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The association between exercise participation and well-being: A co-twin study

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Abstract

Objective. We investigated the association between leisure time exercise participation and well-being (i.e., life satisfaction and happiness) and examined the causality underlying this association.

Method. The association between exercise participation and well-being was assessed in around 8000 subjects, (age range 18–65 years) from The Netherlands Twin Registry (NTR). Causality was tested with the co-twin control method in 162 monozygotic (MZ) twin pairs, 174 dizygotic (DZ) twin and sibling pairs, and 2842 unrelated individuals.

Results. Exercisers were more satisfied with their life and happier than non-exercisers at all ages. The odds ratio for life satisfaction given exercise participation was significantly higher than unity in unrelated pairs, and a trend was visible in DZ pairs. In MZ pairs, the odds ratio was close to unity. The pattern of odds ratios for happiness given exercise participation was similar.

Conclusion. Exercise participation is associated with higher levels of life satisfaction and happiness. This association is non-causal and appears to be mediated by genetic factors that influence both exercise behavior and well-being.

Keywords: Exercise; Life satisfaction; Happiness; Well-being; Causality; Twins

Introduction

There is a large body of literature concerning the effects of exercise on mental health (Byrne and Byrne, 1993; Gauvin and Spence, 1996; Salmon, 2001; Scully et al., 1998). Cross-sectional population studies have shown that non-exercisers are characterized by higher levels of anxiety and depression (Camacho et al., 1991; De Moor et al., 2006; Farmer et al., 1988; Gauvin and Spence, 1996; Steptoe and Butler, 1996; Strawbridge et al., 2002). The most cited mechanism to explain this association is a direct *causal effect of exercise participation on well-being*. Various randomized controlled training trials have shown that exercise acutely reduces feelings of tension, anxiety and anger and increases feelings of vigor (Gauvin, 1990; Gauvin and Spence, 1996; Steptoe et al., 1989; Yeung, 1996). These effects appear to last after the exercise activities, even eliminating clinical depression (Babyak et al., 2000; Moore and Blumenthal, 1998; Steptoe et al., 1989) although the findings are not unanimous (De Geus et al., 1992; Gauvin and Spence, 1996; Salmon, 2001). Alternatively, the association between exercise behavior and well-being may depend on *reversed causality*, i.e., well-being or a personality profile conducive to higher well-being may be a prerequisite for people to engage in exercise in the first place. Emotionally well-adjusted individuals may be more attracted to exercise and have the necessary energy and self-discipline to maintain exercise regime (Dishman, 1988). Finally, the association may be non-causal and due to an *underlying genetic or shared family factor* (e.g., socio-economic status, neighborhood, parental rearing style) influencing both exercise participation and well-being.

A serious limitation of most studies so far is that they almost exclusively used measures of negative affectivity or clinical outcomes. To our knowledge, the association between exercise participation and positive measures of well-being, like life satisfaction and happiness, remains unexplored in large population-based samples. This may not be the best approach to understand effects of exercise in the population at large. The majority of people are not afflicted with psychopathology, but show large variation in the normal range of psychological well-

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being (Diener, 1984; Kahneman et al., 2004; Koivumaa-Honkanen et al., 2004). By focusing exclusively on the “bad” end of the distribution, we may have failed to use the information contained in the bulk of subjects in the middle.

Here we tested for an association between exercise participation and positive measures of well-being using families ascertained through The Netherlands Twin Registry (Boomsma et al., 2002). The availability of twin data allowed us to use the co-twin control method (Gesell, 1942; Hrubec and Robinette, 1984) to discriminate between a direct causal effect of exercise participation on well-being and an association brought about by a “third factor” such as shared environment or shared genes that influence both exercise participation and well-being.

Method

Subjects

All subjects participate in a longitudinal study on health and lifestyle in twin families registered with The Netherlands Twin Registry (NTR) (Boomsma et al., 2002; Stubbe et al., 2005; Vink et al., 2004). In the 2002 wave of this study, they received a survey by mail in which both exercise behavior and life satisfaction were assessed. A total of 10,344 individuals from 3463 families returned the survey. Participants with an injury or disease currently preventing participation in exercise ($n=1344$), participants with missing zygosity ($n=47$), participants younger than 18 and older than 65 ($n=414$) and participants with missing exercise data ($n=98$) were excluded from the analyses. Participants with more than one item missing on life satisfaction ($n=135$) or on happiness ($n=147$) were excluded from the analyses on life satisfaction and happiness respectively. Table 1 gives the composition of the final sample.

For the co-twin control method, three specific groups of twin, twin-sibling or sibling pairs were formed in which one member of the pair exercised regularly and the other did not. For life satisfaction, this led to a group of 46 male MZ and 116 female MZ pairs and a group of 174 first degree same-sex relatives consisting of 27 dizygotic male twins pairs, 87 dizygotic female twin pairs, 31 brother–brother pairs and 29 sister–sister pairs. A third group of 2842 unrelated individuals was formed from the total sample of twins and siblings by randomly selecting one person from a family. Of these subjects, 57% were exercisers. The same procedure was repeated for happiness resulting in similar groups of 161 MZ pairs, 172 DZ pairs and 2842 unrelated subjects.

Approval of the study was obtained from the Medical Ethics Committee of the Vrije Universiteit.

Instruments

Exercise participation was defined as a dichotomy of no monthly leisure time exercise at all versus some form of regular exercise behavior. To assess exercise behavior, all subjects answered the question: “Do you participate in exercise regularly?”. Those answering “yes” were asked what kind of exercise they were involved in (jogging, fitness club, tennis, swimming, team sports, etc.) and how much time (minutes a week) they spent exercising. Ainsworth’s Compendium of physical activity was used to recode each exercise activity into METs (Ainsworth et al., 2000). Twins were classified as exercisers if they were engaged in one or more leisure time exercise activities with a minimum intensity of four metabolic equivalents (METs), where one MET represents the rate of energy expenditure of an individual at rest which is approximately 1 kcal/kg/h (Ainsworth et al., 2000) and a frequency of at least once every month. They were classified as non-exercisers otherwise. Engagement in other types of physical activity, even vigorous activity, related to manual labor, household activities or transportation did not classify as leisure time exercise participation. To establish temporal stability of our classification, exercise participation was re-measured in 186 participants after about 6 months. Stability was computed as the tetrachoric correlation, which is the correlation in the liability distribution assumed to underlie dichotomous traits. The tetrachoric correlation between the two measurements was very high ($r=0.91$; 95% CI=0.82–0.96).

Table 1
Composition of the study sample

	Data on exercise participation and life satisfaction	Data on exercise participation and happiness
Twins	3703	3703
Siblings	1187	1188
Parents	2142	2131
Spouses	1274	1272
Total	8306	8294

The sample consists of twins and their family members from The Netherlands Twin Registry (NTR), 2002.

Table 2
Items of the two well-being scales

Satisfaction With Life Scale (SWLS)
In most ways my life is close to my ideal.
The conditions of my life are excellent.
I am satisfied with my life.
So far I have gotten the important things I want in life.
If I could live my life over, I would change almost nothing.

Subjective Happiness Scale (SHS)
In general, I consider myself a happy person.
Compared to most of my peers, I consider myself less happy.
In general, I am very happy. I enjoy life regardless of what is going on, getting the most out of everything.
In general, I am not very happy. Although I am not depressed, I never seem as happy as I might be.

Subjective well-being (SWB) is defined as the evaluative reaction of a person to his or her life and can be partitioned into cognitive components like *life satisfaction* and affective components like *happiness* (Diener, 1984). Life satisfaction refers to the global assessment of a person’s quality of life according to a person’s own subjective judgment (Shin and Johnson, 1978) and was measured with the Satisfaction With Life Scale (SWLS: Diener et al., 1985). This scale contains five items (listed in the upper panel of Table 2). Both the original and the Dutch version of the SWLS have demonstrated good psychometric properties (Arrindell et al., 1991; Diener et al., 1985; Pavot and Diener, 1993). Participants respond on a scale ranging from one (strongly disagree) to seven (strongly agree). Summing the items resulted in a total score ranging from 5 (low satisfaction) to 35 (high satisfaction). In our sample, Cronbach’s alpha was 0.85. For the co-twin control method, life satisfaction was partitioned into two categories (i.e., low and high), using the mean value of 26.8 as a cutoff point.

Happiness was assessed with a Dutch adjusted version of the Subjective Happiness Scale (Lyubomirsky and Lepper, 1999). This scale contains four items on happiness (listed in the lower panel of Table 2). Participants respond on a scale ranging from one (strongly disagree) to seven (strongly agree). A total score for happiness was computed by summing the four items (the second and the fourth items were reverse-coded) yielding a score between 4 (lowest happiness) and 28 (highest happiness). Reliability in our sample was high (Cronbach’s alpha=0.83). For the co-twin control method, happiness was partitioned into two categories (i.e., low and high), using the mean value of 22.5 as a cutoff point.

For both life satisfaction and happiness, the mean item score was imputed if one item was missing. Subjects with multiple items missing were excluded.

Statistical methods

In the entire sample, linear mixed modeling in SPSS (Norusis, 2004) was used to test for differences in means on life satisfaction and happiness between exercisers and non-exercisers. The effects of exercise participation, gender and age (including interaction effects) on well-being were modeled by including them as fixed effects in the model. The model included a family effect that varied randomly over families, correcting for dependencies among observations within families. As expected, the variances of the family effect on life satisfaction and happiness significantly differed from zero, indicating that the correction for nested sampling was necessary.

To investigate whether the association between exercise participation and well-being was causal or non-causal, the co-twin control method (Gesell, 1942; Hrubec and Robinette, 1984) was applied to the data. This method calculates the odds for an event, which is defined as the probability of occurrence over the probability of non-occurrence. In this paper, the odds ratio (OR) is calculated as the ratio between the chance of having high levels of well-being while exercising and the chance of having high levels of well-being while not exercising. The ORs were calculated separately in three specific groups: (1) MZ pairs in which one twin is an exerciser, while the co-twin is a non-exerciser, (2) same-sex DZ twin and sibling pairs discordant for exercise participation, and (3) unrelated individuals in which about half of the subjects exercise and the others do not.

Different hypotheses about the association between exercise participation and well-being lead to different expectations for the ORs in these three groups. This is illustrated in Fig. 1. If the relationship is causal (i.e., exercise participation directly causes an increase in the level of well-being), the increase in well-being through exercising will be the same in the three groups (Fig. 1: model 1). Exercisers will have a higher chance of having high levels of well-being than non-exercisers, regardless of the degree of genetic similarity between them.

If the association between exercise participation and well-being is non-causal, and due to shared familial environmental factors, the OR for well-being given exercise participation will be significant in the group of unrelated individuals, but in the discordant MZ or DZ twin pairs it will be unity (Fig. 1: model 2). Since the family environment is shared by both types of twins alike, its effect on well-being and exercise participation will make them resemble each other for both traits.

If the association between exercise participation and well-being is non-causal, and due to genetic factors, the expected OR for well-being given exercise participation will again be significantly higher than unity in the group of unrelated individuals (Fig. 1: model 3). In MZ twin pairs, however, the OR will be unity because the exercising and non-exercising members of a discordant MZ pair would completely share their genetic predisposition for well-being. In DZ twins, the OR will be intermediate because the exercising twin and non-exercising co-twin share on average only 50% of their genetic predisposition to well-being.

Results

Table 3 displays the descriptive of life satisfaction and happiness as a function of exercise status per gender and across three age groups. Significant main effects were found for exercise participation, gender and age on life satisfaction and happiness, but all two-way and thee-way interaction effects (exercise * age, exercise * gender, age * gender, exercise * gender * age) were non-significant. Life satisfaction and happiness decreased with increasing age ($\beta = -0.02$ for both traits; p's < 0.01), and men were significantly more satisfied with their lives and happier than women (p's < 0.01). At all ages and in both sexes, exercisers were more satisfied with their lives and happier than non-exercisers (p's < 0.01). Estimated marginal means for life satisfaction were 26.4 (standard error = 0.09) for non-exercisers and 27.2 (standard error = 0.09) for exercisers. Estimated marginal means for happiness were 22.3 (standard error = 0.07) for non-exercisers and 22.8 (standard error = 0.07) for exercisers.

To examine whether the association between exercise participation and well-being was causal or non-causal, we computed the OR and its 95% CI for each of the three groups. These are depicted in Figs. 2 and 3. For life satisfaction, the OR was significantly different from unity in the group of unrelated subjects (OR=1.25; 95% CI: 1.07, 1.45) but not in the group of DZ (OR=1.05; 95% CI: 0.68, 1.63) or MZ twin pairs (OR=1.00; 95% CI=0.63, 1.58). For happiness, a similar pattern was found. The OR was significant in the group unrelated subjects (OR=1.38; 95% CI: 1.18, 1.61) but not in the discordant DZ twins (OR=1.38; 95% CI: 0.89, 2.14) or MZ twin pairs

Table 3
Mean scores of life satisfaction and happiness as a function of exercise participation, gender and age group

Age group	Sex	Exercise participation	Life satisfaction	Happiness
18–30 years	Males	Exercisers	27.6	23.2
		Non-exercisers	26.8	22.8
	Females	Exercisers	27.5	22.9
		Non-exercisers	26.4	21.9
31–45 years	Males	Exercisers	27.5	23.2
		Non-exercisers	26.9	22.8
	Females	Exercisers	27.1	22.8
		Non-exercisers	26.7	22.6
46–65 years	Males	Exercisers	27.3	22.9
		Non-exercisers	26.2	22.0
	Females	Exercisers	26.4	22.2
		Non-exercisers	25.8	21.9

The sample consists of twins and their family members from The Netherlands Twin Registry (NTR), 2002.

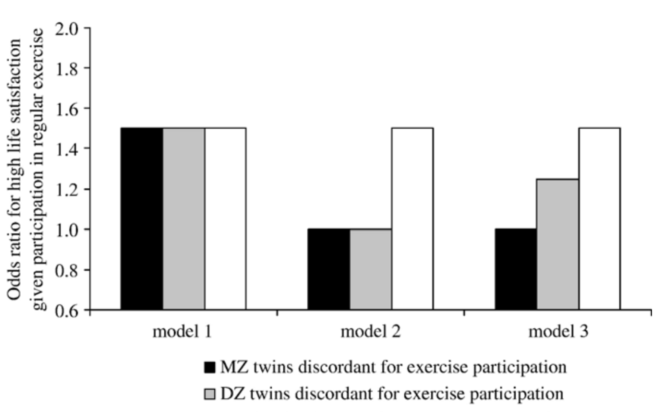

Fig. 1. The co-twin control method (see text for further explanation).

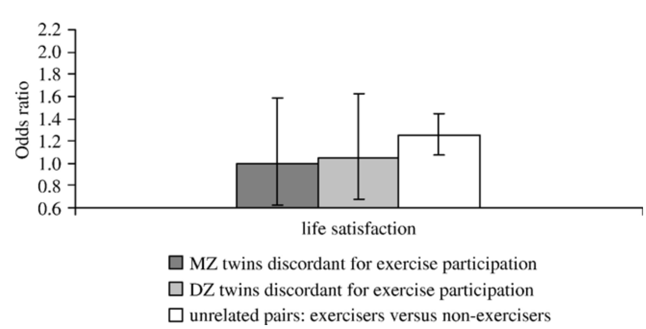

Fig. 2. The odds ratio for high life satisfaction given exercise participation. The sample consists of 8306 twins and their family members from The Netherlands Twin Registry (NTR), 2002. The error shows 95% confidence intervals.

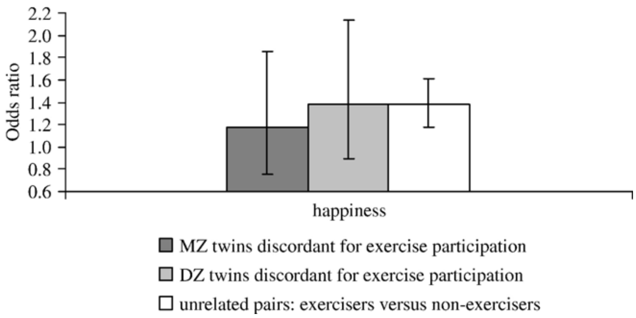

Fig. 3. The odds ratio for happiness given exercise participation. The sample consists of 8294 twins and their family members from The Netherlands Twin Registry (NTR), 2002. The error shows 95% confidence intervals.

(OR=1.18; 95% CI=0.75, 1.85). For both phenotypes, the OR for the MZ twins was close to unity and well outside the CI of the unrelated pairs.

Discussion

A primary finding from this study is that exercisers are on average more satisfied with their lives and happier than non-exercisers. Causal effects of exercise participation, however, do not seem a likely source of these associations. Instead, results from the co-twin control analyses argued strongly in favor of an "underlying factor" influencing both exercise participation and well-being in members of the same family. This factor may consist of shared environmental influences or a shared genetic make-up. The latter seems more likely on two accounts. First, the observed patterns in MZ, DZ and unrelated groups, in particular the ORs close to unity in the MZ twins, most closely resemble model 3 in Fig. 1, which is obtained when genetic factors cause the association. Second, the evidence for shared environmental influences on either well-being or exercise participation is far less convincing than the evidence for genetic influences on both these traits. Previous results from a partly overlapping sample, for instance, concluded that exercise participation and life satisfaction are highly heritable and common environmental factors do not influence individual differences in these two traits (Stubbe et al., 2005). This is in good agreement with results in other adult twin samples that tested the cause of familial resemblance in exercise behavior (De Geus et al., 2003; Frederiksen and Christensen, 2003; Lauderdale et al., 1997) and well-being (Lykken and Tellegen, 1996; Røysamb et al., 2002, 2003; Tellegen et al., 1988) and found significant heritability without evidence for shared environmental effects.

Study limitations

A first potential limitation to the co-twin control method is that the results from twin samples may not properly generalize to the population at large. This theoretical objection finds no empirical support in our findings. When twins and their singleton brothers and sisters were directly compared with regard to life satisfaction, no such specific "twin effects" were found here, as well as in a previous analysis (Stubbe et al., 2005). Likewise, we did not find any difference in the prevalence of exercise participation between twins and singletons at any age.

A second limitation of the co-twin control method is that it does not identify the actual molecular mechanisms by which genetic variation causes individual differences in both well-being and exercise participation. We can, however, speculate about candidate genes based on existing knowledge. A prime source of such genes is the mesolimbic dopaminergic reward system. This system has been proposed to play a key role in a range of phenotypes related to rewarding mechanisms (Schulz, 1999) and is likely to also influence general well-being. Interestingly, Simonen et al. (2003) have shown that a common variant in a gene for a key dopamine receptor (DRD2) was associated with exercise behavior.

Clearly, the dopaminergic system is only one route along which genes may independently affect well-being and the drive to exercise. There are many plausible alternatives, including genetic variation in opioid and serotonergic systems (Chaouloff, 1997; Hara and Floras, 1995; Jarvekulg and Viru, 2002; McCubbin et al., 1992; Schwarz and Kindermann, 1992). A complete mechanistic understanding of the 'nature' of the association between well-being and exercise participation may well have to await progress in gene finding for either of these traits.

Conclusion

Exercisers are on average more satisfied with their lives and happier than non-exercisers. This association appears to be mediated by genetic factors that influence both exercise behavior and well-being.

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