibly congenital anomalies and intestinal disease. They find little evidence that height would be related to mortality rates for other conditions. In poorer countries, stunting has also been related to diarrhea (Martorell et al. 1975; Lutter et al. 1989).

[8] With the exception of conditions of the sensory organs; low hearing acuity and low visual acuity are instead studied separately.

includes, for example, neurosis and personality disorders), conditions of musculoskeletal and connective tissue (e.g., vertebrogenic pain syndrome and scoliosis), diseases of the skin and subcutaneous tissue (e.g., eczema), respiratory conditions (asthma/hay fever/tonsils/adenoids), and injuries and poisonings. While injuries and poisonings largely consist of short-term and temporary conditions, we still consider this category interesting as such outcomes may reflect some important but unobserved behavioral patterns.

Finally, we make use of physical test variables. As we want these variables to be indicators of poor health, we transform them into binary indicators, classifying individuals as having low physical capacity, weak handgrip strength, or being short if they fall below the 5th percentiles (among all twins) for these measures, respectively. We classify individuals as having low visual acuity if their visual acuity on either eye is 0.7 or lower (where 1 is "normal vision") and as having low hearing acuity if the individual was unable to hear tones at 30 dB at 500, 1000, 2000, 3000, 4000, or 6000 Hz with either ear. Individuals are classified as having hypertension if either their systolic blood pressure is higher than or equal to 140 or their diastolic blood pressure is higher than or equal to 90 and are classified as being overweight if their BMI is greater than or equal to 25.[9]

In addition to medical and physical test variables, our enlistment data include cognitive ability as well as a measure of noncognitive ability, enabling us to control for these. Cognitive ability is measured at military enlistment through four tests: logical reasoning, understanding of synonyms, spatial ability, and technical comprehension.[10] Each test is graded on a scale between 1 and 9, approximating a normal distribution, and the grades of the individual tests are then translated into an overall grade between 1 and 9, also approximating a normal distribution. We use this overall score in our analysis, standardized to have mean 0 and standard deviation 1.

Noncognitive ability is determined based on a 25-min semi-structured interview with a psychologist, also at military enlistment, with the objective "to assess the conscript's ability to cope with the psychological requirements of the military service and, in extreme case, war" (Lindqvist and Vestman 2011). This evaluation implies an assessment of personal characteristics such as willingness to assume responsibility, independence, outgoing character, persistence, emotional stability, and power of initiative. Just like cognitive ability, noncognitive ability is indicated on a nine-step scale between 1 and 9, and we standardize this to have mean 0 and standard deviation 1. When determining whether the individual had a mental diagnosis, the physician had access to the score given by the psychologist and any notes that he or she had made.

For cohorts born in 1972 and later, our data further includes information on math grades at age 15. At this time, students could choose between a "general math" class, which was easier, and a "special math" class, which was more challenging. Grades ranged between 1 and 5, but grades obtained in the two classes are not directly comparable. However, using data from a test taken by

[9] BMI, body mass index, is calculated as (weight in kilograms)/(height in meters)^2.

[10] See Carlsson et al. (2015) for a further explanation of the subtests.

both types of students, we can construct an overall score. Again, we use a standardized version of this score.[11]

Some individuals have missing values on one or several physical test variables, on cognitive ability, or on noncognitive ability. In our OLS regressions, we impute sample averages when missing and create a binary variable taking on the value 1 when there is missing information on a variable. Similarly, for our twin-fixed effects estimates, we impute values so that the twin difference becomes zero when there is missing information, and we add a binary variable indicating missing data on the individual.[12]

We exclude 1715 individuals for which data from the military enlistment records is not available (16 %).[13] Of the remaining individuals, 171 (2 %) are dropped due to missing information on educational attainment. Finally, we exclude individuals for which the co-twin is not in the sample (8 %), giving us a sample including 3748 MZ and 4294 DZ male twin individuals. Table 1 shows descriptive statistics for the full population and for the MZ population. Hypertension is the most prevalent health problem, followed by musculoskeletal conditions. Individuals on average obtain 12 years of education, with a standard deviation of 2.[14]

In most cases where an individual has a certain health problem, his co-twin does not have the same condition. This is quite important for our chances to detect any possible effect of health on educational attainment, as the explanatory variables in our twin-differenced equations will only differ from zero and thus contribute to the estimate, when one of the twins is diagnosed with the condition in question and one is not. Most importantly, there are as many as 747 MZ twin pairs (40 %) differing in global health status. This is much higher than the number of pairs differing in educational attainment typically encountered in studies using twins to estimate the returns to schooling. For example, in the samples used by Ashenfelter and Krueger (1994) and Miller et al. (1995), only 76 and 265 MZ twin pairs differ in educational attainment, respectively.

[11] To be specific, we use information on grades and results from a math test described by Pettersson (1993) and restrict attention to children with Swedish-born parents, yielding 7399 individuals. We standardize test scores based on subtest 1a and 2 (as these were taken by all children), sum these, and standardize again. Finally, the average test score is then calculated for each grade in general and special math. Each individual in our data is then assigned this average standardized test score corresponding to their grade, whether in general math or in special math.

[12] Our approach has the advantage that twin pairs with missing data will not contribute to identification of health's effect on schooling. However, in order to take into account the interrelations between regression variables and the occurances of missings, one can also use multiple imputation (Rubin 1986). Implementing this analysis, using the STATA command mi input chained makes little difference to our results. Results are also similar if dropping individuals with missing information on any variable.

[13] More specifically, individuals are excluded if global health is missing. It is not possible to determine whether there is missing information on specific health conditions. However, for individuals reported to suffer from specific health conditions, data on global health is always available. Missing data on global health usually reflects that the data from the enlistment process has not been electronically recorded, which is the case for all conscriptions that took place in 1985 and for parts of several other years.

[14] Descriptive statistics for DZ twins are reported in Appendix Table 7. There are many significant, albeit small, differences in average characteristics when comparing the full male population sample, the MZ twin sample, and the DZ twin sample. For example, both MZ and DZ twins tend to have slightly better global health than the overall male population at age 18. We have run regressions where we re-weight the MZ and DZ twin samples to match the frequencies of global health observed in our full sample; however, this makes little difference to the results.

Table 1 Descriptive statistics (population sample and MZ twins)

	Population		MZ twins			
	Mean (std)	Missing (%)	Mean (std)	*P* value (vs population)	Missing (%)	Pairs differing
Years of schooling	12.16 (2.26)	–	12.43 (2.10)	0.000	–	0.48
Global health	2.67 (4.20)	–	2.37 (4.03)	0.000	–	0.40
Cognitive ability	5.16 (1.92)	0.02	5.04 (1.89)	0.000	0.02	0.63
Noncognitive ability	5.12 (1.73)	0.05	5.23 (1.67)	0.000	0.04	0.63
Father's years of schooling	10.54 (3.09)	0.31	10.66 (3.08)	0.046	0.29	–
Mother's years of schooling	10.50 (2.85)	0.18	10.74 (2.91)	0.000	0.19	–
Family income 1970 (SEK)	76,492 (54,811)	–	78,476 (61,022)	0.047	–	–
Mental	0.06	–	0.05	0.000	–	0.05
Musculoskeletal	0.14	–	0.13	0.000	–	0.18
Skin	0.06	–	0.05	0.057	–	0.06
Respiratory	0.13	–	0.12	0.000	–	0.11
Injuries and poisonings	0.06	–	0.05	0.004	–	0.08
Low physical capacity	0.09	0.15	0.04	0.036	0.14	0.09
Weak handgrip strength	0.03	0.10	0.04	0.001	0.10	0.07
Hypertension	0.19	0.04	0.22	0.039	0.03	0.24
Overweight	0.10	0.03	0.05	0.000	0.02	0.06
Short	0.03	0.03	0.05	0.000	0.02	0.03
Low visual acuity	0.04	0.03	0.05	0.000	0.02	0.08
Low hearing acuity	0.06	0.03	0.06	0.129	0.02	0.09
Math skill	−0.23 (0.81)	0.74	−0.21 (0.79)	0.551	0.68	0.42

Notes: The twin sample includes 3,748 individuals and the full sample 1,093,668. Means refer to means of nonmissing values. "*P* value (vs population)" refers to the *P* value from a *t* test where we test whether the mean is equal to the population average, and "Pairs differing" is the share of twin pairs with different values on the variable in question. Cognitive and noncognitive ability refer to these measures before standardization

2.2 Econometric specifications

As baselines, we run OLS regressions, that is, regressions without twin-fixed effects:

$$S_{ij} = \alpha + \beta H_{ij} + \delta X_{ij} + \varepsilon_{ij}. \qquad (1)$$

i represents the twin pair and j the individual. H is a vector including one or several health variables, and X includes controls such as indicators for year of birth, indicators for years of parental education, and family income (sum of parents' incomes).[15] Later on, we also control for individual abilities. Running a

[15] An effect of parental education on child's health and abilities (as measured at military enlistment in Sweden) was shown in Lundborg et al. (2014a).

regression of this type, we determine whether a correlation between health and schooling is present in our data.

However, our main goal is to determine whether there are within-twin relationships between health and educational attainment. We thus take twin differences and estimate relationships of the following form:

$$S_{i1} - S_{i2} = \beta(H_{i1} - H_{i2}) + \delta(X_{i1} - X_{i2}) + \varepsilon_1 - \varepsilon_2. \quad (2)$$

This gives the twin-fixed effects estimator of β. Our point of interest is whether the health components of β in this equation are equal to zero or not.

3 Results

3.1 Main results

3.1.1 Health and schooling

In most of the paper, we focus on global health as an indicator of health status. Table 2 reports the main results using this measure. Our primary interest lies in MZ twins since these can arguably be used to distinguish between the effects of health and those of genetic as well as environmental factors. However, for a comparison, we also report results for the general male population. We consider results based on DZ twins in Sect. 3.3, where we seek to explain the overall associations obtained.

Columns A–D report OLS results, where columns A and B are based on the full population sample and columns C and D on the MZ twin sample. Columns B and D add controls for year of birth, parental education, and family income. Our findings suggest twins to be fairly representative of the population at large, as estimates are rather similar. As expected, there is a strong relationship between global health and educational attainment. On average, a ten-step increase in global health, which corresponds to the difference between "perfect health" and a health status just a little better than required for military education, corresponds to about half a year less education. The effect is roughly −0.6 for the general population and −0.5 for the twins. Controlling for year of birth and parental education makes little difference but increases the estimates somewhat, as individuals born later have more education and are reported to have slightly worse health on average.[16]

Column E shows our regression results when applying the twin-fixed effects estimator, that is, the health-education relationship is estimated within twin pairs. The previously large effect of health is now precisely estimated around zero, assuming a value of −0.08, and it is statistically insignificant. Taking genetic

[16] This is most likely because the NSA de facto raised their thresholds and evaluated individuals' health less favorably in more recent years. Accounting for this by the use of year of birth dummies increases the effect of global health in absolute value from −0.46 to −0.67 (an increase by 46 %). Adding controls for parental education then reduces this effect by 24 %, which reduces by another 6 % when also controlling for family income.

Table 2 Global health and educational attainment

	A	B	C	D	E
Global health (*10)	−0.649***	−0.655***	−0.464***	−0.477***	−0.078
	(0.005)	(0.005)	(0.106)	(0.093)	(0.099)
R-squared	0.015	0.200	0.007	0.233	0.000
Sample	All	All	MZ	MZ	MZ
Basic controls	No	Yes	No	Yes	–
Twin-fixed effects	–	–	No	No	Yes
Individuals	1,093,668	1,093,668	3,748	3,748	3,748

Notes: Standard errors in parentheses. "Basic controls" include dummies for birth year, parental educational attainment, and family income. In models with twin-fixed effects, R-squared refers to the within-twin R-square. In the twin sample, standard errors are clustered at the twin-pair level

*Indicates 10 % significance; **5 % significance; ***1 % significance

and environmental factors into account, there is thus no evidence that an individual with worse health would end up with fewer years of schooling.[17]

We also consider alternative versions of educational attainment as our outcome. In particular, we create indicators for "at least 10 years of schooling," "at least 11 years of schooling," etc., up to "at least 20 years of schooling." Results are shown in Appendix Table 8. In a model with twin-fixed effects, there is evidence that worse health reduces the likelihood of obtaining 13 years of schooling or more. This effect, however, is only significant at the 10 % level, and no effects on other margins are obtained. In contrast, OLS results based on the twin sample suggest that health is related to schooling across almost all margins, with much larger coefficients than the ones suggested by the fixed-effects results.

In a similar vein, we try alternative versions of our explanatory variable. We thus create indicators for health status being worse than or equal to a certain level and run separate regressions based on these indicators, using years of schooling as the outcome. Results are shown in Appendix Table 9. All estimates obtained using twin-fixed effects are much smaller than their OLS counterparts, and they are all statistically insignificant.

3.1.2 Measurement error

In principle, the small and insignificant coefficient estimates that we obtain within twin pairs could be due to idiosyncratic measurement errors in the health variables, which get exacerbated when using twin-fixed effects (Griliches 1979). In order to deal with this, we apply an instrumental variable technique, instrumenting global health with specific health problems. In doing this, we only use the variables based on the physical tests and not the diagnose variables. The global health variable is by construction a function of diagnoses,

[17] It is possible to run separate OLS regressions on twin pairs differing in global health (thus contributing to the FE estimate) and on those not differing (thus not contributing to the FE estimate). Doing this, with controls, we find an effect of −0.34 in the former sample and −0.58 in the latter. It is not surprising that the latter estimate is larger, as it relies entirely on between-pair comparisons, where healthier twin pairs are also likely to have other advantageous characteristics compared to less healthy ones. Still, it is noteworthy that the former estimate is substantial and strongly significant, as opposed to the result obtained using fixed effects.

and any measurement error in these would most likely show up in the global measure as well. Measurement errors in global health and test variables are arguably orthogonal, however, implying that the latter are valid instruments for global health.

Results obtained when instrumenting global health are shown in Table 3. The table also shows *F* statistics, which are in all cases much above 10, indicating that the first stage is strong enough. We show OLS results (with controls) based on the full sample and the MZ twin sample and FE results based on the same twin sample.

In OLS models, the negative relationship between (worse) global health and educational attainment becomes more pronounced when correcting for measurement error using our instrumental variable technique, showing that there is indication of measurement error. The standard error when using OLS on the MZ twin sample is large, however, and it is not possible to reject that the coefficient is different from the one obtained when not correcting for measurement error.

Within twin pairs, there is again no evidence of an effect of health on schooling. In fact, the estimate is even closer to zero than the one reported in our main results, and it is statistically insignificant. However, the standard error is quite large, so, at the same time, we cannot rule out a relatively substantial effect of health on schooling.

3.1.3 Parental investment

Potentially, our results could be influenced by investments by parents. Parents may try to compensate or reinforce differences in outcomes between their children, generating either smaller or larger differences in various measures than what would otherwise be observed. This may not be such an important issue for twins, however. In their overview of the literature on compensating and reinforcing behaviors of parents, Almond and Mazumder (2013) note that "…it is simply very costly to implement favoritism among twin children and it therefore may be much more difficult to identify instances of reinforcing or compensating behavior."

At the same time, their review does find some support for reinforcing behavior dominating compensating behavior by twin parents. Further, more involved models that take into account both health and cognitive outcomes of children find evidence of parents reinforcing

Table 3 Dealing with measurement error

	A	B	C
Global health (*10)	−1.129***	−0.763***	0.025
	(0.010)	(0.187)	(0.250)
Sample	All	MZ	MZ
First-stage *F* statistic	22,624	75.56	29.14
Twin-fixed effects	–	No	Yes
Individuals	1,093,668	3,748	3,748

Notes: Standard errors in parentheses. Global health is instrumented with low physical capacity, weak handgrip strength, hypertension, overweight, short, low visual acuity, and low hearing acuity. The OLS regressions control for year of birth, parental education, and family income. In the twin sample, standard errors are clustered at the twin-pair level

*Indicates 10 % significance; **5 % significance; ***1 % significance

cognitive skill differences while compensating health differences within twins pairs; see Conti et al. (2015). Together, this suggests that parental responses are not able to explain our findings. On the contrary, if the results of Conti et al. (2015) apply, we would expect an upward-biased effect of health on education when applying twin design, as parents act to reduce health differences and increase schooling-related ability differences in twins.

3.1.4 The role of abilities

We are also interested in potential determinants of health differences within MZ twin pairs. If health is related to other variables even within twin pairs, this could give cause to bias when estimating the effects on schooling. In this section, we only consider fixed effects models. Panel A of Table 4 considers potential determinants of global health: cognitive ability, noncognitive ability, and also math skills. We find that only noncognitive ability is significantly related to health; individuals with higher noncognitive ability are less likely to have poorer health. This could be because individuals with better noncognitive ability engage in more health-promoting behaviors (Chiteji 2010; Mendolia and Walker 2014). One should note, however, that it is also fully possible that the relationship reflects a causation in the opposite direction, so that those with worse health develop a lower

Table 4 The role of abilities in MZ twins: cognitive ability, noncognitive ability, and math skills

	A	B	C	D	E
A. Determinants of global health					
Cognitive ability	−0.025		0.004		−0.003
	(0.016)		(0.016)		(0.029)
Noncognitive ability		−0.106***	−0.106***		−0.179***
		(0.015)	(0.015)		(0.027)
Math skill				−0.029	−0.031
				(0.030)	(0.024)
R-squared	0.082	0.130	0.147	0.002	0.219
B. Educational attainment					
Global health (*10)	−0.112	−0.055	−0.077	−0.180	−0.077
	(0.098)	(0.102)	(0.101)	(0.140)	(0.162)
Cognitive ability	0.403***		0.383***		0.376***
	(0.070)		(0.071)		(0.127)
Noncognitive ability		0.165***	0.113*		0.204**
		(0.059)	(0.058)		(0.093)
Math skill				0.117	0.094
				(0.107)	(0.106)
R-squared	0.024	0.007	0.027	0.006	0.037
Individuals	3,748	3,748	3,748	1094	1094

Notes: Standard errors in parentheses. The outcome is global health. All regressions use twin-fixed effects. R-squared refers to the within-twin R-square. Standard errors are clustered at the twin-pair level. Models D and E are based on twin pairs where both co-twins have nonmissing information on math skill

*Indicates 10 % significance; **5 % significance; ***1 % significance

noncognitive ability. Potentially, it could also reflect the influence of a third variable.

The absence of a relationship between cognitive ability and adolescence health is noteworthy, because it suggests that those with a better ability to process information may still not benefit in terms of health and those with better health may not develop better cognition. It also suggests that it may not be reasonable to think of cognitive ability as an aspect of health. At least, cognitive ability represents something different from health as captured by the measure in the enlistment records.

Using educational attainment as the outcome, panel B in Table 4 then controls for the same ability variables in order to determine if these are important omitted variables in the fixed effects regression based on MZ twins. We find that this is not the case; the inclusion of these variables makes little difference, and the coefficient on global health is still insignificant and close to zero. Cognitive ability is related to education, but since it is unrelated to health, it does not make a difference to our results.[18] Noncognitive ability is positively related to educational attainment, and since it is negatively related to worse health, the exclusion of this variable may be thought of as generating a negative bias to our main results. However, the relationships are not strong enough to make an important difference. If noncognitive ability is measured with noise, there may still be a negative bias. However, as the coefficient on health is already close to zero, a substantial negative bias would imply that the true effect of health is positive—a scenario that would be unexpected given previous literature.

3.1.5 Specific health problems

To further examine the robustness of our results based on global health, Table 5 reports results from regressions using categories of health conditions and indicators created on the basis of the physical tests performed at military enlistment. Regressions are of the same type as in Table 2, but we now account for several dimensions of health separately (and simultaneously). Again, OLS results based on the entire population are reported in columns A and B, while those for (MZ) twins are reported in columns C and D.

As for global health, the results suggest that MZ twins are representative of a larger population, since the OLS estimates are generally very similar across the full population and the twin samples. We find that, in particular, mental illness and low physical capacity are associated with lower educational attainment. For example, according to regressions based on the twin sample and with controls, mental illness and low physical capacity affect years of schooling by −0.9 and −0.8, respectively. There are also strong negative effects of musculoskeletal conditions, being overweight, short, and having low visual acuity and low hearing acuity (although the effect of low visual acuity is not significant in the twin sample when controls are added). A smaller negative effect of injuries and poisonings is found in the full sample.

[18] We can also control for different subscores of cognitive ability. The significant effect turns out to be driven by logical skills and synonym understanding, but whether we use the overall score or the subscores makes virtually no difference for the coefficient on health.

Table 5 Health problems and educational attainment

	A	B	C	D	E
Mental	−1.025***	−0.800***	−1.207***	−0.893***	−0.021
	(0.009)	(0.008)	(0.194)	(0.175)	(0.196)
Musculoskeletal	−0.315***	−0.239***	−0.309***	−0.191*	0.101
	(0.006)	(0.006)	(0.116)	(0.106)	(0.101)
Skin	0.038***	0.008	0.038	0.012	−0.352**
	(0.009)	(0.008)	(0.168)	(0.161)	(0.164)
Respiratory	0.278***	0.134***	0.397***	0.157	0.092
	(0.006)	(0.006)	(0.134)	(0.114)	(0.116)
Injuries and poisonings	−0.194***	−0.202***	0.081	−0.084	−0.024
	(0.009)	(0.008)	(0.163)	(0.150)	(0.113)
Low physical capacity	−0.912***	−0.482***	−1.088***	−0.806***	−0.181
	(0.011)	(0.008)	(0.167)	(0.164)	(0.161)
Weak handgrip strength	0.389***	0.244***	0.101	0.208	−0.024
	(0.011)	(0.012)	(0.212)	(0.194)	(0.187)
Hypertension	0.135***	0.140***	0.035	0.031	0.138*
	(0.005)	(0.005)	(0.103)	(0.094)	(0.080)
Overweight	−0.596***	−0.289***	−0.398**	−0.344**	−0.054
	(0.007)	(0.007)	(0.166)	(0.162)	(0.156)
Short	−0.585***	−0.465***	−0.639***	−0.414**	−0.372*
	(0.012)	(0.011)	(0.223)	(0.196)	(0.192)
Low visual acuity	−0.386***	−0.238***	−0.369**	−0.119	−0.067
	(0.011)	(0.011)	(0.186)	(0.166)	(0.164)
Low hearning acuity	−0.491***	−0.342***	−0.357**	−0.311*	−0.123
	(0.009)	(0.008)	(0.180)	(0.164)	(0.142)
R-squared	0.051	0.211	0.058	0.247	0.010
F test	0.000***	0.000***	0.000***	0.000***	0.210
Sample	All	All	MZ	MZ	MZ
Basic controls	No	Yes	No	Yes	–
Twin-fixed effects	–	–	No	No	Yes
Individuals	1,093,668	1,093,668	3,748	3,748	3,748

Notes: Standard errors in parentheses. "Basic controls" include dummies for birth year, parental educational attainment, and family income. In models with twin-fixed effects, R-squared refers to the within-twin R-square. In the twin sample, standard errors are clustered at the twin-pair level. "*F* test" is the *P* value from an *F* test based on the null hypothesis that all health coefficients equal zero

*Indicates 10 % significance; **5 % significance; ***1 % significance

In contrast, individuals with respiratory conditions or with weak handgrip strength obtain somewhat *more* of education on average, and positive but smaller effects are also found for hypertension and skin conditions. The significant effect of respiratory conditions also shows up in the twin sample. None of the positive effects are significant in the twin sample with controls, however. In all OLS models, F tests based on the null hypothesis that health diagnoses and educational attainment are unrelated were rejected at all levels.[19]

Our estimate within twins is then shown in column E. Here, there is little evidence of any relationship between health and educational attainment as almost all of the previously significant coefficients approach zero and become insignificant. This is particularly striking for mental conditions, which is insignificant with a value of −0.02 but also for low physical capacity whose effect has reduced by four fifths to −0.18.

The only condition that had a significant effect in column D, and which is also significant in column E, is short height. However, the coefficient has reduced in size and it is now only significant at the 10 % level. Skin conditions and hypertension have turned statistically significant, with the effect of hypertension being positive. These significant effects may very well be due to chance, however. As shown below the estimates, an F test does not allow us to reject the possibility that there is no relationship between health conditions and educational attainment at a reasonable level of significance.[20]

3.2 Heterogeneity

If the behavior of parents depends on their child's health or abilities, we may expect to see different effects of adolescent health in different socioeconomic groups. For example, a common hypothesis in the literature has been that the effects of poor health may be more deleterious in families of lower SES (see, e.g., Currie and Hyson 1999), because these families have a lower ability to compensate for poor outcomes. We would then potentially see an effect of health on education only among individuals with low-educated or low-income parents.

We explore this possibility in Appendix Table 10. Low SES is measured in three different ways: mother having primary schooling only, father having primary schooling only, and family income being less than average. OLS regressions based on the full sample suggest that the effects of health are, in fact, weaker if the father is low-educated. On the other hand, a low family income generates a stronger relationship between health and educational attainment. However, these interaction effects do not reach statistical significance when estimated on the MZ twin sample. The same holds when applying twin-fixed effects. And, again, the main effect of health is small and insignificant within twin pairs.

[19] The strong positive relationships between respiratory conditions and education in OLS models without controls may be explained by the fact that smoking used to be more common among individuals with higher levels of educational attainment, a fact that has previously been shown for the USA (Sander 1995). Using the Swedish Level of Living Survey from 1968, we regressed a smoking dummy on a dummy indicating "more than basic education" (no controls) and obtained a coefficient of 0.06; $t = 4.88$. With this positive relationship, in combination with a positive intergenerational transmission of education and the fact that children to smokers are more likely to get respiratory problems (e.g., Cook and Strachan 1999), we would indeed expect these results.

[20] While using the 5th percentile to define "low physical capacity," "weak handgrip strength," "short," "low visual acuity," and "low hearing acuity" is somewhat arbitrary, we have experimented with using the 25th percentile, and this did not change our conclusions. Moreover, since the correlations between different health measures are not too strong, results are quite similar when including them one by one rather than simultaneously. See Appendix Tables 11 and 12 for these results.

Table 6 Exploring mechanisms using DZ twins

	A	B	C	D	E
Global health (*10)	−0.554***	−0.231**	0.118	−0.121	0.131
	(0.088)	(0.102)	(0.108)	(0.207)	(0.207)
Cognitive ability			0.652***		0.633***
			(0.054)		(0.125)
Noncognitive ability			0.142***		0.115
			(0.051)		(0.117)
Math skill				0.378***	0.273**
				(0.133)	(0.129)
R-squared	0.204	0.002	0.087	0.030	0.115
Twin-fixed effects	No	Yes	Yes	Yes	Yes
Individuals	4294	4294	4294	758	758

Notes: Standard errors in parentheses. The OLS model controls for birth year, parental educational attainment, and family income. In models with twin-fixed effects, R-squared refers to the within-twin R-squared. Standard errors are clustered at the twin-pair level. Models D and E are based on twin pairs where both co-twins have nonmissing information on math skill

*Indicates 10 % significance; **5 % significance; ***1 % significance

3.3 Explaining associations using DZ twins

Finally, we seek to shed light on what factors might explain the *associations* between health and education observed in our data. Our results based on comparisons of MZ twins indicated that health and education are unrelated once shared environment and genes are fully accounted for. However, these results do not tell whether it is only environment but also genes that drive the relationship found when using OLS and whether there is a role played by cognition or other skills.

In Table 6, we exploit DZ twins to shed light on this. Just like MZ twins, DZ twins share more or less the same childhood environment, but they only share half of their genes. Any difference between results based on MZ twins and DZ twins may therefore reflect genetic factors.

We begin by running an OLS regression of educational attainment against global health on the DZ twin sample. Controls for year of birth, parental education, and family income are included. We find that the OLS result is rather similar to the one obtained based on the full population sample, as well as similar to the one obtained based on the MZ twins. This indicates that DZ twins are representative of the overall male population. Adding twin-fixed effects reduces the coefficient by more than half, pointing at the importance of genes and environmental factors shared between DZ twins. Importantly, however, the coefficient on health is still significant and it is far from zero. This contrasts to the results based on MZ twins and points to genetic factors as one important determinant of the health-schooling relationship.

To better understand the remaining (genetic) factor creating a relationship between health and education, we then add cognitive and noncognitive ability, or math skills, to the regression. First, column C shows the result when controlling for cognitive and noncognitive ability. We find that accounting for these factors renders the coefficient on health small and insignificant, suggesting that the genetic component influencing education may be fully represented by these abilities.[21] Similarly, controlling for math skills at age 15 produces a coefficient on global health that is insignificant and rather close to zero; however, the coefficient is imprecisely measured due to a smaller sample. In sum, our results are consistent with the idea that health does not impact on educational attainment among DZ twins and that part of the overall association between health and education can be attributed to genes, generating differences in abilities.

4 Conclusion

Using a large dataset of twins, including comprehensive information on their health status at the age of 18 and later educational attainment, this study investigated whether years of schooling is related to health within twin pairs. On the whole, we obtained no evidence of such a relationship within MZ twin pairs. This result holds both with and without controls for cognitive and noncognitive ability. Within DZ pairs, a significant relationship between health and education is obtained, but only when not controlling for abilities, suggesting the presence of some genetic factors influencing education through their effect on abilities.

The zero relationship between health and education holds true for global health status as well as for a number of other health conditions and for physical test variables. Moreover, when instrumenting global health with other health variables in order to account for measurement error, there is still no significant evidence of a health-schooling relationship. While several previous studies have found that birth weight improves educational outcomes, our findings strongly suggest that adolescent health does not have such an effect. We can only speculate about reasons for this discrepancy, but one explanation could be that health at birth is mediated by cognitive and noncognitive abilities, which are most malleable in the early years (e.g., Cunha et al. 2006; Figlio et al. 2013). Improving health without being able to influence such characteristics may not generate any important payoffs in terms of human capital.

Although this study circumvents many of the issues with twin studies, such as having a large enough sample to render important variation within twins, it has a few potential limitations. First, although our total population-twin comparisons indicate that twins are rather representative of the population at large, it is not testable whether the effect of health on education is the same in the general population as in twins. Second, there might exist important variables which are unobserved by us and not captured by the twin-fixed effect (or the other controls), but in order to bias our results upwards towards zero, these unobserved variables need to be associated with more schooling and at the same time with worse health (or vice versa)—a scenario that may be less reasonable. Finally, one has to note that our results are based on Sweden, a country known for a large degree of redistribution, low inequality, and free access to higher education. We leave it to future studies to determine if there is any relationship between health and educational attainment in countries where different policy environments are in place.

[21] We can also account separately for either cognitive or noncognitive ability. These two are positively correlated, and controlling for either of them renders the effect of health small and insignificant.

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Compliance with ethical standards

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Conflict of Interest The authors declare that they have no conflict of interest.

Appendix

Table 7 Descriptive statistics (population sample and DZ twins)

	Population		DZ twins				
	Mean (std)	Missing (%)	Mean (std)	*P* value (vs pop)	*P* value (MZ vs DZ)	Missing (%)	Pairs differing
Years of schooling	12.16 (2.26)	–	12.17 (2.34)	0.669	0.000	–	0.64
Global health	2.67 (4.20)	–	2.24 (3.95)	0.000	0.132	–	0.50
Cognitive ability	5.16 (1.92)	0.02	4.93 (1.92)	0.000	0.012	0.02	0.78
Noncognitive ability	5.12 (1.73)	0.05	5.23 (1.71)	0.000	0.790	0.04	0.76
Father's years of schooling	10.54 (3.09)	0.31	10.52 (3.23)	0.703	0.104	0.45	–
Mother's years of schooling	10.50 (2.85)	0.18	10.39 (2.98)	0.058	0.000	0.31	–
Family income 1970 (SEK)	76,492 (54,811)	–	86,079 (66,917)	0.000	0.000	–	–
Mental	0.06	–	0.07	0.078	0.000	–	0.10
Musculoskeletal	0.14	–	0.12	0.000	0.890	–	0.19
Skin	0.06	–	0.05	0.021	0.954	–	0.09
Respiratory	0.13	–	0.08	0.000	0.000	–	0.13
Injuries and poisonings	0.06	–	0.04	0.000	0.012	–	0.07
Low physical capacity	0.09	0.15	0.07	0.007	0.001	0.18	0.14
Weak handgrip strength	0.03	0.10	0.03	0.032	0.014	0.07	0.07
Hypertension	0.19	0.04	0.21	0.012	0.823	0.02	0.30
Overweight	0.10	0.03	0.06	0.000	0.140	0.02	0.10
Short	0.03	0.03	0.04	0.188	0.031	0.02	0.07
Low visual acuity	0.04	0.03	0.05	0.000	0.838	0.02	0.10
Low hearing acuity	0.06	0.03	0.07	0.018	0.006	0.017	0.12

Notes: The population sample includes 1,093,668 individuals and the DZ sample 4294 individuals. Means refer to means of non-missing values. "*P* value (vs pop)" refers from the *P* value from a *t* test where we test whether the mean is equal to the population average, and "*P* value (DZ-MZ)" refers to the *P* value from a *t* test where we test whether MZ and DZ twins have the same mean. "Pairs differing" is the share of twin pairs with different values on the variable in question. Cognitive and noncognitive ability refer to these measures before standardization

Table 8 Effect at different margins of schooling

	At least 10	At least 11	At least 12	At least 13	At least 14	At least 15	At least 16	At least 17	At least 18	At least 20
Panel A (OLS)										
Global	−0.057***	−0.079***	−0.069***	−0.091***	−0.067***	−0.050***	−0.037***	−0.008	−0.003	−0.006**
health (*10)	(0.017)	(0.017)	(0.020)	(0.020)	(0.019)	(0.018)	(0.013)	(0.005)	(0.004)	(0.003)
R-squared	0.103	0.113	0.236	0.184	0.167	0.164	0.127	0.043	0.021	0.029
Panel B (FE)										
Global	−0.002	−0.030	−0.004	−0.038*	0.001	0.010	−0.014	0.005	0.005	−0.005
health (*10)	(0.019)	(0.021)	(0.022)	(0.021)	(0.024)	(0.023)	(0.018)	(0.010)	(0.007)	(0.005)
R-squared	0.000	0.002	0.000	0.002	0.000	0.000	0.000	0.000	0.000	0.000
Individuals	3,748	3,748	3,748	3,748	3,748	3,748	3,748	3,748	3,748	3,748

Notes: Standard errors in parentheses. OLS models include dummies for birth year, parental educational attainment, and family income. In models with twin-fixed effects, R-squared refers to the within-twin R-square. Standard errors are clustered at the twin-pair level

*Indicates 10 % significance; **5 % significance; ***1 % significance

Table 9 Effect of different margins of health

X	1	2	3	4	5	6	7	8	9	10	11	12	13
Panel A (*OLS*)													
Global	−0.298***	−0.306***	−0.399***	−0.391***	−0.459***	−0.435***	−0.429***	−0.402***	−0.481***	−0.480***	−0.591***	−0.600***	−0.600***
health ≥ X	(0.076)	(0.077)	(0.078)	(0.086)	(0.095)	(0.101)	(0.104)	(0.107)	(0.112)	(0.112)	(0.127)	(0.128)	(0.128)
R-squared	0.230	0.230	0.233	0.231	0.232	0.231	0.231	0.230	0.231	0.231	0.232	0.232	0.232
Panel B (*FE*)													
Global	−0.126	−0.091	−0.050	−0.032	−0.054	−0.079	−0.076	−0.078	−0.022	−0.026	−0.022	−0.011	−0.024
Health ≥ X	(0.077)	(0.076)	(0.081)	(0.094)	(0.096)	(0.099)	(0.105)	(0.107)	(0.111)	(0.110)	(0.123)	(0.121)	(0.184)
R-squared	0.002	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Individuals	3,748	3,748	3,748	3,748	3,748	3,748	3,748	3,748	3,748	3,748	3748	3,748	3,748

Notes: Standard errors in parentheses. OLS models include dummies for birth year, parental educational attainment, and family income. In models with twin-fixed effects, R-squared refers to the within-twin R-square. Standard errors are clustered at the twin-pair level

*Indicates 10 % significance; **5 % significance; ***1 % significance

Table 10 Interactions with socioeconomic background

	A	B	C	D	E	F	G	H	I
Global health (*10)	−0.668***	−0.579***	−0.595***	−0.551***	−0.431***	−0.497***	0.029	−0.161	−0.070
	(0.006)	(0.007)	(0.008)	(0.122)	(0.152)	(0.162)	(0.145)	(0.180)	(0.200)
Global health (*10)*	−0.003		0.004	0.238		0.024	−0.165		−0.191
Mother low educated	(0.010)		(0.010)	(0.214)		(0.195)	(0.189)		(0.185)
Global health (*10)*	0.048***		0.060***	0.017		0.245	−0.171		−0.201
Father low educated	(0.010)		(0.010)	(0.194)		(0.215)	(0.205)		(0.201)
Global health (*10)*		−0.125***	−0.129***		−0.073	−0.092		0.138	0.198
Family low income		(0.009)	(0.009)		(0.195)	(0.196)		(0.213)	(0.208)
R-squared	0.200	0.200	0.201	0.234	0.233	0.234	0.041	0.000	0.043
F test	0.000***	0.000***	0.000***	0.000***	0.000***	0.000***	0.424	0.659	0.411
Twin-fixed effects	–	–	–	No	No	No	Yes	Yes	Yes
Individuals	1,093,668	1,093,668	1,093,668	3,748	3,748	3,748	3748	3,748	3,748

Notes: Standard errors in parentheses. In models with twin-fixed effects, R-squared refers to the within-twin R-square. OLS regressions control for year of birth, parental education, and family income. In the twin sample, standard errors are clustered at the twin-pair level. "*F* test" is the *P* value from an *F* test based on the null hypothesis that all health coefficients equal zero

*Indicates 10 % significance; **5 % significance; ***1 % significance

Table 11 Using the 25th percentiles to define poor health (low physical capacity, low handgrip strength, short height, poor visual acuity, and poor hearing acuity)

	A	B	C	D	E
Mental	−0.963***	−0.828***	−1.115***	−0.950***	−0.018
	(0.008)	(0.008)	(0.188)	(0.177)	(0.194)
Musculoskeletal	−0.278***	−0.243***	−0.250**	−0.187*	0.106
	(0.005)	(0.006)	(0.112)	(0.106)	(0.101)
Skin	0.048***	0.023***	0.036	−0.022	−0.337**
	(0.008)	(0.008)	(0.173)	(0.168)	(0.163)
Respiratory	0.267***	0.154***	0.380***	0.162	0.074
	(0.006)	(0.006)	(0.132)	(0.116)	(0.115)
Injuries and poisonings	−0.194***	−0.207***	0.152	−0.008	−0.011
	(0.008)	(0.008)	(0.164)	(0.152)	(0.112)
Low physical capacity	−0.674***	−0.462***	−1.050***	−0.711***	−0.182
	(0.004)	(0.005)	(0.106)	(0.105)	(0.114)
Weak handgrip strength	0.288***	0.254***	0.241**	0.280***	0.117
	(0.005)	(0.005)	(0.103)	(0.096)	(0.090)
Hypertension	0.133***	0.123***	−0.016	−0.017	0.135*
	(0.005)	(0.005)	(0.102)	(0.095)	(0.081)
Overweight	−0.264***	−0.237***	−0.195	−0.187	−0.015
	(0.006)	(0.007)	(0.167)	(0.163)	(0.159)
Short	−0.510***	−0.414***	−0.681***	−0.460***	−0.187
	(0.005)	(0.005)	(0.101)	(0.097)	(0.127)
Low visual acuity	−0.230***	−0.172***	−0.159	−0.032	−0.009
	(0.008)	(0.008)	(0.157)	(0.145)	(0.146)
Low hearning acuity	−0.304***	−0.269***	0.047	−0.010	0.024
	(0.006)	(0.006)	(0.122)	(0.115)	(0.099)
R-squared	0.052	0.187	0.058	0.221	0.010
F test	0.000***	0.000***	0.000***	0.000***	0.210
Sample	All	All	MZ	MZ	MZ
Basic controls	No	Yes	No	Yes	–
Twin-fixed effects	–	–	No	No	Yes
Individuals	1,093,668	1,093,668	3,748	3,748	3,748

Notes: Standard errors in parentheses. In models with twin-fixed effects, R-squared refers to the within-twin R-square. In the twin sample, standard errors are clustered at the twin-pair level. "*F* test" is the *P* value from an *F* test based on the null hypothesis that all health coefficients equal zero

*Indicates 10 % significance; **5 % significance; ***1 % significance

Table 12 Including health variables one by one

	A	B	C	D	E
Mental	−1.253***	−1.003***	−1.425***	−1.066***	−0.022
	(0.009)	(0.008)	(0.180)	(0.167)	(0.194)
Musculoskeletal	−0.369***	−0.311***	−0.318***	−0.255**	0.073
	(0.006)	(0.006)	(0.116)	(0.106)	(0.099)
Skin	0.066***	0.015*	0.064	−0.066	−0.325**
	(0.009)	(0.009)	(0.174)	(0.158)	(0.163)
Respiratory	0.351***	0.150***	0.526***	0.160	0.045
	(0.006)	(0.006)	(0.121)	(0.111)	(0.114)
Injuries and poisonings	−0.224***	−0.264***	0.163	−0.056	−0.013
	(0.009)	(0.009)	(0.176)	(0.159)	(0.108)
Low physical capacity	−1.005***	−0.665***	−1.354***	−0.986***	−0.194
	(0.008)	(0.007)	(0.184)	(0.169)	(0.157)
Weak handgrip strength	0.138***	0.129***	−0.051	0.129	−0.022
	(0.013)	(0.012)	(0.195)	(0.177)	(0.188)
Hypertension	0.122***	0.113***	0.038	0.011	0.129
	(0.006)	(0.005)	(0.094)	(0.085)	(0.080)
Overweight	−0.552***	−0.463***	−0.551***	−0.536***	−0.057
	(0.007)	(0.007)	(0.173)	(0.157)	(0.153)
Short	−0.705***	−0.516***	−0.652***	−0.437***	−0.366*
	(0.012)	(0.011)	(0.182)	(0.165)	(0.191)
Low visual acuity	−0.547***	−0.354***	−0.455***	−0.207	−0.085
	(0.012)	(0.011)	(0.173)	(0.157)	(0.165)
Low hearning acuity	−0.605***	−0.423***	−0.493***	−0.375**	−0.121
	(0.009)	(0.009)	(0.169)	(0.153)	(0.142)
Sample	All	All	MZ	MZ	MZ
Basic controls	No	Yes	No	Yes	–
Twin-fixed effects	–	–	No	No	Yes
Individuals	1,093,668	1,093,668	3,748	3,748	3,748

Notes: Standard errors in parentheses. OLS models include dummies for birth year, parental educational attainment, and family income. In the twin sample, standard errors are clustered at the twin-pair level

*Indicates 10 % significance; **5 % significance; ***1 % significance

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