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Sports club participation impacts life satisfaction in adolescence: A twin study

Alexander Dings [*], Frank M. Spinath

Universität des Saarlandes, Saarbrücken, Germany

1. Background

1.1. Introduction

A large amount of research has investigated precursors to subjective well-being in general and high life satisfaction in particular, in other words, what makes people happy. Some of the more commonly cited antecedents of well-being and life satisfaction are fulfilling relationships, personality factors such as low neuroticism, a sense of purpose and meaning, and a healthy lifestyle, including sports, exercise or physical activity in general (for reviews, see Diener et al., 2018; Diener & Ryan, 2009; Veenhoven, 1996; Proctor et al., 2009).

However, as in many other research domains, direction and extent of causality are less clearly established (Diener et al., 2018; Veenhoven, 1996). One approach for supporting hypotheses of causality is to use genetically informed samples, such as twin pairs (Pingault et al., 2018; McAdams et al., 2021). Direct evidence of causality, with no room for alternative explanations, remains elusive under this framework as well. Twin models can, however, cover some of the distance towards this ideal. For variables that cannot be experimentally manipulated, monozygotic (MZ) twin pairs that happen to differ (be discordant) on this variable provide a decent approximation to two experimental groups where subjects in one condition ideally do not systematically differ from the other group in variables other than the manipulated variable (McGue et al., 2010). Thus, differences within MZ twin pairs are at the core of using twin samples to strengthen causal inferences (albeit indirectly by ruling out alternative explanations rather than unequivocally establishing causality; see Sjölander et al., 2012).

The present study uses a twin sample to investigate possible associations between life satisfaction and one of its most frequently cited possible causes – physical activity, and participation in sports clubs in particular.

1.2. Physical activity and life satisfaction

Numerous studies show associations between physical activity and well-being (e. g., Buecker et al., 2021; Wiese et al., 2018; Cerin et al., 2009). Among others, this was shown in a large sample taken from the German Family Panel (Schmiedeberg and Schröder, 2017) and in longitudinal analyses that point to possible causal links (Varca et al., 1984). Physical activity is seen as a major component of life satisfaction among adolescents (Proctor et al., 2009) and appears to be effective in reducing symptoms of depression and other mental illnesses (Fox, 1999). Research during the COVID-19 pandemic identified physical activity as a protective factor for mental health (Pietsch et al., 2022).

It is less clear *which* kinds of physical activity, and in which context, are beneficial. For instance, vigorous (as opposed to moderate) training may backlash, with one study finding it associated with *lower* well-being (Wicker & Frick, 2015). Evidence on the associations between usual everyday activity, as opposed to organized exercise, and life satisfaction is generally positive, but mixed (for an overview, see Maher, 2008), with some studies finding no effect (e. g., Pedišić et al., 2015). In contrast, there is some evidence that participation in sports clubs not only is generally associated with better physical and mental health (Larsen et al., 2021), but also that such effects are more pronounced than for other kinds of physical activity. Participation in sports clubs was associated with good health to a greater extent than leisure time physical activity in general in a German sample (Spengler & Woll, 2013), and studies by Mutz et al. (2021) as well as Vilhjalmsson and Thorlindsson (1992) show more pronounced effects on general and domain-specific well-being for sports club participation than for other forms of exercise. As social connectedness is often found to be linked to well-being and life satisfaction (e. g., Becchetti et al., 2012; Jose et al., 2012; O'Rourke & Sidani, 2017 O'Rourke et al., 2017), the "club" aspect of sports clubs may be as pivotal as the "sports" aspect in promoting well-being. For example, sports clubs may foster social integration (e. g., Elmose-Østerlund et al., 2019) and participation in them is associated with higher social functioning (Eime et al., 2010).

* Corresponding author.
E-mail address: alexander.dings@uni-saarland.de (A. Dings).

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1.3. A behavioral genetics perspective on physical activity and life satisfaction

In the classical twin design, interindividual variance in a trait is decomposed into additive (A) genetic influences as well as shared (C) and nonshared (E) environmental effects. Non-additive genetic factors, particularly dominance effects (labeled D) may also play a role, although MZ and DZ twin pairs alone do not provide enough statistical information to incorporate both C or D in one model (see section 3.3.). For an overview on this and other analytical approaches to twin data, see Røysamb and Tambs (2016). It is important to note that estimates of heritability and environmental effects are sample-specific and do not represent universally "true" values (see Plomin et al., 2016).

With regards to physical activity, heritability estimates at least partially appear to depend on the kind of activity that is measured. For example, objective measurements of how much young children move during the day are mostly attributable to shared environmental influences instead of genetic effects (Fisher et al., 2010). On the other hand, twin studies with adolescents and adults generally show that the differences between individuals in leisure-time physical activity are partly explained by their different genetic background, thus showing heritability (Carlsson et al., 2006; Mustelin et al., 2012). In line with the aforementioned context-dependent nature of heritability estimates, some studies have even found moderation effects in the sense that heritable influences are especially pronounced in younger compared to older adults (Vink et al., 2011) and at higher compared to lower levels of activity (Duncan et al., 2008).

Twin models have been used to investigate effects of physical activities through environmental pathways, i. e. by exploiting MZ twin differences as described above. One finding suggests that physical activity lowers mortality risk, although the study in question did not include enough MZ twin pairs discordant for activity to yield robust conclusions (Kujala et al., 1998). Leskinen et al. (2009) showed physical benefits (lower high-risk body fat) for the active twins in discordant twin pairs. Korhonen et al. (2009) showed that physical activity was a protective factor against future illicit drug use. BMI is less heritable among physically active twins, suggesting an environmentally mediated link (Mustelin et al., 2009). Tentative results also point to higher average life satisfaction for the physically active twin in a small number of discordant MZ pairs (Waller et al., 2010).

General life satisfaction is typically found to be moderately heritable, although estimates vary considerably (for an overview, see Bartels, 2015). The remaining variance appears to be accounted for by unshared environmental influences, with shared environment only being a significant factor in relatively few studies (e. g., Nes et al., 2008). Hahn et al. (2013) found that the heritable proportion of the variance overlaps with genetic sources of variance in personality, and low neuroticism and high extraversion in particular. The remaining variance in Hahn et al.'s (2013) study, however, was explained by nonshared environmental influences which showed no relations to personality.

1.4. The elusive nature of specific nonshared environmental influences

The findings cited above, pointing to a much more prominent role of nonshared rather than shared environment in the etiology of life satisfaction, are similar to what behavioral genetics research has shown in many areas of personality, health and development. It is in fact such a common result that Turkheimer (2000) summarized the fact that a "substantial portion of the variation in complex human behavioral traits" (p. 160) is unexplained by genetic or shared environmental effects as his third of three "laws of behavior genetics". More recently, Plomin et al. (2016) reiterated this point as one of ten reliably replicated findings from behavioral genetics, and an extensive meta-analysis of virtually all classical twin studies published at the time similarly demonstrated that nonshared environmental influences explain more variance than shared environmental influences in most traits (Polderman et al., 2015).

This importance of nonshared environmental influences across a wide range of domains can partly be explained by two theoretical reasons. First, the nonshared environmental component will include measurement error (Rijsdijk & Sham, 2002) unless it is accounted for through the use of latent modeling (see van den Berg et al., 2007). Furthermore, as a variance component in twin models, the "nonshared" environment does not only include external influences that are *objectively* different between twins: an objectively shared variable, such as socioeconomic status, may impact twins differently and therefore act as a nonshared influence. Since the reverse is not possible (i. e., attending different classes in school cannot make twins systematically *more* similar), the nonshared environmental component therefore includes all objectively nonshared factors *plus* some objectively shared factors. As highlighted by Turkheimer and Waldron (2000), in this light, the finding that nonshared environment influences explain substantial proportions of variance in most traits is less surprising.

However, pinpointing specific sources of nonshared environmental variance has proven to be the proverbial search for a needle in a haystack. Spanning several decades, Plomin and co-authors have repeatedly discussed the empirical and theoretical state of nonshared environment in behavior genetics (Plomin, 2011; Plomin & Daniels, 1987; Plomin et al., 2001; Rowe & Plomin, 1981). Across these articles, and even in more recent work (e. g., Gidziela et al., 2023), the respective authors stress that identifying specific influences which act to make siblings different from one another has been difficult. For instance, Plomin (2011) noted that "the big question for nonshared environment is how to identify the 'missing' nonshared environment" (p. 585). This is reminiscent of the "missing heritability" term coined to describe the (initially) tedious search for specific genotypes that make up heritable sources of variance (Maher & Conroy, 2017). Earlier, Plomin et al. (2001) had considered an even more pessimistic outlook, which they termed the "gloomy prospect" (p. 231). This refers to the view that broad outcomes such as happiness might be shaped through an accumulation of tiny effects, which furthermore might be highly idiosyncratic in nature and therefore difficult to detect as main effects across a population (see also Smith, 2011; Tikhodeyev & Shcherbakova, 2019). In line with this notion, an early overview (Turkheimer & Waldron, 2000) showed that empirical attempts to identify concrete factors that can explain the large nonshared environmental components of variance generaly met with little success. However, similarly to more recent successes in addressing the "missing heritablity" gap, more recent investigations into concrete nonshared environmental influences have been more fruitful (e. g., Mann et al., 2019; von Stumm & Plomin, 2018), encouraging further research such as the present study.

1.5. Establishing environmentally mediated links through twin differences

Most studies that attempt to identify nonshared environmental effects on behavior make use of twin/co-twin differences, especially among MZ twin pairs. The underlying logic is that since MZ twins are virtually genetically identical, any measured difference between the two members of an MZ twin pair cannot be explained by genetic sources of variance (commonly denoted by A in twin models). Similarly, any non-genetic influences that affect them in the same way (shared environment - C) can, by definition, also be ruled out as an explanation (Pike et al., 1996). Therefore, using MZ differences in a regression approach is equivalent to a regression where *every* variable that affects the outcome through genetical or shared environmental pathways has been entered as a control variable. The truism that "correlation is not causation" still applies, especially because confounding can also arise from nonshared factors if they are not explicitly controlled for (Sjölander et al., 2012). Still, this method rules out a wide range of alternative explanations implicitly, without the need for direct measurement. For a more detailed overview on this approach, we refer readers to Vitaro et al. (2009).

In accordance with the pessimism expressed in Plomin et al.'s (2001) "gloomy prospect", such research often finds a seemingly external influence on an outcome to actually be fully confounded by shared factors – common genetic (or shared environmental) factors act as a third variable that impacts both traits and thereby creates an illusory correlation. For example, this approach has been used to show that while negative life events are generally associated with lower quality of sleep, this seemingly obvious link disappears when the analysis focuses on differences within MZ pairs, thereby controlling for common genetic background and shared environmental variance (Barclay et al., 2012).

In the same vein, some ostensible influences on life satisfaction appear to be spurious when viewed through a behavioral genetic lens. For example, in accordance with the results cited above (Hahn et al., 2013), being extroverted and low in neuroticism is associated with higher life satisfaction in the general population. However, this is not the case when analyzing MZ twin differences (Misheva, 2016). Similarly, it seems almost trivial to assume that harsh parental discipline directly lowers life satisfaction, or that being unemployed impacts it causally, but these associations vanished in MZ difference analyses (see Mann et al., 2019, for parental discipline; Schnittker, 2008, for employment status).

Arguably the most striking finding in this regard comes from a study by Stubbe et al. (2007), which compared twins who regularly engage in exercise to their co-twins who do not. Within MZ pairs, there was no significant difference in happiness between such discordant twins, suggesting that the overall correlation between the two variables is not causal, but instead the result of genetic (or shared environmental) confounding, as described above. If the same genetic characteristics predispose people both to engaging in exercise and to being happy, these two outcomes will be correlated even if one does not cause the other, and the finding by Stubbe et al. (2007) suggests that this might be the case.

Considering the large number of studies that link physical activity to well-being, evidence that this correlation might be spurious is surprising and would constitute an impactful finding for the field if backed up by further studies. As such, these results invite attempts to replicate them in other samples. It is worth noting that some precursors to life satisfaction do persist in MZ twin difference analyses. In particular, within MZ twin pairs discordant for friend support, well-being differed significantly both in Mann et al. (2019) and Schnittker (2008), strengthening the evidence for the importance of social connectedness. Overall, success in identifying specific nonshared environmental influences on life satisfaction is mixed, and investigations into the role of physical activity under this framework are scarce and inconclusive.

2. Research questions

The present study uses data from a twin panel study with the aim of clarifying possible unmeasured familial confounding of presumed links between adolescents' sports club participation and life satisfaction. Although there is no shortage of findings that link physical activity – and participation in sports clubs in particular - to well-being, genetically informed evidence is, to our knowledge, limited to two studies with conflicting results (Stubbe et al., 2007; Waller et al., 2010). It therefore currently remains unclear whether the observed associations can be explained through genetical confounding, shared environmental confounding or neither of these, and the aim of the present study is to help clarify this issue.

More so than in other countries, local associations based on shared pastimes (*Vereine*) are a prominent part of social life in German culture, with about six associations per 1000 inhabitants (Franzen & Botzen, 2011). Sports clubs are the most frequent kind among them, playing a major role in the country's economy (Breuer, Feiler, & Wicker, 2015). In contrast to the situation in the United States, where most high school students participate in an athletic team within the school (Veliz et al., 2019), extracurricular activity plays a relatively small role in Germany, as sports clubs are typically independent from schools (Schmidt et al., 2020). We hypothesize that regularly participating in such a club should phenotypically be correlated with life satisfaction because it arguably combines two variables commonly implicated in life satisfaction: physical activity and social connectedness. We then use twin regression models to investigate whether such correlations, if they are present in the current sample, can be explained through genetic confounding or remain significant within MZ twin pairs. As previous research is inconclusive and the present study does not build on a specific theory that would suggest either the presence or absence of such an effect beyond confounding, we regard this analysis as exploratory and do not formulate a hypothesis in either direction.

3. Methods

3.1. Sample

The present study uses data from TwinLife, an ongoing twin panel study of about 4000 twin pairs, and their families, in Germany starting in 2014 (Mönkediek et al., 2019; for details on the sampling procedure and characteristics of the final sample, see Lang & Kottwitz, 2020). This panel includes four birth cohorts of twins. At the time of the first interview, twins in these cohorts were approximately 5, 11, 17 and 23–24 years old, respectively. Data from TwinLife are publicly available via the GESIS data archive (https://nam11.safelinks.protection.outlook.com/?url=https%3A%2F%2Fdoi.org%2F10.4232%2F1.14186&data=05%7C02%7CH.Moorthy%40elsevier.com%7Ccf6a6c9a2a5b4a38c97208dc637c7813%7C9274ee3f94254109a27f9fb15c10675d%7C0%7C0%7C638494633456809247%7CUnknown%7CTWFpbGZsb3d8eyJWIjoiMC4wLjAwMDAiLCJQIjoiV2luMzIiLCJBTiI6Ik1haWwiLCJXVCI6Mn0%3D%7C0%7C%7C%7C&sdata=qQa5O9z3RizwV0HtJxbacLoQ2AwPmaB66cPpK5NRaBQ%3D&reserved=0).

3.2. Measures

Information on sports club participation was available for the three older cohorts out of the four in the first data collection wave. For cohort 2 (about 11 years old at the time), parents answered for their kids. This cohort was not included in the final sample for the analyses because it included very few discordant MZ pairs (see below). For older cohorts, participation was self-reported by the twins.

Among the four response categories on sports club participation, "never" (55.6%) and "weekly" (36.9%) were far more prevalent than the intermediate categories ("every month" at 4.9% and "less than every month" at 2.6%). We grouped these intermediate cases together with those who reported they never went to a sports club, i. e. dummy-coded participation as 1 (weekly) or 0 (rarely or never). This was done with the goal of enabling a more straightforward interpretation of the results, as 1 now stands for frequent participation in a sports club and 0 for no such (regular) participation. While dichotomizing data is generally not recommended (Irwin & McClelland, 2003), it is more justifiable when the data clearly do not follow a normal distribution and the underlying variable may more sensibly be interpreted as an ordinal rather than an interval scale (Streiner, 2002). As the interpretation of the response categories on the current question as an interval scale appears doubtful, the data are clearly not normally distributed and the discarded categories only included 7.5% of participants, we concluded that the benefit of easier interpretation of results outweighed the small loss of information.[1]

Since the analyses fundamentally rely on differences within MZ pairs, those differences must occur frequently enough in the sample to provide a decent sample size. This is not the case for club participation

[1] As a sensitivity check, results of the subsequent analyses do not differ meaningfully when this variable is not dichotomized.

among the youngest cohort of twins, where only 11 MZ pairs out of 302 were discordant on this (dichotomized) variable (see Results). Notably, almost 90% of dizygotic (DZ) pairs in this age group were concordant as well. A pattern of high similarity within MZ twin pairs, but almost equal similarity within DZ twin pairs indicates that neither nonshared environmental nor genetic factors play a large role (see Rijsdijk & Sham, 2002). It follows that the remaining source of variance – shared environmental factors – is of high importance. A possible explanation for this pattern could be that presumably, joining a sports club at this age may typically be a decision made by the parents jointly for both kids, rather than the kids themselves individually. As the analyses in the current studies rely heavily on differences between twins, and MZ twins especially, this youngest cohort, with only 11 discordant MZ pairs, was excluded from subsequent analyses.

In older cohorts, discordant pairs were more common (and participation became less common in general), and concordance rates among MZ twins differed more notably from those among DZ twins. Since the difference between concordance rates or correlations in MZ versus in DZ pairs provides an index of heritability, this suggests that heritable sources of variance explain an increasing amount of variance in sports club participation as children grow into adolescents and young adults.

General life satisfaction was measured with the *Satisfaction with Life Scale* (SLWS; Diener et al., 1985). Cronbach's alpha for this scale, which consists of 5 items answered on a scale of 1–5, was $\alpha = 0.84$ in the current sample, indicating excellent internal consistency. Domain-specific life satisfaction was measured using ad-hoc items that asked participants: "How satisfied are you …" and providing an 11-point response scale from "not at all satisfied" (0) to "completely satisfied" (10) to rate satisfaction in several domains. The items used in the present study were: "… with your health", "with your leisure time" and "with your circle of friends and acquaintances". Other items (satisfaction with romantic relationships, family life, school, income and occupation) were not included because these did not have any straightforward connection to the benefits plausibly associated with activity in a sports club and/or because they did not apply to all participants.

3.3. Analysis

As a precursor to the main analyses, the Results section includes intraclass correlations (ICCs) among MZ and DZ twins as well as parameters estimated from structural equation models to estimate the contribution of genetic and environmental factors to the study variables. Intraclass correlations, in this context, refer to the phenotypic correlations within twin pairs, presented separately for MZ and DZ twin pairs. They can be used to estimate the heritability, or h^2, of a trait via Falconer's formula (Falconer, 1965), where $h^2 = 2*(r_{MZ} - r_{DZ})$, with r_{MZ} and r_{DZ} referring to the intraclass correlations within MZ and DZ pairs, respectively. By extension, the influence of shared environmental factors can be inferred as $c^2 = r_{MZ} - h^2$ (Røysamb & Tambs, 2016). The remaining variance ($1 - h^2 - c^2$) can be attributed to nonshared environmental factors (referred to as e^2). These calculations are valid only under certain certain conditions, particularly *proportion homogenity* (i. e., the proportions of a^2, c^2 and e^2 are assumed to be the same in MZ and DZ twins; see Arbet et al., 2020). However, these formulas only serve as approximations, and structural equation models using maximum likelihood criteria can more accurately decompose variance into additive (A) and non-additive (D, for dominance effects) genetic influences as well as shared (C) and nonshared (E) environmental effects. Because C and D are perfectly confounded in twin pairs reared together, classic twin models cannot estimate them if only data from MZ and DZ twin pairs is available (see Røysamb & Tambs, 2016). Instead, fit statistics are used to compare a model including A, C and E to an ADE model. In addition, if any of the variance components are close to zero, a reduced, more parsimonious model might be preferable. In the present study, these analyses were conducted using the R package *umx* (Bates et al., 2019). The *umxReduceACE* function in this package was utilized to select the best-fitting model according to Akaike's Information Criterion (AIC), which balances model fit and parsimony (Akaike, 1987). In general, all analyses in the present study were performed using R Statistical Software (v4.1.2; R Core Team, 2021).

As described earlier (see section 1.5), linear regressions that use twin difference data are helpful for untangling effects of nonshared environmental factors from those explained by genetic and environmental factors common to both twins in a pair. Historically, such regression approaches to analyzing twin data have typically focused on the differences within MZ pairs only (see Carlin et al., 2005). More recently, a "mixed strategy" has become more common. Besides within-pair differences, this approach also takes into account between-pair differences, that is, a twin pair's mean value in the variable of interest compared to the other pairs in the sample. This can be expressed by the following regression equation:

$$E(Y_{ij}) = \beta_0 + \beta_W * (X_{ij} - \overline{X_i}) + \beta_B * \overline{X_i}$$

Here, the between-pair factor (β_B) measures effects resulting from factors common to both twins in a pair, i. e., shared genetic or environmental background. In statistical terms, "it gives the expected change in Y for a one-unit change in the twin-pair average X, while holding the individual deviation from the average constant" (Carlin et al., 2005, p. 1092). In contrast, the within-pair factor (β_W) indicates changes in the outcome that are associated with each individual twin's deviation from the pair's average (i. e., differences between a twin and their co-twin) while controlling for the pair's mean value. Significant values for β_W therefore indicate that the observed effects cannot be explained by genetic and environmental confounding alone, instead pointing to nonshared environmental effects. If, in fact, *only* the β_W coefficient is significant, confounding by shared factors appears to play no role at all. Conversely, a significant value for β_B while β_W does not significantly differ from zero can be taken as evidence that such confounding factors can *fully* explain the observed effects. In this case, the twins in an MZ pair will on average not differ from one another in Y no matter how much they differ in X. If between-pair and within-pair effects are both significant, results should accordingly be interpreted to reflect both mechanisms, taking into account their relative magnitudes. For further details on the mixed strategy and its interpretation, we refer readers to Carlin et al. (2005).

We use a linear mixed regression model (not to be confused with the "mixed strategy" outlined above, which refers to the separation of within-pair and between-pair effects) with the index of a twin pair in the data set modeled as random effects to account for the fact that twin data is clustered in pairs (see Carlin et al., 2005). Age and sex, which are necessarily shared by twins (the TwinLife panel only includes same-sex DZ pairs), were included as covariates. All variables were z-standardized, with the exception of sports club participation. As this is a binary "yes/no" variable (see Results section), its unstandardized values of 1 and 0 have a straightforward interpretation.

We follow the procedure in Arseneault et al. (2008) in reporting the regression results by first including the full sample (that is, including DZ twins), followed by only the MZ twins and as a third step using future (i. e., measured at the second measurement wave in TwinLife) rather than concurrent life satisfaction as the outcome, controlling for current levels of life satisfaction. DZ twin pairs control for confounding through shared environment to the same extent as MZ twins, assuming that MZ twins are not treated more similarly to each other than DZ twins in a way that acts to increase similarities within MZ twin pairs (empirical tests of this so-called *equal environments assumption* typically confirm it or find only small biases; see Felson, 2014). However, since DZ twins, who share 50% of their segregating genes on average, are no more similar genetically than regular siblings, genetic similarities between the twins will be less pronounced in this full sample than among MZ twins only. Therefore, DZ twins might differ in genetic factors that impact both sports club participation and life satisfaction, i. e. display genetic confounding.

Since this is not possible among MZ twins, a decrease of the between-pair coefficient β^W in the MZ pairs sample compared to the sample of MZ *and* DZ twins implies that these between-pair effects are at least partly driven by genetic confounding (as opposed to shared environmental confounding, which is as controlled for among DZ twins as among MZ twins).

We apply these analyses to both general and domain-specific life satisfaction as these different conceptualizations of well-being offer distinct value (Long & Huebner, 2014) with only moderate overlap (Lent et al., 2005). If participating in a sports club is indeed beneficial for adolescents' well-being, the domain-specific items may help clarify why that is the case.

To further illustrate the results of this analysis, we also use an approach exemplified in Stubbe et al. (2007). The dichotomous nature of the predictor variable, which leads to twin pairs either being concordant or discordant for sports participation, can be used to illustrate the pattern behind associations that are confounded through common genetic or environmental factors versus those that are not. If participation affects life satisfaction beyond genetic and shared environmental confounding, twin pairs where only one twin participates in a sports club should differ in this regard, and crucially, this should hold true not only for DZ twins, but also for MZ twins. If an individual's genetic makeup explains both their levels of sports club participation and of life satisfaction, leading to a spurious correlation, MZ twins who do participate in a sports club should not, on average, be happier than their genetically identical twins. The same is true for shared environmental confounding.

4. Results

The full sample used for the analysis included 3492 twins from cohorts 3 (around 17 years old) and 4 (around 23–24 years old), 58% of which were female. These included 423 MZ and 483 DZ pairs from cohort 3 and 454 MZ and 386 DZ pairs from cohort 4. More detailed summary statistics grouped by cohort, zygosity and gender are presented in the Supplementary Materials.

Means and standard deviations for the variables used, as well as their intercorrelations, are provided in Table 1.

Table 2 shows concordance rates for the dichotomous variable of frequent sports club participation by cohort. Similarly, Table 3 displays intraclass correlations (ICCs) for the continuous variables. Prior to calculating ICCs, each variable was regressed on age and sex to control for the paired nature of twin data (see McGue & Bouchard Jr, 1984).

While there is no consistent pattern in the ICCs for the various measures of general and domain-specific life satisfaction in the current sample, MZ correlations in Table 3 generally exceed DZ correlations to a small or moderate degree, suggesting heritabilities between 0.00 (for domain-specific satisfaction with leisure activities at time 1) and 0.52 (domain-specific satisfaction with leisure activities at time 1).

The results from the structural equation models presented in Table 4 are mostly consistent with previous findings that nonshared environmental sources of variance play a large role[2] and heritability is modest. For domain-specific life satisfaction with health and leisure time activities, modeling the genetic effects as dominance effects (i. e., non-additive effects) resulted in a better fit than the standard ACE model.

Both the general life satisfaction scale as well as the domain-specific satisfaction items were somewhat negatively skewed (skew values between −0.72 and −1.99). Still, raw data were used to estimate linear mixed models as transformations can introduce bias in regression models (Schmidt & Finan, 2018) and are not typically necessary in linear mixed models, especially in large samples such as the current one (Schielzeth et al., 2020).[3] All regression models include age and sex as covariates. Table 5 shows the regression coefficients as well as confidence intervals.[4]

Results show that sports club participation is associated with higher life satisfaction at the general and domain-specific level, but that patterns of within-pair and between-pair effects differ.

For general life satisfaction, within-pair effects are evident only in the full sample (i. e., when DZ pairs are included). Among MZ pairs, between-pair effects remain significant, but within-pair effects do not, indicating that factors common to a pair are sufficient to explain the observed associations: taking into account a particular MZ twin's participation or lack of participation in a sports club does not predict this twin's general life satisfaction more accurately after the twin pair's average level of participation is taken into account (see Carlin et al., 2005).

However, within-pair coefficients, indicative of effects beyond genetic and shared environmental confounding, stay significant for the links between sports club membership and domain-specific happiness with health and leisure activities. For satisfaction with leisure, the between-pair and within-pair coefficient are similar in magnitude, suggesting that twins discordant for sports club participation differ in this outcome on average to the same extent as two unrelated people discordant for sports club participation (see Carlin et al., 2005). For satisfaction with health, the within-pair effect is more prominent than between-pair effect, which does not reach statistical significance. Therefore, shared twin-pair factors do not appear to explain much, if any, of the association between this outcome and sports club participation.

For domain-specific satisfaction with one's social life, the within-pair effect is approximately as large within MZ pairs as in the full sample, but does not reach statistical significance in the smaller MZ subset (neither does the between-pair effect).

All of these associations disappear when predicting future satisfaction beyond the current baseline. Here, both within-pair and between-pair coefficients for current happiness are significant predictors, indicating that both an individual twin's life satisfaction compared to their co-twin as well as the pair's joint level of life satisfaction compared to the rest of the population play a role in predicting future levels of satisfaction.

As an additional illustration of these results, Table 6 shows that for general life satisfaction, only DZ twins discordant for sports club participation, but not discordant MZ twins, tend to differ in life satisfaction. For the domain-specific item of satisfaction with health, however, a significant difference remains even within MZ-pairs. Similarly, for satisfaction with leisure, twins engaging in sports clubs appear to be consistently happier on average, both in DZ and MZ pairs, although statistical significance at $p < 0.05$ is only marginally achieved in the MZ group. The sample size for the present analysis, which necessarily focuses on discordant pairs (with fewer instances among MZ than DZ twins) may not have been quite sufficient to test differences of about 0.2–0.3 standard deviations with a high degree of confidence. Of note, for health and leisure time satisfaction, the numerical differences among the MZ twins are in fact greater than those among the DZ twins.

[2] Nonshared environmental variance includes measurement error by default, which may be more substantial than usual for the domain-specific satisfaction categories, as these were measured by single items.

[3] Running a generalized mixed regression model with log-transformed data (and a Gaussian distribution) instead yields the same conclusions. We present the linear mixed model with raw data for ease of interpretation.

[4] While we denote significant values as such in the table, inference statistics in mixed regression models must be interpreted with caution; we report them as provided in the R package *parameters* (Lüdecke et al., 2020).

Table 1
Descriptive statistics and correlations for study variables.

Variable	*M*	*SD*	1	2	3	4	5	6	7	8	9	10	11
1. Age	19.9	3.07	–										
2. Sex [a]	0.58	–	0.02	–									
3. GLS (time 1)	3.86	0.79	−0.03*	0.00	–								
4. DLS: health (time 1)	7.82	2.19	−0.08**	−0.04*	−0.31**	–							
5. DLS: leisure (time 1)	7.52	2.19	−0.07**	−0.04*	−0.31**	−0.36**	–						
6. DLS: friends (time 1)	8.44	1.89	−0.06**	−0.00	−0.26**	−0.39**	−0.49**	–					
7. GLS (time 2)	3.84	0.79	−0.01	−0.00	−0.63**	−0.26**	−0.22**	−0.22**	–				
8. DLS: health (time 2)	7.55	2.24	−0.04	−0.04	−0.31**	−0.44**	−0.17**	−0.15**	−0.37**	–			
9. DLS: leisure (time 2)	7.30	2.1	−0.07**	−0.05*	−0.29**	−0.18**	−0.33**	−0.24**	−0.35**	−0.29**	–		
1. DLS: friends (time 2)	8.25	1.78	−0.04	−0.01	−0.24**	−0.12**	−0.19**	−0.32**	−0.32**	−0.27**	−0.45**	–	
11. Sports club participation [b]	0.47	–	−0.16**	−0.10**	−0.14**	−0.09**	−0.12**	−0.08**	−0.13**	−0.09**	−0.10**	−0.09**	–

Note: [a] 0 = male, 1 = female. [b] 0 = no frequent participation (includes "never", "less than once a month" and "monthly"; see section 3.2) and 1 = weekly participation. GLS = general life satisfaction (range: 1–5), DLS = domain-specific life satisfaction (range: 1–10). n = 3492 for all variables. *p < 0.05. **p < 0.01.

Table 2
Concordance rates for weekly sports club participation by cohort and zygosity.

Cohort	Zygosity	Weekly sports club participation		
		Both twins	One twin	Neither twin
2 (around 11 years old)	MZ	204 (67.5%)	11 (3.6%)	87 (28.8%)
	DZ	304 (67.1%)	51 (11.3%)	98 (21.6%)
3 (around 17 years old)	MZ	202 (47.8%)	61 (14.4%)	160 (37.8%)
	DZ	193 (4.0%)	136 (28.2%)	154 (31.9%)
4 (around 23 years old)	MZ	141 (31.1%)	90 (19.8%)	223 (49.1%)
	DZ	71 (18.4%)	128 (33.2%)	187 (48.4%)

Note: Because of the low proportion of discordant MZ pairs in cohort 2, only cohorts 3 and 4 were used in the final analysis (see section 3.2).

Table 3
Intraclass correlations for measure of life satisfaction.

	Zgyosity	
	MZ	DZ
GLS (time 1)	0.39 [0.34, 0.45]	0.31 [0.25, 0.37]
DLS: health (time 1)	0.23 [0.15, 0.31]	0.05 [-0.04, 0.13]
DLS: leisure (time 1)	0.15 [0.07, 0.23]	0.15 [0.07, 0.23]
DLS: friends (time 1)	0.32 [0.23, 0.41]	0.06 [-0.04, 0.16]
GLS (time 2)	0.40 [0.31, 0.48]	0.33 [0.24, 0.42]
DLS: health (time 2)	0.29 [0.17, 0.39]	0.12 [0.00, 0.23]
DLS: leisure (time 2)	0.27 [0.16, 0.36]	0.20 [0.09, 0.30]
DLS: friends (time 2)	0.22 [0.09, 0.34]	0.06 [-0.06, 0.19]

Note: GLS = general life satisfaction, DLS = domain-specific life satisfaction. n = 877 MZ pairs and 869 DZ pairs. Confidence intervals for ICCs presented in brackets.

Table 4
Estimates from best-fitting twin models for measures of life satisfaction.

	A	C	E	D
GLS (time 1)	0.21 [0.08, 0.36]	0.20 [0.08, 0.32]	0.59 [0.54, 0.65]	–
DLS: health (time 1)	–	–	0.72 [0.66, 0.79]	0.28 [0.21, 0.34]
DLS: leisure (time 1)	0.22 [0.16, 0.27]	–	0.78 [0.73, 0.84]	–
DLS: friends (time 1)	–	–	0.69 [0.63, 0.75]	0.31 [0.25, 0.37]
GLS (time 2)	–	0.35 [0.29, 0.41]	0.65 [0.59, 0.71]	–
DLS: health (time 2)	–	–	0.84 [0.77, 0.90]	0.16 [0.14, 0.23]
DLS: leisure (time 2)	–	0.16 [0.14, 0.23]	0.84 [0.77, 0.90]	–
DLS: friends (time 2)	–	–	0.78 [0.70, 0.87]	0.22 [0.13, 0.30]

Note: Parameter estimates from structural equation models for measures of life satisfaction (both cohorts; n = 877 MZ pairs and 869 DZ pairs). A = additive genetic effects, C = shared environmental effects, E = nonshared environmental effects, D = dominance effects (non-additive genetic effects). GLS = general life satisfaction, DLS = domain-specific life satisfaction. For each variable, only the best-fitting model according to the Akaike Information Criterion (AIC) is shown. Confidence intervals for parameter estimates in brackets.

5. Discussion

5.1. General discussion

The present study shows that participating in sports clubs is linked to general and domain-specific life satisfaction and that genetic and shared environmental confounding account for some, though not all, of these associations.

Within the utilized twin panel, we observed cross-sectional associations between adolescents' and young adults' participation in a sports club and their satisfaction with life in various domains, including general life satisfaction as well as domain-specific satisfaction with health, social life and leisure activities. We employed regression models suitable for twin samples to disentangle the effects attributable to genetic and environmental factors shared by twins from those reflecting nonshared environmental influences.

The results indicate that the relationship between sports club participation and general life satisfaction was attributable to both within-pair and between-pair effects, but this was the case only in the full sample, which included DZ twins. The within-pair effect disappeared when limiting the sample to MZ pairs, suggesting that phenotypic correlations between participation and general life satisfaction can be fully explained by genetic and environmental confounding. Comparisons within DZ pairs control for shared environmental confounders to the same extent as MZ pairs, assuming that MZ twins do not grow up in more similar environments than DZ pairs (equal environments assumption; see section 3.3.). Therefore, the presence of a significant within-pair effect in the full sample, but not among MZ twins, indicates that genetic (as opposed to shared environmental) confounding plays at least a partial role in this case.

For satisfaction with leisure time activites, both the between-pair and within-pair effects remained significant among MZ twins and were of similar magnitude. This pattern suggests that confounding through common genetic and environmental factors partly explains the association between sports club participation and satisfaction, but that a significant part of the association can only be explained through nonshared environmental effects. Carlin et al. (2005) highlight that, in this scenario (where $ß_W \approx \beta_W \approx \beta_B$), two individuals differing in the exposure (here, sports club participation) should, on average, exhibit the same difference in outcome regardless of whether they are MZ twins or unrelated. However, for satisfaction with health, the pattern appears to be different, with the within-pair effect seeming to be the primary factor.

Table 5
Coefficients from linear mixed models predicting life satisfaction from sports club participation, with twin pair IDs as random effects.

Outcome	Predictor	Sample		
		both MZ and DZ twins (n = 877 MZ pairs, 869 DZ pairs)	MZ twins only (n = 877 pairs)	MZ twins only, outcome measured at time 2 (n≥899 individuals, see Note)
GLS	age	0.03** [-0.04, −0.01]	−0.01 [-0.02, 0.01]	−0.01 [-0.01, 0.02]
	sex	−0.09 [-0.19, 0.02]	0.07 [-0.03, 0.18]	−0.03 [-0.13, 0.08]
	β_B	0.32*** [0.23, 0.40]	0.27*** [0.15, 0.38]	0.07 [-0.05, 0.19]
	β_W	0.15** [0.04, 0.25]	0.01 [-0.16, 0.18]	0.05 [-0.18, 0.27]
	β_{Bsat}	–	–	0.75*** [0.69, 0.82]
	β_{Wsat}	–	–	0.47*** [0.38, 0.56]
DLS: health	age	−0.02*** [-0.03, −0.01]	−0.03** [-0.04, −0.01]	−0.00 [-0.02, 0.02]
	sex	−0.06 [-0.13, 0.01]	−0.09 [-0.19, 0.02]	−0.03 [-0.15, 0.10]
	β_B	0.12** [0.04, 0.20]	0.11 [0.00, 0.22]	0.03 [-0.11, 0.16]
	β_W	0.26*** [0.14, 0.38]	0.31*** [0.13, 0.49]	0.09 [-0.16, 0.35]
	β_{Bsat}	–	–	0.55*** [0.47, 0.63]
	β_{Wsat}	–	–	0.34*** [0.25, 0.43]
DLS: leisure	age	−0.02** [-0.03, 0.01]	−0.02* [-0.17, 0.03]	−0.00 [-0.02, 0.02]
	sex	−0.05 [-0.12, 0.02]	−0.07 [-0.17, 0.03]	−0.05 [-0.18, 0.08]
	β_B	0.20*** [0.12, 0.29]	0.23*** [0.11, 0.34]	0.14 [-0.01, 0.28]
	β_W	0.19*** [0.07, 0.31]	0.21* [0.02, 0.40]	−0.08 [-0.35, 0.19]
	β_{Bsat}	–	–	0.41*** [0.33, 0.50]
	β_{Wsat}	–	–	0.29*** [0.19, 0.38]
DLS: friends	age	−0.02** [-0.03, 0.00]	−0.01 [-0.03, 0.00]	−0.00 −0.03, 0.02]
	sex	0.01 [-0.06, 0.07]	−0.00 [-0.11, 0.10]	−0.02 [-0.15, 0.12]
	β_B	0.12** [0.04, 0.20]	0.10 [-0.01, 0.21]	0.10 [-0.05, 0.25]
	β_W	0.19** [0.08, 0.31]	0.17 [-0.01, 0.34]	0.05 [-0.22, 0.31]
	β_{Bsat}	–	–	0.46*** [0.36, 0.55]
	β_{Wsat}	–	–	0.35*** [0.24, 0.45]

Note: β_B = between-pair effects for frequent sports club participation; β_W = within-pair effects for frequent sports club participation. For longitudinal analyses, β_{Bsat} = between-pair effects for general or domain-specific life satisfaction at time 1; β_{Wsat} = within-pair effects for satisfaction at time 1. GLS = general life satisfaction, DLS = domain-specific life satisfaction. Sample sizes for longitudinal analyses: n = 899 individuals for GLS, 945 for DLS: health, 932 for DLS: leisure, 927 for DLS: friends. Sample sizes differ due to missing data for some participants at the second measurement time. Intercepts are omitted for brevity. * = $p < 0.05$, ** = $p < 0.01$, *** = $p < 0.001$.

Nevertheless, caution is warranted in interpreting this as evidence for mere nonshared environmental effects, as the between-factor only very marginally misses statistical significance and the confidence intervals of both terms still overlap.

For satisfaction with one's social life ("network of friends and acquaintances"), neither the within-pair effect nor the between-pair effect was statistically significant among MZ twins. Thus, it cannot be concluded that frequent participation in sports clubs is associated with this outcome beyond genetic and shared environmental confounding. In the sample including DZ twins, these coefficients did reach significance. Interpreting this as evidence for genetic confounding, as described above, seems questionable since coefficients in both samples were almost identical numerically, and the difference in significance is clearly explained by the differing sample sizes.

None of these within-pair effects remained significant when future life satisfaction was used as the outcome, controlling for earlier levels of satisfaction. This and the remaining possibility of nonshared environmental confounders mean that the present results should not be taken as conclusive evidence of causal links (see Limitations).

These patterns of results are reflected in descriptive differences within pairs discordant for sports club participation. Welch's t-tests showed that among 151 MZ twins pairs where only one twin regularly participated in a sports club, that twin was, on average, significantly happier about their health and their leisure time activities than their co-twin. Effect sizes were small (Cohen's d = 0.36 and 0.23, respectively; see Cohen, 1988).

Previous research has established physical activity in general as a possible protective factor for mental and physical health and as a precursor to life satisfaction. Some studies have indicated particularly pronounced effects of sports clubs as opposed to other forms of physical activity, perhaps because of their additional social aspect. The present results add to this literature by providing some tentative evidence that these associations remain solid, although small in effect size, when genetic and shared environmental confounding is controlled for. To our knowledge, it is the first study examining within-pair effects among twins in relation to sports club participation. Two previous studies applied similar analyses to measures of physical activity and life satisfaction: Waller et al. (2010) found significant within-pair effects, providing evidence of associations beyond genetic and shared environmental confounding, in a longitudinal study that predicted general life satisfaction from physical activity. Stubbe et al. (2007) found no significant differences in general life satisfaction among MZ twins discordant for regular exercise. The different scope of these studies and the present one make it difficult to arrive at clear-cut conclusions, and further research is required to establish if, and in what context, physical activity directly benefits general or domain specific life satisfaction. If sports clubs do have a causal effect on well-being, is this effect driven by the physical activity itself, or does the social aspect have additional merit, as suggested by some studies in the general population (e. g., Vilhjalmsson & Thorlindsson, 1992)? The fact that associations witha domain-specific satisfaction with one's physical health were the most pronounced in our study suggests that staying physically fit could play a role, but this is not necessarily purely an effect of physical activity since social connectedness may also improve physical and mental health (Haslam et al., 2015).

A suitable comparison category would be other clubs for leisure activities, unrelated to sports, where adolescents could be active. Participants in TwinLife, the family panel dataset used in the present study, were indeed asked not only about sports clubs, but various kinds of leisure associations, but these included a highly heterogeneous range of activities, from religious communities to becoming a voluntary firefighter. Sports clubs were the most frequent activity in the sample by a wide margin, while the other activities were mostly scattered across relatively few twin pairs. For these reasons, a direct comparison did not seem viable within the present study.

In addition to the main analysis, a secondary finding of the present study was that within-pair coefficients were almost as important in predicting future satisfaction among MZ twins as between-pair effects. Differences between MZ twins in life satisfaction therefore appear to be meaningful and partially stable, encouraging future investigations into the specific nonshared environmental factors at play. Generally speaking, variables of well-being, such as life satisfaction, are among the traits with the most pronounced "E" components in univariate twin models and are thus promising candidate variables in the search for nonshared environmental influences on psychological traits.

Table 6
Welch's t-tests Comparing Life Satisfaction Among Twins Discordant for Frequent Sports Club Participation.

Variable	Zygosity	Twin in sports club		Discordant co-twin		df	*t*	*p*	Cohen's d
		M	SD	M	SD				
GLS	MZ	3.86	0.85	3.86	0.85	300	0.08	0.935	0.01 [-0.22, 0.24]
	DZ	3.91	0.77	3.73	0.81	524.78	2.61**	0.009	0.23 [0.06, 0.40]
DLS: Health	MZ	8.30	1.53	7.58	2.39	255.55	3.09**	0.002	0.36 [0.12, 0.58]
	DZ	7.95	2.13	7.47	2.24	524.7	2.65**	0.008	0.23 [0.06, 0.40]
DLS: Leisure	MZ	7.85	1.92	7.36	2.32	292.4	1.93*	0.4949	0.23 [0.00, 0.45]
	DZ	7.59	2.09	7.17	2.36	518.6	2.16*	0.031	0.19 [0.02; 0.36]
DLS: Friends	MZ	8.60	1.76	8.27	2.13	289.92	1.47	0.142	0.17 [-0.06, 0.40]
	DZ	8.61	1.6	8.18	2.18	482.27	2.59**	0.0098	0.23 [0.05, 0.40]

Note: GLS = general life satisfaction (range: 1–5), DLS = domain-specific life satisfaction (range: 1–10). For all analyses, n = 151 MZ twin pairs and 264 DZ pairs. Welch's t-tests are used because they are robust to violations of the assumption of equal variances, with little to no disadvantages compared to Student's *t*-test (Delacre et al., 2017).

5.2. Limitations

There are several limitations to our study that we would like to acknowledge. First of all, the cross-sectional links we found are far from establishing causation. If such a causal link exists, it might work in the opposite direction: happier adolescents might be more inclined to join a sports club. The concurrent nature of our main analyses cannot rule this out. In tentative longitudinal analyses, within-pair associations did not show any incremental validity in predicting subsequent life satisfaction beyond earlier satisfaction. This is consistent with life satisfaction as a possible cause of participation rather than the other way around. It must be noted that our longitudinal results were based on smaller sample sizes, particularly within the subset of discordant twins. With one exception, the nonsignificant coefficients for sports club participation were numerically positive, hinting at possible small effects that remain. Since small effect sizes are the norm for measured environmental sources of variances (e. g. Plomin, 2001), large sample sizes, especially of discordant MZ twin pairs, are necessary for a study such as the present one to reach a high level of statistical power. The fact that only a minority of MZ twin pairs in the current sample (less than 20% in each cohort) differed in sports club participation led to a final sample size that is likely not sufficient in this regard (151 discordant MZ twin pairs). Future studies with larger samples are necessary to come to more robust conclusions.

Furthermore, while analyzing differences between MZ twins implicitly rules out genetic and shared environmental explanations, nonshared environmental influences can still act as confounding variables and lead to spurious within-pair effects (Frisell et al., 2012). If a third variable is the true cause for the observed exposure, such as sports club participation in the present study, discordant twin pairs will typically be discordant on the confounding variable as well, which biases within-pair comparisons. For example, if one of the twins in an MZ pair is physically healthier, they might also be more likely to join a sports club and to be more satisfied with life. Since the present analysis can only rule out common genetic and environmental background, such a difference between MZ twins in a third variable would not be controlled for.

Due to the panel nature of the present study, very brief measures were utilized, including single items in the case of domain-specific life satisfaction. Focusing on brevity in panel studies allows the inclusion of a wider range of measures, but comes with the tradeoff of lower reliability and, in turn, validity. This is particularly true as twin difference models are prone to bias due to measurement error (Frisell et al., 2012). This low scale quality is reflected in the fact that parameter estimates of variance components for the measures of life satisfaction showed nonshared environmental contributions (which include measurement error) of up to 0.84. This was particularly pronounced for the single-item measures, while the 5-item scale for general life satisfaction, which showed very good internal consistency, generated lower estimates of E. Previous studies on the topic have also shown substantial nonshared environmental components to life satisfaction (Bartels et al., 2015), but some of the coefficients are still unusually large and presumably reflect a relatively large portion of measurement error.

Our measurement of participation is very broad. Sports clubs may differ in numerous aspects, such as the particular sport being practiced. A comparison of characteristics of sports club across European countries reveals marked differences, such as German clubs placing relatively low emphasis on competitiveness and success (Breuer, Hoekman, et al., 2015). This makes it unclear to what extent our results can be generalized beyond the current sample or the country of Germany. It also stands to reason that the adolescents and young adults in the sample may have highly heterogenous motives for participating, and that some of them are urged to do so by their parents rather than joining a sports club out of intrinsic motivation. Our analysis cannot differentiate between such contextual differences. The fact that concordance within twin pairs declined with age appears to be consistent with the common sense assumption that joining a club becomes more of an individual decision in adolescence and young adulthood, as parents have less and less influence over their offspring's life choices. It might thus start to more strongly reflect a person's heritable tendencies (e. g. through active gene-environment correlation), making it less likely that sports participation impacts life satisfaction through an environmentally mediated pathway. This remains to be explored by future genetically informed research. It also remains unclear if there is a dose-response relationship between sports club participation and well-being, i.e., whether more frequent participation is more beneficial than occasional activity (as is the case for physical activity in general, e.g. Lee & Skerrett, 2001). In the present study, self-reported participation was used as a dichotomized variable to ease interpretation and because most twins either reported frequent participation or none at all. Studies that use more refined scales to measure the extent and nature of participation in sports clubs could yield more detailed conclusions.

Despite these limitations, the present findings based on a large, representative twin sample suggest that sporting activities with peers may play a role in impacting life satisfaction. Uncovering specific factors associated with life satisfaction, or other measures of well-being, through nonshared environmental pathways has remained difficult in behavioral genetic research to date (see Plomin et al., 2001; Smith, 2011; Turkheimer & Waldron, 2000). Given this context, our finding that significant effects of sports club participation on well-being persist, even when genetic and shared environmental confounding is controlled for, is notable. It suggests that adolescents and young adults who participate in sports clubs may, on average, be happier not only because they are, for example, genetically predisposed to high life satisfaction regardless. While the present research cannot conclusively demonstrate that joining a sports club causally impacts happiness among adolescents and young adults, it encourages offering such opportunities.

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Ethical statement

The TwinLife project received ethical approval from the German Psychological Association (protocol numbers: RR 11.2009 and RR 09.2013).

Informed consent

Informed consent was obtained from all individual participants included in the study or from their legal guardians.

CRediT authorship contribution statement

Alexander Dings: Writing – review & editing, Writing – original draft, Software, Methodology, Investigation, Formal analysis, Data curation, Conceptualization. **Frank M. Spinath:** Validation, Supervision, Resources, Project administration, Methodology, Funding acquisition, Conceptualization.

Declaration of competing interest

None.

Data availability

The data are available in a public repository (GESIS; for details see statement in article).

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.psychsport.2024.102639.

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