

## Summary

Subjective wellbeing (SWB) is characterized by a positive sense of wellbeing which is highly subjective and non-specific in such a way that it is concerned with abstract feelings that individuals have about themselves in a general sense. Individual levels of SWB show substantial stability over time (Cummins, 2010; Wagner et al., 2007; Lucas, 2007; Huebner, 2004; Lykken & Tellegen, 1996). SWB is a moderately heritable trait with genetic factors typically accounting for 40 – 55% of the individual differences (Caprara et al., 2009; Bartels & Boomsma, 2009; Nes et al., 2006; Stubbe et al., 2005; Røsbjerg et al., 2002; Lykken & Tellegen, 1996; Tellegen et al., 1988). An extensive literature on many aspects of adult SWB has been developed, whereas studies on adolescent SWB have only emerged recently. This thesis aimed to provide insight into the causes of individual differences in adolescent SWB. To this end, data on SWB and on factors that may be associated with SWB, such as family functioning, exercise behavior, sedentary behavior, internet use, psychopathology, and truancy, were analyzed. The genetic architecture of these associated factors was investigated. In addition, it was assessed whether the associations between SWB and these factors reflected causal effects or whether genetic factors accounted for the relationships by genetic pleiotropic effects and / or gene-environment interaction. Data were analyzed in a large sample of Dutch adolescent twins and their non-twin siblings, registered with the Netherlands Twin Registry. Data collection is ongoing and the content of the surveys changed throughout the period this thesis was written. Therefore, the different studies in this thesis were based on different subsamples.

### *Introductory chapter*

The first chapter of this thesis served as an introduction into the concept of SWB and reviews the current knowledge regarding genetic influences on SWB. In addition, factors associated with adolescent SWB which were considered throughout this thesis and the possible mechanisms through which these factors may affect individual differences in adolescent SWB were introduced.

### *Family environment and SWB*

Chapter two focused on the relation between SWB and different aspects from adolescents' family environment, such as parental divorce and family functioning. We investigated the degree to which genetic and environmental factors contributed to individual differences in evaluations of family functioning and SWB, and the association between them. In addition,

we assessed whether genetic and environmental influences differed between adolescents living in intact families compared to those from divorced families. Two measures of family functioning, i.e. general family functioning (McMaster Family Assessment Device; Epstein et al., 1983) and family conflict (Family Environment Scale; Moos, 1974), and a measure of SWB, i.e. quality of life (Cantril Ladder, Cantril, 1965), were studied in a sample of 5,773 adolescent twins and 1,000 non-twin siblings.

Univariate genetic analyses showed that genetic, shared environmental, and nonshared environmental factors accounted for variation in evaluations of general family functioning and family conflict, with genetic factors being relatively more important for girls compared to boys with regard to general family functioning. Heritabilities of general family functioning were estimated at 6% for boys and 35% for girls, and heritability of family conflict at 31%. Genetic and nonshared environmental factors accounted for individual differences in quality of life, with genetic factors being relatively more important for girls (43%) compared to boys (30%). Adolescents' evaluations of family functioning and their SWB are thus partly genetic in origin.

Evidence was found for interaction between genetic factors and parental divorce: genetic influence on general family functioning was larger in participants from divorced families (boys: 14%, girls: 45%) compared to those from intact families (boys: 6%, girls: 35%). Furthermore, girls from divorced families showed larger heterogeneity in their evaluations of quality of life compared to girls from intact families, as was evident from increased variation in SWB for girls from divorced families compared to those from intact families.

Higher levels of general family functioning and lower levels of family conflict were associated with higher levels of quality of life. Bivariate genetic analyses showed that the associations between these measures were primarily accounted for by genetic factors, with nonshared environmental factors accounting for the remaining part. In addition, interaction between latent genetic factors and latent nonshared environmental factors was explored by looking at the correlations between intrapair sum and difference scores in monozygotic twin pairs (Jinks & Fulker, 1970). Variation in intrapair sumscores appears because twins belonging to different families have different genotypes and/or family environments, whereas intrapair difference scores provide an estimate of nonshared environmental influences within families. Significant negative correlations were found for evaluations of general family functioning, family conflict, and quality of life, indicating that genetic factors in adolescents' evaluations of family functioning and SWB interact with factors from their personal environment. Genetic factors are relatively more

important in those adolescents reporting higher levels of family functioning and SWB (since twin pairs reporting higher levels of family functioning and SWB were more similar) compared to those reporting lower levels of family functioning and SWB.

### *Exercise behavior and SWB*

Chapters three and four focused on adolescent exercise behavior and its relation with SWB. We examined the degree to which genetic and environmental factors affect individual differences in exercise behavior throughout adolescence in chapter three. In a large sample of adolescent twins (i.e. 7,195 individuals) we were able to estimate the relative influence of genetic and environmental factors on self-reported leisure time exercise behavior within three different age groups (13 – 14, 15 – 16, and 17 – 19 years) and to assess quantitative as well as qualitative sex differences in the genetic architecture within these age groups. Exercise behavior was assessed with survey items about type of regular leisure time exercise, frequency, and duration of the activities. Using Ainsworth Compendium of physical activity (Ainsworth et al., 2000) a total weekly MET score was computed for each participant. Participants were classified as non-exercisers, moderate exercisers or vigorous exercisers based on their total weekly MET score. The prevalence of moderate exercise behavior declined from age 13 to 19 years with a parallel increase in the prevalence of non-exercise. However, the prevalence of vigorous exercise behavior remained constant throughout adolescence. At all ages, girls were more often non-exercisers than boys. When regularly engaged in exercise, girls more often exercised at a moderate rather than a vigorous level. The genetic analyses indicated that the genetic architecture of exercise behavior changed during adolescence for girls, such that genetic effects increased with age while shared environmental effects diminished. During early adolescence, individual differences in exercise behavior could be accounted for by genetic (boys: 85%, girls: 38%) and nonshared environmental factors (boys: 15%, girls: 16%), whereas for girls shared environmental factors accounted for a substantial part of the individual differences as well (46%). Genetic factors accounted for the largest part of the variation in exercise behavior during middle (80%) and late adolescence (72%), while the remaining variation was accounted for by nonshared environmental factors. No evidence was found for qualitative sex differences in the genetic factors, indicating that the same genetic variants appear to influence exercise behavior in boys and girls.

In chapter four, it was investigated whether exercise behavior causally influenced SWB and internalizing problems or whether the association reflected the effects of underlying genetic factors. Data on exercise behavior, internalizing problems, and SWB were available in a sample of 6,317 adolescent twins and 1,180 non-twin siblings. The

majority of the sample had longitudinal data with 2-year follow-up. Exercise behavior was assessed using the same procedure as described above and it was treated as a continuous measure. Self-reported internalizing problems were collected with the Youth Self Report (Achenbach & Rescorla, 2001). Satisfaction with life (Satisfaction with Life Scale; Diener et al., 1985), subjective happiness (Subjective Happiness Scale; Lyubomirsky & Lepper, 1999), and quality of life (Cantril Ladder; Cantril, 1965) were used as measures for SWB and these were summarized into a single factor score. In keeping with population based studies investigating adult samples (Stubbe et al., 2007; De Moor et al., 2006; Norris et al., 1992; De Moor et al., 2008; Wise et al., 2006; Camacho et al., 1991), we found that exercise behavior was cross-sectionally and longitudinally associated with increased levels of SWB and fewer internalizing problems across the total sample of adolescents. However, within genetically identical twin pairs, a twin who exercised more did not have higher levels of SWB or fewer internalizing problems than his or her less exercising co-twin. In addition, a twin showing increased frequency and intensity of exercise behavior over time did not show higher levels of SWB or lower levels of internalizing problems over time than his or her co-twin with unchanged or decreased levels of exercise behavior. The cross-sectional and longitudinal associations between exercise behavior and SWB and internalizing problems were entirely accounted for by genetic factors in boys and genetic and shared environmental factors in girls, whereas nonshared environmental factors influencing exercise participation did not affect individual differences in SWB and internalizing problems, currently or 2 years later. Based on these results, the hypothesis that increased levels of SWB and lower levels of internalizing problems found in adolescent exercisers reflect a causal effect of exercise, has to be rejected. Instead, these results are compatible with the hypothesis that the associations between exercise behavior and SWB and internalizing problems in adolescence are mainly due to underlying pleiotropic genes.

### *Sedentary behavior and SWB*

Sedentary behavior has often been addressed as the opposite of physical activity, but research has shown this to be incorrect (e.g. Biddle, 2007; Te Velde et al. 2007). Sedentary behavior may therefore contribute to adolescents' SWB independently of their exercise participation level. Chapters five and six addressed adolescent sedentary behavior and its relation to SWB. In chapter five, a study was described in which the genetic and environmental contribution to individual differences in self-reported screen-viewing sedentary behavior during adolescence was estimated, in a sample of 5,074 adolescent twins and 937 of their non-twin siblings aged between 12 – 20 years. We assessed whether genetic and environmental influences on variation in sedentary behavior were moderated

by age. Screen-viewing sedentary behavior was assessed with survey items about weekly frequency of TV viewing, playing electronic games, and engaging in personal computer / internet activities. The results indicated that adolescents become less frequently engaged in sedentary behavior throughout adolescence and that boys were more often sedentary than girls. We observed that the overall decline in frequency of sedentary behavior during adolescence was due to a lower frequency of TV viewing. Sex differences in frequency of sedentary behavior were mainly due to a higher frequency of playing electronic games in boys. The genetic analyses indicated that genetic and environmental influences on individual differences in sedentary behavior were moderated by age, such that genetic and nonshared environmental effects increased with age while shared environmental effects diminished. Individual differences in sedentary behavior among the youngest participants in our sample (i.e. age 12) were accounted for by genetic (boys: 35%, girls: 19%), shared environmental (boys: 29%, girls: 48%), and nonshared environmental factors (boys: 36%, girls: 34%). Variation in sedentary behavior among the oldest participants in our sample (i.e. age 20) was accounted for by genetic (boys: 48%, girls: 34%) and nonshared environmental factors (boys: 52%, girls: 66%). No evidence was found for qualitative sex differences in genetic factors, indicating that the same genetic variants appear to influence sedentary behavior in boys and girls. The substantial genetic influence on sedentary behavior suggests that there is genetic liability towards sedentary activities such as TV viewing, gaming, and engagement in personal computer and internet activities.

To increase our knowledge about the impact of sedentary activities on adolescents' wellbeing, we investigated the association between internet use and low wellbeing at the phenotypic level in chapter six. It was hypothesized that (a) linkages between high levels of daily internet use and low wellbeing would be mediated by compulsive internet use, and (b) that adolescents with low levels of neuroticism, extraversion, and agreeableness would be more likely to develop compulsive internet use and lower wellbeing. In a sample of 7,888 Dutch adolescents, daily and compulsive internet use was assessed by survey items about the time spent on the internet on a daily basis and by means of the Compulsive Internet Use Scale (Meerkerk et al., 2009). Low wellbeing was operationalized in terms of loneliness (revised UCLA Loneliness Scale; Russell et al., 1980), self-esteem (Rosenberg Self-Esteem Scale; Rosenberg, 1989), and depressive moods (Depressive Mood List, Kandel & Davies, 1986). Big Five personality traits were assessed by using the Quick Big Five (Vermulst & Gerris, 2005). Results indicated that daily internet use was indirectly related to low wellbeing through compulsive internet use. In addition, daily internet use was found to be more strongly related to compulsive internet use, and compulsive internet use was more strongly linked to loneliness in emotionally less-stable, introverted, and low-agreeable adolescents.

Chapter seven addressed the question whether SWB and psychopathology constitute the opposite ends of a mental health continuum or whether SWB and psychopathology constitute distinct dimensions of mental health. Although SWB has been found to be strongly negatively associated with different types of psychopathology (e.g. Proctor et al., 2009), there is also evidence that SWB and psychopathology are distinct dimensions of mental health with separate determinants (Ryff et al., 2006; Greenspoon & Saklofske, 2001; Bergsma et al., 2010). Three measures of SWB captured in one factor score, eight syndrome scales of the Youth Self-Report (YSR; Achenbach & Rescorla, 2001), measuring eight different forms of emotional and behavioral problems, and the broadband scales internalizing and externalizing behavior problems were studied in a sample of 6,381 adolescent twins and 1,195 of their non-twin siblings. Results indicated that affected individuals rate their SWB significantly lower than individuals scoring below a clinical cut-off for the syndrome scales of the YSR. If psychopathology and SWB were opposite ends of a mental health continuum, two groups should have been distinguishable: one group with participants scoring low on psychopathology and high on SWB, and another group with participants scoring high on psychopathology and low on SWB. Only 15% of our sample fit these groups, whereas the remaining 85% did not. On the phenotypic level, negative correlations ranging between  $-.24$  and  $-.57$  were observed between SWB and the syndrome scales. These phenotypic correlations were mainly driven by significant genetic correlations ( $-.31$  to  $-.71$ ) and to a smaller extent by overlapping environmental factors ( $-.13$  to  $-.42$ ). No significant environmental correlations between SWB and externalizing problems were found for boys. These results indicate that SWB and psychopathology are not simply opposite ends of a mental health continuum, but that they are partly independent dimensions of mental health.

Besides the association between psychopathology and SWB in general, assessing specific types of psychopathology might provide useful information as well. To this end, chapter eight examined the relative importance of genetic and environmental factors on frequency of truancy while in high school. In addition, the presence of environmental influences specifically shared by twins but not by their siblings was assessed. Data on frequency of truancy were analyzed in a sample of 3,406 twins and 1,429 non-twin siblings. Results showed that the prevalence of truancy increased with age and that boys skipped class more often than girls. Overall, individual differences in liability to truancy could be accounted for by genetic (45%) and nonshared environmental factors

(55%). For twins, the environmental variance could be partitioned into twin specific environmental (25%) and nonshared environmental factors (30%), whereas for singletons all environmental variance was nonshared (i.e. 55%).

### *Data collection procedures and study sample*

In chapter nine, an overview of the data collection procedures and the study sample was presented. Because response rates were moderate to low, non-response analyses were conducted in which respondents and nonrespondents were compared on several characteristics, such as previous participation in survey research of the NTR, socioeconomic status (SES), parental education level, religion, smoking and alcohol consumption during pregnancy, emotional and behavioral problems of the twins at 3 ages during childhood, unhappiness, CITO scores, and educational achievement in language and arithmetic as reported by parents. Results showed that nonrespondents were less willing to participate in survey research of the Y-NTR during childhood compared to respondents. Differences between respondents and nonrespondents were found with regard to SES, parental educational level, prevalence of smoking during pregnancy, externalizing problems at ages 3, 7 and 12, and CITO scores, whereas no differences were found on religion, internalizing problems and unhappiness at ages 3, 7, and 12 and educational achievement on language and arithmetic as was reported by parents. It is important to note that whenever differences between respondents and nonrespondents were observed they were rather small.