Published in final edited form as:

Psychol Med. 2007 November ; 37(11): 1625–1633.

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

Anu Raevuori, MD¹, Danielle M. Dick, PhD², Anna Keski-Rahkonen, MD, PhD, MPH^{1,3,6}, Lea Pulkkinen, PhD⁴, Richard J. Rose, PhD⁵, Aila Rissanen, MD, PhD⁶, Jaakko Kaprio, MD, PhD^{1,7}, Richard J. Viken, PhD⁵, and Karri Silventoinen, PhD¹

¹Department of Public Health, University of Helsinki, Finland ²Departments of Psychiatry and Psychology, Washington University in St. Louis, St. Louis, MO USA ³Department of Epidemiology, Columbia University, U.S.A. ⁴University of Jyväskylä, Department of Psychology ⁵Department of Psychological and Brain Sciences, Indiana University, Bloomington, Indiana, U.S.A. ⁶Obesity Research Unit, Department of Psychiatry, Helsinki University Central Hospital, Finland ⁷Department of Mental Health, National Public Health Institute, Helsinki, Finland

Abstract

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

Methods—Finnish twins born in 1983–1987 were assessed by questionnaire at ages 14y (N= 4132 twin individuals) and 17y (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% CI 0.56–0.68) in 14-y-old boys and 0.40 (95% CI 0.26–0.54) in 14-y-old girls, while the corresponding estimates at age 17y were 0.48 (95% CI 0.39–0.56) and 0.29 (95% CI 0.11–0.45). Rosenberg self-esteem scores at age 14 y and 17 y were modestly correlated ($r=0.44$ in boys, $r=0.46$ 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 how these factors interact with genetic influences.

Keywords

Self-esteem; twin study; longitudinal study; adolescence

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). On the other hand, high self-esteem seems to be a heterogeneous concept which may promote initiative 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 life span: its stability increases throughout adolescence and young adulthood until midlife (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 life-span 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 10–18 y adolescents. Interestingly, 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 y. Neiss et al. (2006) assessed genetics of self-esteem level and its self-assessed stability in 10–19 y 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 via 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.

Materials and methods

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 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 y for both genders (SD 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 y for both genders (SD in boys =0.24, SD in girls =0.27). The participation rates were 87% in boys and 91% in girls at the age 14 y assessment and 89% and 95%, respectively, at the age 17 y assessment.

Twin zygosity was determined by a questionnaire using questions on physical similarity, a method which 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 in boys and 2062 in girls at 14 y and 1857 and 1984 twin individuals at 17 y, respectively. For twin analyses at 14 y, Rosenberg Self-Esteem Scale data 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 y, 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 9 twin individuals from pairs in which only one co-twin answered.

Measure

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 ten statements related to overall feelings of self-worth and self-acceptance. Half of the items are worded in the 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 alpha for the internal consistency of Rosenberg self-esteem scores at 14 y was 0.84 for girls and 0.80 for boys, and at 17 y 0.88 for girls and 0.85 for boys. In 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 modelling (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, i.e. interaction of alleles between different loci, is assumed to be absent. Additive and dominance genetic effects have a correlation of one 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, i.e. 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. Because we only had information on MZ and DZ twin pairs reared together, dominance genetic and common environmental effects cannot be simultaneously modelled. Decisions about fitting ACE models versus ADE models were made based on the pattern of the twin correlations. Because 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 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 modelling 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 analysed by log-likelihood tests. The difference in the -2 LL values and corresponding degrees of freedom is distributed as a chi-square. 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 y and self-esteem at 17 y. 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 y and self-esteem at 17 y explained by shared genetic (A), common (C) or unique (E) environmental factors.

Descriptive statistics were derived using Stata (version 9.1). 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 reasonable normally distributed, although in boys skewing towards higher scores (median 32 at 14 y and 33 at 17 y) was evident compared to girls (median 29 at 14 y and at 17) 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 y and 17 y: $p < 0.001$): 31.8 (95% CI 31.6–32.0) among boys and 29.0 (95% CI 28.7–29.2) among girls at age 14 y, and 32.4 (95% CI 32.2–32.6) and 29.1 (95% CI 28.8–29.3) at 17 y, respectively. In boys, the self-esteem scores were higher at age 17 y than at age 14 y in all zygosity groups.

We compared the mean self-esteem scores of each individual at 14 y and 17 y: in DZ opposite sex males, the increase in self-esteem scores from 14 y to 17 y was statistically significant, but of little clinical relevance (mean 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 y, both MZ females' and DZ same-sex females' self-esteem scores were statistically significantly higher than those of DZ opposite sex females' (Table 1). The trait, i.e. Pearson correlation of self-esteem scores between ages 14 y and 17 y was 0.44 in boys and 0.46 in girls.

Those who dropped out of the study after the 14 y assessment and did not answer at 17 y, 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 y, were more likely to drop out ($\chi^2 = 55.2$, $p < 0.001$) and not answer at 17 y. 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 intrapair 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 y, 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 y DZ same sex males, the intrapair 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 intrapair correlations were lower at 17 y than at 14 y.

We performed univariate modelling for self-esteem scores at age 14 y and 17 y for both sexes using sex-limitation models to test the assumptions of the twin modelling and find the best model to be used in subsequent bivariate modelling. The detailed model fit statistics for univariate modelling 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 ACE model in girls and 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 good fit compared to the saturated model. However at this age, we found evidence for some possible sex differences. Fixing common environmental effect as zero in girls decreased the model fit compared to the full ACE model ($\Delta\chi^2_1 = 9.62$, $p = 0.002$). Due to 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 ($\Delta\chi^2_1 = 0.09$, $p = 0.764$ at age 14; $\Delta\chi^2_1 = 0.15$, $p = 0.70$ 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 modelling. 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 y under the AE model; the corresponding estimates at age 17 y 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 0.30 (95% CI 0.25–0.35) of the variance in self-esteem scores at age 14 y whereas the corresponding estimates at age 17 y 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% ($r_A=0.78$ 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 ($r_A=0.46$ 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 three years apart; the contribution of unique environment was almost 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 12–17 y 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 y and 17 y. However, as previously suggested (Block & Robins 1993), regardless of equivalent stability levels in both sexes, the change of 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 like 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 of self-esteem level at two time points between 10–19 y were significant. Inconsistent with our results, McGuire et al. (1999) found significant heritability of general self-worth in mid- but not in the early adolescence: at average age 13 y 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 y), 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 first time point at 14 y. The intrapair correlations of self-esteem scores in our study decreased from 14 y to 17 y 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 14y, 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, though 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 while 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 as well 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 y (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 y would manifest in DZ boys' relative dissimilarity, since 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 intrapair correlation in 17 y compared to that of 14 y 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 y to 17 y and to 23 y 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 behaviour differently, these individual differences within a family would fall under unique environment. On the other hand, 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 like depression and eating disorders, where low self-esteem evidently plays a role (Button et al. 1996, Kendler et al 2002). In childhood, children's 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 critical 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. Interestingly, self-esteem scores were also slightly lower in 17 y girls who grew up with a male versus female co-twin; a finding also observed in adult twins (Kendler 1998). Boys from the DZ opposite sex pairs on the contrary were the only zygoty group whose increase in self-esteem from 14 to 17 y 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, e.g. relationships with one's siblings or shared friends.

Antisocial and violent behaviour is more prevalent in boys (van Lier et al. 2005). Attempts to link self-esteem to externalizing behaviour have produced mixed results: Donellan et al. (2004) recently found a fairly robust and independent correlation between low self-esteem and delinquent aggressive behavior. On the other hand, 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 had some limitations. Although self-esteem by definition is 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 (eg. 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 like 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). Further, it is possible that gene-environment interactions affect self-esteem in the manner 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 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.

Acknowledgements

This study was funded by NIH grants AA12502 and AA08315, the Academy of Finland (44069 and 201461), the Academy of Finland Centre of Excellence for Complex Disease Genetics, and the European Union (QLG2-CT-2002-01254), with additional NIH support to DMD (AA015416). AR received funding by the Finnish Medical Association Duodecim. KS was supported by the Academy of Finland (grant #108297). Esko Levälahti, MSc, provided statistical assistance. Eila Voipio, R.N., Kauko Heikkilä, Lic. Phil., Mrs Pia Ruokolinna and Ms Pirkko Särkijärvi provided technical assistance.

References

- Baumeister, RF.; Campbell, JD.; Krueger, JI.; Vohs, KD. Psychological Bulletin. 4. 2003. Does high self-esteem cause better performance, interpersonal success, happiness, or healthier lifestyles?.
- Biro FM, Striegel-Moore RH, Franko DL, Padgett J, Bean JA. Self-esteem in adolescent females. Journal of Adolescent Health 2006;39:501–7. [PubMed: 16982384]
- Block J, Robins RW. A longitudinal Study of Consistency and Change in Self-Esteem from Early Adolescence to Early Adulthood. Child Development 1993;64:909–923. [PubMed: 8339703]
- Bouchard TJ Jr, Lykken DT, McGue M, Segal NL, Tellegen A. Sources of human psychological differences: the Minnesota Study of Twins Reared Apart. Science 1990;12:223–228. [PubMed: 2218526]

- Buhrmester D, Furman W, Wittenberg MT, Reis HT. Five Domains of Interpersonal Competence in Peer Relationships. *Journal of Personality & Social Psychology* 1988;55:991–1008. [PubMed: 3216292]
- Button EJ, Sonuga-Barke EJ, Davies J, Thompson M. A prospective study of self-esteem in the prediction of eating problems in adolescent schoolgirls: questionnaire findings. *British Journal of Clinical Psychology* 1996;35:193–203. [PubMed: 8773797]
- Caspi A, Sugden K, Moffitt TE, Taylor A, Craig IW, Harrington H, McClay J, Mill J, Martin J, Braithwaite A, Poulton R. Influence of life stress on depression: moderation by a polymorphism in the 5-HTT gene. *Science* 2003;18:386–389. [PubMed: 12869766]
- Diener E, Diener M. Cross-cultural correlates of life satisfaction and self-esteem. *Journal of Personality & Social Psychology* 1995;68:653–663. [PubMed: 7738768]
- Donnellan MB, Trzesniewski KH, Robins RW, Moffitt TE, Caspi A. Low self-esteem is related to aggression, antisocial behaviour, and delinquency. *Psychological Science* 2004;16:328–335. [PubMed: 15828981]
- Eaves L, Heath A, Martin N, Maes H, Neale M, Kendler K, Kirk K, Corey L. Comparing the biological and cultural inheritance of personality and social attitudes in the Virginia 30,000 study of twins and their relatives. *Twin Research* 1999;2:62–80. [PubMed: 10480741]
- Furnham A, Cheng H. Perceived parental behaviour, self-esteem and happiness. *Social psychiatry and psychiatric epidemiology* 2000;35:463–470. [PubMed: 11127721]
- Glendinning A. Family life, health and lifestyles in rural areas: The role of self-esteem. *Health education* 1998;2:59–68.
- Kamakura T, Ando J, Ono Y. Genetic and environmental influences on self-esteem in a Japanese twin sample. *Twin Research* 2001;4:439–442. [PubMed: 11780935]
- Kaprio J, Pulkkinen L, Rose RJ. Genetic and environmental factors in health-related behaviors: studies on Finnish twins and twin families. *Twin Research* 2002;5:366–371. [PubMed: 12537860]
- Kendler KS, Gardner CO, Prescott CA. A population-based twin study of self-esteem and gender. *Psychological Medicine* 1998;28:1403–1409. [PubMed: 9854281]
- Kendler KS, Gardner CO, Prescott CA.). Toward a comprehensive developmental model for major depression in women. *American Journal of Psychiatry* 2002;159:1133–1145. [PubMed: 12091191]
- Kendler KS, Gardner CO, Prescott CA. Toward a Comprehensive Developmental Model for Major Depression in Men. *American Journal of Psychiatry* 2006;163:115–124. [PubMed: 16390898]
- Kernis MH, Cornell DP, Sun CR, Berry A, Harlow T. There's more to self-esteem than whether it is high or low: the importance of stability of self-esteem. *Journal of Personality and Social Psychology* 1993;65:1190–1204. [PubMed: 8295118]
- LePine JA, Van Dyne L. Predicting Voice Behavior in Work Groups. *Journal of Applied Psychology* 1998;83:853–868.
- McGuire S, Manke B, Saudino KJ, Reiss D, Hetherington EM, Plomin R. Perceived Competence and Self-Worth during Adolescence: A Longitudinal Behavioral Genetic Study. *Child Development* 1999;70:1283–1296. [PubMed: 10621957]
- Neale, MC.; Boker, SM.; Xie, G.; Maes, HH. Mx: Statistical modelling. Richmond, VA: Virginia Institute for Psychiatric and Behavioral Genetics, Virginia Commonwealth University, Department of Psychiatry; 2002.
- Neale, MC.; Cardon, LR. Methodology for genetic studies of twins and families. Dordrecht, the Netherlands: Kluwer Academic; 1992.
- Neiss MB, Sedikes C, Stevenson J. Self-esteem: A behavioral genetic perspective. *European Journal of Personality* 2002;16:351–367.
- Neiss MB, Sedkides C, Stevenson J. Genetic influences on level and stability of self-esteem. *Self and Identity* 2006;5:247–266.
- Nirkko O, Lauroma M, Siltanen P, Tuominen H, Vanhala K. Psychological risk factors related to coronary heart disease. Prospective studies among policemen in Helsinki. *Acta medica Scandinavica Supplementum* 1982;660:137–46. [PubMed: 6958183]
- Pulkkinen, L.; Feldt, T.; Kokko, K. Personality in young adulthood and functioning in middle age. In: Willis, S.; Martin, M., editors. *Middle Adulthood: A lifespan perspective*. Thousand Oaks, CA: Sage; 2005. p. 99-141.

- Pulkkinen L, Vaalamo I, Hietala R, Kaprio J, Rose RJ. Peer reports of adaptive behavior in twins and singletons: is twinship a risk or an advantage? *Twin Research* 2003;6:106–18. [PubMed: 12723997]
- Robson, PJ. *The British journal of psychiatry: the journal of mental science.* 153. 1988. Self-esteem - a psychiatric view; p. 6-15.Review
- Rosenberg, M. *Society and the adolescent self-image.* Princeton, NJ: Princeton University Press; 1965.
- Roy MA, Neale MC, Kendler KS. The genetic epidemiology of self-esteem. *The British journal of psychiatry: the journal of mental science* 1995;166:813–20. [PubMed: 7663835]
- Salmivalli C, Kaukiainen A, Kaistaniemi L, Lagerspetz K. Self-evaluated SE, peer-evaluated SE, and defensive egotism as predictors of adolescents' participation in bullying situations. *Personality and Social Psychology Bulletin* 1999;25:1268–1278.
- Sarna S, Kaprio J, Sistonen P, Koskenvuo M. Diagnosis of twin zygosity by mailed questionnaire. *Human Heredity* 1978;28:241–54. [PubMed: 566252]
- Stein JA, Newcomb MD, Bentler PM. Stability and Change in Personality: A longitudinal Study from Early Adolescence to Young Adulthood. *Journal of Research in Personality* 1986;20:276–291.
- Trzesniewski KH, Donnellan MB, Robins RW. Stability of Self-Esteem Across the Life-Span. *Journal of Personality and Social Psychology* 2003;84:205–220. [PubMed: 12518980]
- van Lier PA, Vitaro F, Wanner B, Vuijk P, Crijnen AA. Gender differences in developmental links among antisocial behavior, friends' antisocial behavior, and peer rejection in childhood: results from two cultures. *Child Development* 2005;76:841–55. [PubMed: 16026500]
- Whisman MA, Kwon P. Life stress and dysphoria: the role of self-esteem and hopelessness. *Journal of Personality & Social Psychology* 1993;65:1054–60. [PubMed: 8246113]
- Williams, RL. *Biometrics.* 56. 2000. A note on robust variance estimation for cluster-correlated data; p. 645-6.

Table 1

Mean values and SDs of Rosenberg self-esteem score within MZ, same-sex DZ and opposite-sex DZ twin individuals for self-esteem at ages 14y and 17y

	MZ Males	DZ Same sex males	MZ Females	DZ Same sex females	DZ Opposite sex females	DZ Opposite sex males
Age	Mean (SD)	Mean (SD)	Mean (SD)	Mean (SD)	Mean (SD)	Mean (SD)
14y	32.7 (4.5)	31.6 (5.0)	29.3 (5.7)	28.8 (5.5)	28.9 (5.5)	31.3 (4.7)
17y	33.3 (4.6)	32.1 (5.0)	29.3 (5.8)	29.3 (5.6)	28.6 (6.1)	32.0 (5.2)

Table 2

Number of complete twin pairs, intraclass 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 14y and 17y

Age	MZ Males		DZ Same-sex males		MZ females		DZ Same-sex females		DZ Opposite-sex pairs	
	N	r	N	r	N	r	N	r	N	r
14y	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)
17y	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)

Table 3

Model fit statistics for univariate models for Rosenberg self-esteem scores at ages 14 y and 17 y

	$2LL^{-}$	d.f.	$\Delta\chi^2$	$\Delta d.f.$	p-value
14y					
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
17y					
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

⁻2LL = minus two log likelihood

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 self-esteem 14y	0.62	0.56–0.68	0.40	0.26–0.54
c^2 self-esteem 14y	-		0.31	0.18–0.42
e^2 self-esteem 14y	0.38	0.32–0.44	0.30	0.25–0.35
a^2 self-esteem 17y	0.48	0.39–0.56	0.29	0.11–0.45
c^2 self-esteem 17y	-		0.34	0.21–0.47
e^2 self-esteem 17y	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

Note: 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 specific environmental factors, r_A additive genetic correlation, r_C common environmental correlation, r_E specific environmental correlation