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Genetic and environmental factors affecting self-esteem from age 14 to 17: a longitudinal study of Finnish twins

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ABSTRACT

Background. We analysed genetic and environmental influences on self-esteem and its stability in adolescence.

Method. Finnish twins born in 1983–1987 were assessed by questionnaire at ages 14 ($n = 4132$ twin individuals) and 17 years ($n = 3841$ twin individuals). Self-esteem was measured using the Rosenberg global self-esteem scale and analyzed using quantitative genetic methods for twin data in the Mx statistical package.

Results. The heritability of self-esteem was 0·62 [95% confidence interval (CI) 0·56–0·68] in 14-year-old boys and 0·40 (95% CI 0·26–0·54) in 14-year-old girls, while the corresponding estimates at age 17 were 0·48 (95% CI 0·39–0·56) and 0·29 (95% CI 0·11–0·45). Rosenberg self-esteem scores at ages 14 and 17 were modestly correlated ($r = 0{\cdot}44$ in boys, $r = 0{\cdot}46$ in girls). In boys, the correlation was mainly (82%) due to genetic factors, with residual co-variation due to unique environment. In girls, genetic (31%) and common environmental (61%) factors largely explained the correlation.

Conclusions. In adolescence, self-esteem seems to be differently regulated in boys *versus* girls. A key challenge for future research is to identify environmental influences contributing to self-esteem during adolescence and determine how these factors interact with genetic influences.

INTRODUCTION

Self-esteem is defined as a person's positive or negative attitude toward himself or herself (Rosenberg, 1965), and it is closely associated with personality functioning. High self-esteem is manifest in enhanced initiative, happiness and life satisfaction (Buhrmester *et al.* 1988; Diener & Diener, 1995; LePine & Van Dyne, 1998; Furnham & Cheng, 2000). Self-esteem is positively associated with better self-rated health (Glendinning, 1998), and low self-esteem has been related to poor physical health outcomes (Nirkko *et al.* 1982). Under some circumstances, low self-esteem predisposes to depression and disordered eating (Whisman & Kwon, 1993; Button *et al.* 1996; Kendler *et al.* 2002, 2006). However, high self-esteem seems to be a heterogeneous concept that may promote initiative

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and confident action in either constructive or destructive ways (Salmivalli *et al.* 1999).

It has been suggested that instability of self-esteem may be more strongly associated with negative outcomes than simply having low self-esteem (Kernis *et al.* 1993). Self-esteem does not remain unchanged across the lifespan: its stability increases throughout adolescence and young adulthood until mid-life (Pulkkinen *et al.* 2005) and starts to decline thereafter (Trzesniewski *et al.* 2003). Stability does not differ by gender (Trzesniewski *et al.* 2003). Over time, self-esteem has shown substantial continuity, with test–retest correlations being on average 0·40–0·65 across the lifespan and 0·46–0·63 during adolescence.

There are some gender-specific differences in average self-esteem scores: boys have ubiquitously higher baseline scores and experience continuous linear growth throughout adolescence, whereas girls have more variable trajectories and may experience an increase or decrease of self-esteem during teenage years (Stein *et al.* 1986; Block & Robins, 1993).

Interactions in the family environment were previously considered the primary source in the development of self-esteem (Robson, 1988). Recently, several studies have challenged this traditional view, demonstrating that genetic factors play a significant role in the etiology of self-esteem (Kendler *et al.* 1998; Kamakura *et al.* 2001; Neiss *et al.* 2002), with heritability estimates varying from 0·29 to 0·40. Roy *et al.* (1995) assessed heritability of self-esteem within time in adult female twins. They found moderate heritability for self-esteem (52% in the repeated measurement model), which was higher than the heritability estimates at two separate time points; the rest of the liability was explained by environmental influences unshared by a twin pair. In addition to genetic effects, non-shared environmental influences play a significant role in variance in self-esteem, whereas the influence of shared environment has been minimal. No sex-specific differences in genetic influences have been found in adults (Kendler *et al.* 1998).

To our knowledge, there are only a few previous genetically informative studies of factors that influence self-esteem or its stability/change in adolescents. McGuire *et al.* (1999) studied self-worth in a longitudinal genetic study among 10- to 18-year-old adolescents. They found significant heritability in mid- but not in early adolescence. Genetic factors explained 40% and non-shared environmental factors 60% of the correlation in general self-worth between two time points from age 10 to 18. Neiss *et al.* (2006) assessed genetics of self-esteem level and its self-assessed stability in 10- to 19-year-old adolescent twins. In addition, they examined whether the two self-esteem components were subject to different genetic influences: genetic and non-shared environmental influences were found to best explain the variance in level and perceived stability as well as the covariance between the two components. Importantly, self-esteem level and stability appeared to share common antecedents through genetic and non-shared influences.

Because longitudinal studies have suggested both continuity and change in patterns of self-esteem across adolescence, it is particularly important to understand the factors contributing to self-esteem at this age and to examine potential gender differences in stability and change. The aim of this study was to investigate changes in self-esteem during adolescence and the contribution of genetic and environmental influences to these changes using a longitudinal design in Finnish adolescent twins.

METHOD

Participants

The data were derived from the FinnTwin12 Study, a longitudinal population-based study of five consecutive and complete nationwide birth cohorts of Finnish twins born between 1983 and 1987. Data collection was approved by local ethic committees. Baseline data collection took place when the twins were 11–12 years of age, but did not include a self-esteem measure. Follow-up questionnaires were mailed in the month the twins turned 14 for those who had responded at baseline. They were completed at mean age of 14·1 years for both genders [standard deviation (S.D.) in boys and in girls = 0·08]. At age 17, the questionnaires were mailed to each birth cohort four times a year, with a mean age at response of 17·6 years for both genders (S.D. in boys = 0·24, S.D. in girls = 0·27). The participation rates were 87% in boys and 91% in girls at the age-14 assessment and 89% and 95% respectively at the age-17 assessment.

Twin zygosity was determined by a questionnaire using questions on physical similarity, a method that has shown high reliability in Finnish twin data (Sarna *et al.* 1978). In some ambiguous cases, questionnaire information was supplemented with additional information from photographs, fingerprints and DNA marker studies as described previously (Sarna *et al.* 1978; Kaprio *et al.* 2002). The number of participating twin individuals with known zygosity was 2070 boys and 2062 girls at age 14 and 1857 and 1984 twin individuals at age 17 respectively. For twin analyses at 14 years, data from the Rosenberg Self-Esteem Scale were available from 683 male–male pairs [317 monozygotic (MZ) and 366 dizygotic (DZ) male pairs], 671 female–female pairs (346 MZ and 325 DZ), 670 opposite-sex dizygotic (OSDZ) pairs, and 84 twin individuals whose co-twin did not answer. At 17 years, data were available for 619 male–male pairs (290 MZ and 329 DZ), 667 female–female pairs (346 MZ and 321 DZ), 630 OSDZ pairs, and nine twin individuals from pairs in which only one co-twin answered.

Measures: Rosenberg global self-esteem

Self-esteem was assessed by the 10-item Rosenberg Self-Esteem Scale (Rosenberg, 1965), a brief, unidimensional measure of global self-esteem originally designed for adolescents, consisting of 10 statements relating to overall feelings of self-worth and self-acceptance. Half of the items are worded in a positive direction and half in the opposite direction, which requires reverse scoring. The measurement used the original four-point Likert scale with response options ranging from strongly agree (4) to strongly disagree (1) for each item. These were summed to generate the standard score ranging from a minimum of 10 to a maximum of 40. Cronbach's α for the internal consistency of the Rosenberg self-esteem scores at 14 years was 0·84 for girls and 0·80 for boys, and at 17 years 0·88 for girls and 0·85 for boys. In the text that follows, we refer to this measure as the self-esteem score.

Statistical analysis

We used quantitative genetic methods for twin data based on linear structural equation modeling (Neale & Cardon, 1992). MZ twins are genetically identical, whereas DZ twins share, on average, 50% of their segregating genes. Two sources of genetic influence can be estimated: additive genetic variation, which is the sum of the effects of all alleles affecting the phenotype, and dominance, the part of the genetic variation due to interaction between alleles at the same locus. Epistatic genetic effect, that is interaction of alleles between different loci, is assumed to be absent. Additive and dominance genetic effects have a correlation of 1 within MZ pairs and 0·5 and 0·25 within DZ pairs respectively (Neale & Cardon, 1992). Both MZ and DZ twins are assumed to share the same amount of environmental variation, which is partly shared by a twin pair (common environment) and partly unique to each twin individual (unique environment), the latter including any random measurement error. The relative magnitude of same-sex dizygote (SSDZ) and OSDZ twin correlations offers an opportunity to test whether sex-specific genetic or shared environmental factors exist, that is whether the genes or shared environmental factors that influence the liability to self-esteem are the same in boys and girls. If there is a different set of genes affecting self-esteem in men and women, this is seen as lower OSDZ correlations compared to SSDZ correlations.

Based on these assumptions, the model allows decomposition of the phenotypic variation into additive (A) and dominance (D) genetic variation as well as common (C) and unique (E) environmental variation. As we only had information on MZ and DZ twin pairs reared together, dominance genetic and common environmental effects cannot be modeled simultaneously. Decisions about fitting ACE models *versus* ADE models were made based on the pattern of the twin correlations. As we did not have information on parental self-esteem, we could not determine the possible effects of assortative mating. If phenotypic assortment by self-esteem existed, this would inflate DZ correlations and consequently cause overestimation of the common environmental variance and underestimation of heritability. The presence of gene–environment interaction (i.e. genetic-based susceptibility to environmental conditions) is confounded with the additive genetic component or in some cases with the unique

Table 1. *Mean values (and standard deviations) of Rosenberg self-esteem score within MZ, same-sex DZ and opposite-sex DZ twin individuals for self-esteem at ages 14 and 17*

Age (years)	MZ males	DZ same-sex males	MZ females	DZ same-sex females	DZ opposite-sex females	DZ opposite-sex males
14	32·7 (4·5)	31·6 (5·0)	29·3 (5·7)	28·8 (5·5)	28·9 (5·5)	31·3 (4·7)
17	33·3 (4·6)	32·1 (5·0)	29·3 (5·8)	29·3 (5·6)	28·6 (6·1)	32·0 (5·2)

MZ, Monozygotic; DZ, dizygotic.

environment depending on whether the environmental factors interacting with genetic factors are shared or unshared by a twin pair (Neale & Cordon, 1992). The raw data input option of the Mx software was used (Neale *et al.* 2002).

Genetic modeling was started by fitting univariate models to self-esteem at each age separately. First, we tested the assumptions of twin models by comparing the fit of the twin models to saturated models, which do not make these assumptions. Second, we compared nested twin models to find the best model, which guided our choice of bivariate models for final estimate of variance components and decomposition of the longitudinal phenotypic correlation. The fit of the nested models was analyzed by log-likelihood (LL) tests. The difference in the -2 LL values and corresponding degrees of freedom is distributed as χ^2. If the difference in the log-likelihoods between two nested models associated with the difference in degrees of freedom ($\Delta\chi^2{}_{df}$) is statistically significant, the more parsimonious model fits significantly worse and lacks important parameters. In subsequent bivariate models, a Cholesky decomposition of covariance and variance was used, with model testing following the same principles as for univariate models. In the bivariate model, A, C and E influences can be estimated on both variables (self-esteem at each age). In addition, it is possible to estimate to which extent the correlation between the variables is due to correlations between the genetic, shared or unique environmental factors affecting self-esteem scores at these two ages. Under the bivariate model, the square of additive genetic correlation (r_A) indicates the percentual extent of genetic factors common (or of closely linked loci) to self-esteem at 14 years and self-esteem at 17 years. The corresponding computation applies to common and unique environmental correlations (r_C and r_E respectively). The proportion of phenotypic correlation explained by genetic and environmental factors indicates the percentual extent of the correlation between self-esteem at 14 years and self-esteem at 17 years explained by shared genetic (A), common (C) or unique (E) environmental factors.

Descriptive statistics were derived using Stata Statistical Software release 9.1 (Stata Corporation, College Station, TX, USA). All individual-level analyses on means were controlled for clustered sampling (Williams, 2000) within the twin pair.

RESULTS

In both sexes, self-esteem scores were reasonably normally distributed, although in boys skewing towards higher scores (median 32 at 14 years and 33 at 17 years) was evident compared to girls (median 29 at 14 and 17 years) in both age groups.

Mean values of self-esteem scores of twin individuals from different zygosity groups are presented in Table 1. The overall mean of self-esteem scores in boys was significantly higher than that of girls in both age groups (14 and 17 years: $p<0{\cdot}001$): 31·8 (95% CI 31·6–32·0) among boys and 29·0 (95% CI 28·7–29·2) among girls at age 14, and 32·4 (95% CI 32·2–32·6) and 29·1 (95% CI 28·8–29·3) at age 17 respectively. In boys, the self-esteem scores were higher at age 17 than at age 14 in all zygosity groups.

We compared the mean self-esteem scores of each individual at 14 and 17 years: in DZ opposite-sex males, the increase in self-esteem scores from age 14 to 17 was statistically significant but of little clinical relevance (mean

Table 2. *Number of complete twin pairs, intra-class correlations and 95% confidence intervals of Rosenberg self-esteem score within MZ, same-sex DZ and opposite-sex DZ twin pairs for self-esteem at ages 14 and 17*

Age (years)	MZ males		DZ same-sex males		MZ females		DZ same-sex females		DZ opposite-sex pairs	
	n	*r* (95% CI)	*n*	*r* (95% CI)	*n*	*r* (95% CI)	*n*	*r* (95% CI)	*n*	*r* (95% CI)
14	317	0·57 (0·49–0·64)	366	0·34 (0·24–0·43)	346	0·66 (0·60–0·72)	325	0·45 (0·35–0·53)	670	0·27 (0·19–0·34)
17	290	0·47 (0·37–0·56)	329	0·15 (0·04–0·26)	346	0·55 (0·47–0·62)	321	0·35 (0·25–0·45)	630	0·18 (0·10–0·26)

MZ, Monozygotic; DZ, dizygotic; CI, confidence interval.

Table 3. *Model fit statistics for univariate models for Rosenberg self-esteem scores at ages 14 and 17*

	−2 LL	df	Δx^2	Δdf	*p* value
Age 14 years					
Saturated model	24309·4	4029	—	—	—
ACE boys/girls	24329·1	4045	19·69	16	0·23
AE boys/ACE girls	24329·5	4046	0·38	1	0·54
ACE boys/AE girls	24336·2	4046	7·06	1	0·008
ADE boys/girls	24336·5	4045	27·14	16	0·04
AE boys/ADE girls	24337·1	4046	0·59	1	0·44
ADE boys/AE girls	24336·6	4046	0·06	1	0·81
Age 17 years					
Saturated model	23504·8	3811	—	—	—
ACE boys/girls	23524·9	3827	20·12	16	0·22
AE boys/ACE girls	23525·3	3828	0·34	1	0·56
ACE boys/AE girls	23534·6	3828	9·62	1	0·002
ADE boys/girls	23524·7	3827	19·88	16	0·23
AE boys/ADE girls	23533·6	3828	8·96	1	0·003
ADE boys/AE girls	23524·7	3828	0·03	1	0·87

LL, Log-likelihood; df, degrees of freedom.

Phenotypic variation was decomposed into additive (A) and dominance (D) genetic variation, common (C) and unique (E) environmental variation.

self-esteem scores of 31·3 to 32·0). Mean values of self-esteem scores were statistically significantly higher in MZ twin individuals compared to that of DZ twins in both age groups for boys. In girls at 17 years, self-esteem scores in both MZ females and DZ same-sex females were statistically significantly higher than those of DZ opposite-sex females (Table 1). The trait correlation (i.e. Pearson's correlation of self-esteem scores between ages 14 and 17) was 0·44 in boys and 0·46 in girls.

Those who dropped out of the study after the 14-year assessment and did not answer at 17 years had significantly lower self-esteem [mean 29·9 (95% CI 29·4–30·3) *versus* mean 30·5 (95% CI 30·3–30·7)]. Subjects whose co-twin had not answered at 14 years were more likely to drop out ($\chi^2 = 55·2$, $p < 0·001$) and not answer at 17 years. There was no statistically significant difference in self-esteem scores between those individuals whose co-twin did and did not answer in either age group (data not shown).

The intra-pair intra-class correlations within each five zygosity groups for self-esteem scores are presented in Table 2. Among same-sex pairs in both age groups, with the exception of male pairs at age 17, MZ correlations were significantly greater but not more than double the DZ same-sex correlations, implying the effect of additive genetic influences with no dominance effects. In 17-year-old DZ same-sex males, the intra-pair correlation ($r = 0·15$) was only a third of the MZ male correlation ($r = 0·47$), implying a possible genetic effect due to dominance. In all zygosity groups, the intra-pair correlations were lower at 17 than at 14 years.

We performed univariate modeling for self-esteem scores at ages 14 and 17 for both sexes using sex-limitation models to test the assumptions of the twin modeling and find the best model to be used in subsequent bivariate modeling. The detailed model fit statistics for univariate modeling are presented in Table 3. At 14 years of age, the ACE model offered the best fit compared to the saturated model ($\Delta\chi^2_{16} = 19·7$, $p = 0·234$) with constrained means and variances. Fixing the common environmental effect to zero worsened the fit statistically significantly in girls ($\Delta\chi^2_1 = 7·06$, $p = 0·008$) but not in boys ($\Delta\chi^2_1 = 0·38$, $p = 0·537$), suggesting the ACE model in girls and the AE model in boys at this age. At 17 years of age, both ACE ($\Delta\chi^2_{16} = 20·1$, $p = 0·215$) and ADE models ($\Delta\chi^2_{16} = 19·88$, $p = 0·226$) had a good fit compared to the saturated model. However, at this age, we found evidence for some possible sex differences. Fixing the common environmental effect as zero

Table 4. *Proportion of trait variance explained by genetic and environmental factors, correlations between these variance components and proportion of phenotypic correlation explained by these correlations in the bivariate model for self-esteem at 14 and 17 years of age*

	Boys		Girls	
	Estimate	95% CI	Estimate	95% CI
$a^2_{\text{self-esteem 14}}$	0·62	0·56–0·68	0·40	0·26–0·54
$c^2_{\text{self-esteem 14}}$	—		0·31	0·18–0·42
$e^2_{\text{self-esteem 14}}$	0·38	0·32–0·44	0·30	0·25–0·35
$a^2_{\text{self-esteem 17}}$	0·48	0·39–0·56	0·29	0·11–0·45
$c^2_{\text{self-esteem 17}}$	—		0·34	0·21–0·47
$e^2_{\text{self-esteem 17}}$	0·52	0·44–0·61	0·37	0·30–0·46
r_A	0·78	0·69–0·86	0·46	0·22–0·86
% explained	82	0·72–0·92	31	0·12–0·52
r_C	—		0·97	0·71–1·00
% explained			61	0·43–0·76
r_E	0·21	0·10–0·31	0·13	0·00–0·25
% explained	18	0·08–0·28	8	0·00–0·17

CI, Confidence interval; a^2, proportion of trait variation explained by additive genetic factors; c^2, proportion of trait variation explained by common environmental factors; e^2, proportion of trait variation explained by unique environmental factors; r_A, additive genetic correlation; r_C, common environmental correlation, r_E, unique environmental correlation.

in girls decreased the model fit compared to the full ACE model ($\Delta\chi^2_1 = 9{\cdot}62$, $p = 0{\cdot}002$). Because of the inability of the basic twin model to simultaneously model C and D, we decided to use the ACE model in girls and the AE model in boys in order to fit models examining the stability of self-esteem. In a sex-limitation model using all five sex-zygosity groups, the sex-specific genetic effects were found to be statistically non-significant ($\Delta\chi^2_1 = 0{\cdot}09$, $p = 0{\cdot}764$ at age 14; $\Delta\chi^2_1 = 0{\cdot}15$, $p = 0{\cdot}70$ at age 17), indicating that the same genes were accounting for genetic effects on self-esteem in boys and girls, but their relative magnitude might nonetheless differ.

Table 4 presents the results for the final bivariate modeling. In boys, additive genetic factors accounted for 0·62 (95% CI 0·56–0·68) and unique environmental factors 0·38 (95% CI 0·32–0·44) at age 14 under the AE model; the corresponding estimates at age 17 were 0·48 (95% CI 0·39–0·56) and 0·52 (95% CI 0·44–0·61) respectively. In girls, for whom the ACE model was used, the additive genetic factors (A) accounted for 0·40 (95% CI 0·26–0·54), common environmental factors 0·31 (95% CI 0·18–0·42), and unique environment 30 (95% CI 0·25–0·35) of the variance in self-esteem scores at age 14 whereas the corresponding estimates at age 17 were 0·29 (95% CI 0·11–0·45), 0·34 (95% CI 0·21–0·47) and 0·37 (95% CI 0·30–0·46) respectively. In boys, genetic factors explained 82% ($r_A = 0{\cdot}78$ 95% CI 0·69–0·86) and unique environmental factors 18% of the correlation in self-esteem between these two ages. In girls, 31% of the correlation was explained by the genetic factors ($r_A = 0{\cdot}46$, 95% CI 0·22–0·86), 61% by the common environmental factors and 8% by the unique environmental factors.

DISCUSSION

In our study, the genetic and environmental determinants of age-to-age correlation in self-esteem differed by gender: in boys, it was largely due to genetic influences, which suggests a substantial biological basis to the development of self-esteem in adolescent males. In girls, genetic and those environmental factors shared by a twin pair explained most of the correlation between self-esteem assessed 3 years apart; the contribution of unique environment was almost the same as in boys. This suggests that earlier theories of the salience of shared environment (Robson, 1988) on self-esteem development would only apply to females. In addition, we found no evidence that the genetic factors affecting self-esteem were different in boys and girls.

In line with a previous meta-analysis (Trzesniewski *et al.* 2003), where the test–retest correlation of self-esteem from 12 to 17 years was 0·48 and did not differ significantly by sex, we found no sex differences in the correlation of self-esteem scores between ages 14 and 17. However, as suggested previously (Block & Robins, 1993), regardless of equivalent stability levels in both sexes, the change in self-esteem may be regulated by different factors: it is possible that in males, self-focused, action-oriented characteristics dominate, whereas in females, interpersonal qualities such as warmth and nurturance may be more important.

Using our significantly larger sample size of adolescent twins we replicated the results of

Neiss *et al.* (2006), where genetic and non-shared variances in self-esteem level at two time points between 10 and 19 years were significant. Inconsistent with our results, McGuire *et al.* (1999) found significant heritability of general self-worth in mid- but not in early adolescence: at average age 13 the genetic variance of general self-worth was 0·16, shared environmental variance was 0·01 and non-shared environmental variance 0·83. At the second time point (average age 16), genetic variance was 0·60 and non-shared variance 0·40. In our study, proportions of genetic variances were significant in both genders and at both ages, yet larger at the first time point at 14 years. The intra-pair correlations of self-esteem scores in our study decreased from 14 to 17 years in all zygosity groups, which suggests that unshared environmental events increasingly influence self-esteem over the course of adolescence.

We further replicated the previous findings for gender difference in self-esteem levels: compared to girls, boys' scores were initially significantly higher at 14 years, then exhibited a slight growth pattern, whereas girls' scores did not follow any consistent pattern. In addition, the mean self-esteem scores were significantly higher in male MZ twins compared to male DZ twins, although the effect size was small. However, Kendler *et al.* (1998), who found the corresponding zygosity difference controlling for sex, suggested that this effect might be present in the population, perhaps reflecting the greater sense of specialness experienced by MZ twins or the unusually close emotional bond between MZ twins. Supporting this, Pulkkinen *et al.* (2003) showed in the same FinnTwin12 sample as used in this study that being a twin may have a positive effect on early adolescent development: twins were more popular than non-twins in peer nominations and scored higher on positive sociality, in particular twins from opposite-sex pairs.

From genetic studies in adult twins we have learned that, although genetic influences are substantial, unique environmental influences explain the largest amount of variance in self-esteem in both genders. In this study, one of the main findings was the large influence of genetic effects in boys' self-esteem development, which may reflect an association between self-esteem and physical maturation. Different timing of puberty, which we know to be under genetic influence, may also have acted as a confounding factor. Mean age for voice break, a commonly used sign for termination of physical puberty in boys, was in our sample at age 14·0 (95% CI 13·9–14·0). It is possible that mental changes following the physical puberty ongoing especially among boys at the age of 17 would manifest in DZ boys' relative dissimilarity, because timing of the development within a DZ twin pair is not synchronic as in genetically identical MZ twin pairs. This would be manifest as a relatively low intra-pair correlation in 17 years compared to that of 14-year-old DZ same-sex boys. The assumption of boys' malleable personal views throughout teenage years is supported by Block & Robins (1993), who studied consistency and change of self-esteem in a longitudinal study in adolescents from age 14 to 17 and to 23 and stated that a significantly greater longitudinal ordering consistency within their sample of girls implies that, unlike for boys, for many girls levels of self-esteem are relatively well established by adolescence. Finally, it is worth noting that even if shared environmental factors did not influence boys' self-esteem at either time point, or the correlation of self-esteem, this does not necessarily imply that shared environment (e.g. home, peer interactions) has no influence on boys' self-esteem. Individuals within a family or a peer group can hold very different internal representations. If, for example, parents treated siblings differently or siblings interpreted parental behavior differently, these individual differences within a family would fall under unique environment. However, lack of evidence for shared environmental effect suggests only that its influence is less powerful than the dominant genetic influences, not that shared environmental effect would be non-existent.

Girls tend to internalize whereas boys tend to externalize behaviors resulting from psychological problems. Adolescent girls more often than boys suffer from conditions such as depression and eating disorders, where low self-esteem evidently plays a role (Button *et al.* 1996; Kendler *et al* 2002). In childhood, self-worth is equal between sexes. In early adolescence, girls' self-esteem begins to decline and becomes vulnerable, for example to appearance and weight-related issues (Biro *et al.* 2006). The crucial question is which specific factors in shared environment (social interactions, rearing, home) contribute to girls' self-esteem development. Once uncovered, interventions to support girls' self-esteem could be planned. Compared to boys, it appears that there is a definitive need to support girls' self-esteem: Salmivalli *et al.* (1999) showed that girls tend to under-evaluate themselves compared to peer evaluation, while over-evaluation of self is typical of boys. Of interest, self-esteem scores were also slightly lower in 17-year-old girls who grew up with a male *versus* female co-twin; a finding also observed in adult twins (Kendler *et al.* 1998). Boys from the DZ opposite-sex pairs were, on the contrary, the only zygosity group whose increase in self-esteem from 14 to 17 years was statistically significant. This suggests that a male co-twin, whose own self-esteem development is largely genetically driven, may have an adverse effect on self-esteem of his female co-twin, whose self-esteem development in turn is more sensitive to shared environmental influences, such as relationships with one's siblings or shared friends.

Antisocial and violent behavior is more prevalent in boys (van Lier *et al.* 2005). Attempts to link self-esteem to externalizing behavior have produced mixed results. Donellan *et al.* (2004) recently found a fairly robust and independent correlation between low self-esteem and delinquent aggressive behavior. However, individuals with good self-esteem have been shown to be over-represented among both antisocial and psychologically healthy adolescents (Salmivalli *et al.* 1999).

Strengths and limitations

This study is the first attempt to explore the genetic and environmental influences on adolescent global self-esteem and its stability over time. Additional strengths include the longitudinal population-based cohort design, inclusion of OSDZ pairs, high response rate, and large sample size.

Our study also has some limitations. Although self-esteem is by definition a person's global positive or negative attitude toward him/herself (Rosenberg, 1965) and thus self-reported better than most other traits, multiple sources of information (e.g. evaluation by peers or parents) might be less affected by self-presentational motives (Salmivalli *et al.* 1999; Baumeister *et al.* 2003).

Limitations also include the necessary assumptions of random mating and equal environments, and the failure to directly model gene–environment interaction in the quantitative genetic models. Previous twin studies suggest that mating is selective for individual qualities such as intelligence and height, but relatively non-selective for personality traits (Eaves *et al.* 1999). The assumption that the shared environmental correlation between MZs is the same as DZs with respect to personality dimensions also appears tenable: adoption studies of twins reared apart have typically found comparable levels of MZ–DZ differences as have traditional twin analyses (Bouchard *et al.* 1990). Furthermore, it is possible that gene–environment interactions affect self-esteem in the same manner that they influence depression (Caspi *et al.* 2003). We did not model gene–environment interaction: in our study, it would be subsumed as a part of the additive genetic effect.

CONCLUSION

In our study, stability in self-esteem was differently regulated in adolescent boys compared to girls. In boys, genetic factors contributed to a large degree. In girls, significant shared environmental influences suggest that interventions intended to strengthen girls' self-esteem could be more feasible than among boys: this challenges future research to explore the core factors in family or social environment. In both sexes, an important remaining challenge is the identification of specific environmental factors contributing self-esteem during adolescence. These factors can act independently or in interaction with genes.

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DECLARATION OF INTEREST

None.

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