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Physical activity in adolescence and smoking in young adulthood: a prospective twin cohort study

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Abstract

Aims— To control for familial confounds, we studied the association between adolescent physical activity and later smoking in twin siblings discordant for their baseline physical activity.

Design and measurements— In this prospective population-based twin study, we asked whether persistent physical activity/inactivity in adolescence (assessed at 16, 17 and 18.5 years) predicted questionnaire-reported daily smoking at ages 22–27. Twins who, on the three baseline questionnaires, consistently reported frequent leisure physical activity (more than three times weekly) were classified as persistent exercisers, those who exercised less than three times monthly were called persistently inactive, others were occasional exercisers.

Setting— Finland

Participants— 4240 individuals, including 1870 twin pairs.

Findings— In analyses of individual twins, compared to persistent activity, persistent physical inactivity predicted increased risk of daily smoking (age-and sex-adjusted odds ratio 5.53, 95% confidence interval 3.88 to 7.88, $P < 0.001$). The risk remained elevated even after excluding all those who had smoked 50 cigarettes or more lifetime at baseline and adjusted for educational level in adolescence. In within-pair analyses compared to the active members of discordant twin pairs, the physically inactive co-twins had increased risk of future daily smoking (sex-adjusted odds ratio 3.39, 95% confidence interval 1.56 to 7.39, $P = 0.002$).

Conclusions— Persistent physical inactivity in adolescence relates to adult smoking, even after familial factors are taken into account.

Keywords

exercise; physical activity; smoking; twins

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INTRODUCTION

It has been shown that smoking is associated with many health risks including increased risk of specific cancers, coronary heart disease and mortality.[1, 2]

Adolescents' smoking is generally associated with less physical activity.[3–9] A major question is whether a physically active lifestyle causally influences adoption of smoking habits. The association might be correlational only, mediated by third variable differences between families, including differences in social class and education, family structure and parental models. Within-pair analyses of twins from pairs discordant for their physical activity offer a control for both known and unknown familial factors (childhood environment and shared genetic dispositions) in the development of health related lifestyles.[1, 10]

We studied how persistent physical activity in mid and late adolescence predicts smoking habits in young adulthood. To more incisively study causality between physical activity and other health habits, we complemented the analyses of twins as individuals by within-pair analyses of co-twins discordant for persistent physical activity at baseline.

METHODS

The FinnTwin16 study and questionnaires

Twins from consecutive birth cohorts were identified from the Central Population Registry of Finland (Fig. 1).[11] Three adolescent baseline questionnaires were sent to the twins at ages 16, 17 and 18.5 years.[11] After excluding twins reporting an illness or handicap that could affect physical activity, as described elsewhere,[12] at adult follow-up (ages 22–27), the final study group of 4240 twins included 1870 twin pairs (Fig. 1), who had replied to all adolescent questionnaires and who replied to a fourth questionnaire in young adulthood (see below). Zygosity was determined from well-validated questionnaire items[13] included in baseline questionnaires separately administered to twins and their parents. There was an approval for the data collection study protocol from Indiana University's Institutional Review Board and the ethics committee of the Helsinki metropolitan hospital region.

Baseline assessments

Frequency of physical activity outside school was assessed with a structured question included in all four questionnaires, in identical format with six alternatives.[14] The six alternatives were: not at all or less than once a month, 1–2 times a month, about once a week, 2–3 times a week, 4–5 times a week, and every day. Those who, in all three baseline questionnaires, reported that their frequency of physical activity was 4–5 times a week or more were defined as persistently active at baseline, and those who exercised 1–2 times a month or less were classified as persistently inactive at baseline; all others were classified as occasionally active.[12] Validity information has been reported in detail elsewhere.[14, 15]

Attendance at different types of schools at age of 17 was assessed in an item in the second questionnaire, and we classified respondents as attending senior high school (61%), vocational school (30%) or other (9%), including those at work or unemployed. At age 16, virtually all students attended compulsory basic education.

Also, smoking habits were assessed at baseline. The first baseline questionnaire, mailed to the twins within two months of their 16th birthday, included one question on whether the responder ever smoked or even tried smoking. Those replying that they had smoked were asked how many cigarettes they had smoked altogether until that time. The response alternatives were none, only one, 2–50 cigarettes, and more than 50 cigarettes. Those who chose the alternative more than 50 cigarettes were classified as smokers at baseline and excluded from some

analyses. We also classified subjects as never smokers (at most one cigarette ever smoked), quitters, at least weekly smokers, and other (occasional) smokers as four categories used to adjust for smoking status at baseline in some analyses. Among boys the percentage of weekly smokers at age 16 was 4.8% for persistently active, 23.6% for occasionally active and 41.5% for persistently passive. Among girls 6.7%, 20.1% and 45.2% were weekly smokers, respectively. The median age of smoking the first cigarette was 13 years. Information on smoking status from the questionnaires at ages 17 and 18½ years was not used in the analyses.

Assessment of physical activity and smoking at follow-up

Our follow-up questionnaire, at mean age 24.4 years (range 22–27 years), included structured questions on physical activity and smoking.

Frequency of leisure physical activity was assessed with the same question as that at baseline, and responses were classified into three classes as at baseline (see Tables 1 & 2). Those who exercised at least 4–5 times a week were active exercisers. To characterize better the association between baseline activity frequency and follow-up activity habits, different aspects of follow-up physical activity were verified as shown in table 2.

Smoking was assessed with a structured question with seven alternatives. The seven alternatives were: I smoke daily at least 20 cigarettes, I smoke daily 10–19 cigarettes, I smoke daily at most 9 cigarettes, I smoke once or more a week but not daily, I smoke less often than once a week, I am trying to or have quit smoking, I have never smoked. To provide sufficient contrast for our within-pair analyses of activity-discordant co-twins and to facilitate interpretation, we dichotomised smoking habits at follow-up. Daily smokers were those who chose any one of the first three alternatives.

Data analysis

After deriving descriptive data (Tables 1–2), we used logistic regression analysis (procedure *logistic* in Stata)[16] to study baseline physical activity and follow-up smoking in the entire study cohort (4240 individuals); we calculated odds ratios (OR) at follow-up with their 95 percent confidence intervals (CI) for different categories of baseline leisure physical activity (Table 3). The persistently active group was the reference group. Because the data were from twin individuals, the clustering of possibly correlated observations from twin pairs was taken into account in computing standard errors of the coefficients using robust estimators of variance.[17] The results were adjusted for sex, educational level, and baseline smoking in three different models. Because the interaction between sex and physical activity was non-significant in individual based analyses, the results are not reported separately for men and women in any of the analyses.

Twin pairs discordant for follow-up smoking, and for categories of baseline physical activity, were examined to determine whether physical activity level at baseline was associated with smoking at follow-up, after controlling for shared family environments. A twin pair discordant for physical activity can be discordant for smoking in two ways. Based on the existence of the two different combinations of discordance, odds ratios at follow-up with their 95 percent confidence intervals according to different leisure physical activity categories at baseline were calculated using conditional logistic regression (procedure *clogit* in Stata)[16] (Table 4). For discordant twin pair analyses we analyzed interactions for zygosity, but significant activity group by zygosity interaction was not found. In statistical analyses, data were pooled across zygosity.

We also repeated the analyses among all individuals, as well as among physical activity discordant twin pairs, those who had smoked altogether at most 50 cigarettes at baseline even

though the primary aim was to study the initiation of smoking habits (before and after our baseline assessments) in relation to participation in physical activity and controlled for familial factors in twin pairs.

Data were analyzed with Stata software (release 8.2; Stata Corporation, College Station, Texas).[16] All P values are two-sided.

RESULTS

Different measures of physical activity at follow-up are strongly associated with baseline persistent physical activity category both among men and women (for distributions see Table 2). Twin pairs discordant for baseline physical activity formed the target group for within-pair analyses. Of all twin pairs, 1434 were concordant, and 436 discordant for baseline physical activity category. Of the discordant pairs, 41 were male monozygotic, 56 female monozygotic, 74 male dizygotic, 71 female dizygotic, 181 opposite sex (dizygotic), and 13 same-sex pairs with unknown zygosity. There were 270 twin pairs whose discordance was such that one twin had persistent activity and the other occasional activity, and 157 pairs whose discordance was between occasional activity in one twin and persistent inactivity in the co-twin. There were but nine twin pairs who were extremely discordant for physical activity frequency (persistently passive vs. active).

Individual-based analyses showed that, compared to twins who were persistently physically active at baseline, lower baseline activity levels predicted lower probability of being physically active at follow-up: the sex- and age-adjusted odds ratios were 0.20 ($P < 0.001$) for those who were occasionally active and 0.09 ($P < 0.001$) for those who were persistently inactive at baseline (Table 3). That finding was replicated in within-pair analyses of twin pairs discordant for physical activity at baseline: the sex adjusted odds ratios were 0.30 ($P < 0.001$) and 0.17 ($P < 0.001$), respectively (Table 4). Among the 171 pairs discordant for baseline physical activity and also discordant for physical activity at follow-up, 126 of the more active twins at baseline were the more active exerciser at follow-up.

Among all individuals, daily smoking at follow-up was much more prevalent among those who at baseline were only occasionally active (odds ratio 2.54, $P < 0.001$) or persistently inactive (odds ratio 5.53, $P < 0.001$) compared to those persistently active (Table 3). The odds ratios were attenuated but remained statistically significant when adjusted for educational level and baseline smoking status (Table 3). The association was statistically significant, as well, in within-pair analyses (P values = 0.007 and 0.002, respectively) (Table 4). In within-pair analyses sex by exercise level interactions were non-significant ($p>0.37$). Among the 119 pairs discordant for baseline physical activity and follow-up smoking, 72 of the less active pair members at baseline were smokers at follow-up. Among discordant same-sex pairs the less active member was a smoker at follow-up in 35 pairs (and the co-twin a non-smoker) and the more active pair member was the smoker in 22 pairs, the trends being similar for opposite-sex pairs; 37 vs. 25.

Among all individuals, 28% of subjects reported having smoked 50 or more cigarettes by age 16. After excluding baseline smokers from analysis, daily smoking at follow-up was still more prevalent among those who at baseline were only occasionally active (age- and sex-adjusted odds ratio 1.89, $P < 0.001$) or persistently inactive (2.85 $P < 0.001$) compared to those persistently active (Table 3). Adjustment for educational path at age 17 reduced the risk estimates, but they remained statistically significant. A similar but statistically non-significant trend was seen in within-pair analyses of twin pairs who were non-smokers and discordant for physical activity at baseline (Table 4).

At adult follow-up the percent of daily smokers by adult physical activity category was 15.9% in the 1140 physically active (4–5 times per week or more), 23.8% in the 2236 occasionally active (3 times per month to 3 times per week), and 44.9% in the 858 inactive (1–2 times per month or less) subjects. Corresponding age- and sex-adjusted odds ratios were 1.68 (95% confidence interval 1.39 to 2.04) in the occasionally active and 4.11 (3.32 to 5.10) in the inactive.

DISCUSSION

Our analyses confirm that persistent physical activity during late adolescence predicts physical activity at age 24 (Tables 2, 3 & 4), a result consistent with earlier studies tracking physical activity habits.[4, 7, 18, 19] Correlations between pre-adolescent physical activity and activity in adulthood are low to moderate, while physical activity declines during adolescence.[4, 7, 18–20] Persistent physical activity in late adolescence, compared to physical activity before adolescence, tracks better into adulthood.

Childhood environments of persistently physically active and inactive adolescents differ, including differences in socio-economic status of parents[12] and differences in school type (Table 1).[21]

Our study shows that persistent physical inactivity, compared to persistent physical activity during late adolescence, predicted higher prevalence of smoking during young adulthood. This association replicates earlier cross-sectional and longitudinal studies.[3–5, 7, 22] Because this finding was statistically significant in within-pair analyses of activity discordant twin pairs, the association is not explained by between-family differences in environments that encourage physical activity and discourage smoking. Persistent physical activity seems to be an important factor in the causal pathway in selecting and maintaining non-smoking behaviour.

There are several possible mechanisms by which high physical activity could relate to low smoking. First, physically active subjects usually aim to improve and maintain their fitness and health; they know that smoking interferes with achieving that goal. Further, children and adolescents with interests in physically active lifestyles selectively seek as friends those with similar interests.[23] The weight control benefits of exercise may be of importance to females, because some female smokers report taking up smoking to control weight.[24, 25]

As a third of our twin pairs were of opposite sex, this means that the friends of these co-twins were more often different, and the parental influences to which they were exposed may differ more than between same-sex pairs. However, we adjusted for sex in our analyses, and the studied relations were similar in same-sex and opposite-sex pairs. Thus, the association of physical activity and smoking is also independent of gender.

The behavioural theory of choice provides one more possible explanation on how exercise may prevent smoking as exercise and smoking may stimulate the same parts of CNS.[26–28] Interestingly, Audrain-McGovern et al.[29] reported that having one or more smoking risk genotypes was related to higher levels of physical activity, which, in turn, was related to lower levels of smoking progression for adolescents participating in at least one team sport. Also, exercise has been shown to have a positive effect on other factors that may protect against smoking initiation or relapse, such as perceived coping ability,[30] self-esteem,[31] and global physical self-concept.[32] Daniel et al.[33] reported recently that exercise can lead to rapid reduction in desire to smoke and withdrawal discomfort, which is not due to the distracting effect of exercise or the effects of mood. Altogether, these findings support the causal relation between high physical activity and low smoking.

Our study has limitations. First, though our results are consistent with a causal relation between high physical activity and low smoking, the results cannot establish causality: there may be factors, such as those related to self image, that mediate the association. Secondly, our follow-up started from an age 16 baseline, and physically active lifestyle and smoking habits may have been partially formed before then. According to our main study aim to control for unknown and known familial factors we carried out our primary analyses without excluding those who were smokers at the age of 16, because the members of twin pairs have been reared together before that. However, adolescent physical activity was related similarly to adult smoking even after adolescent smokers were excluded though the statistical power for analyses for physical activity discordant pairs were low in this case. Follow-up studies starting from an earlier age could confirm our results.

In conclusion, our study design, and the within-pair analyses we employed, are new steps forward in efforts to understand how physical activity is associated with the development of other health habits. Independent of between-family environmental differences, persistent physical inactivity at adolescence is a predictor of adult daily smoking.

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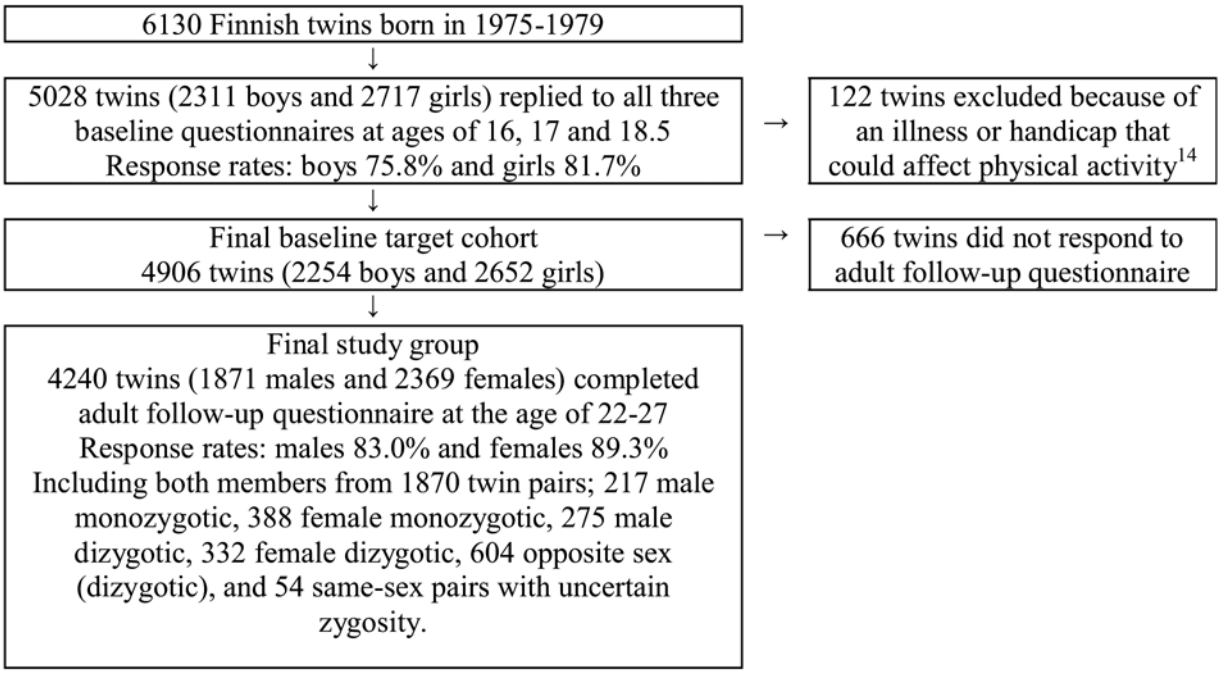

FIGURE 1.
Flow chart: Study cohort and questionnaires.

TABLE 1

Persistent physical activity/inactivity at baseline (ages 16–18.5) and education.

	Baseline physical activity					
	Men (n=1871)			Women (n=2369)		
	Persistently active	Occasionally active	Persistently inactive	Persistently active	Occasionally active	Persistently inactive
% (n) of men and women	20.6 (385)	72.6 (1358)	6.8 (128)	12.7 (302)	81.4 (1929)	5.8 (138)
Age, mean at follow-up	24.4	24.3	24.4	24.3	24.3	24.4
% who completed upper secondary school or higher education	71.2	50.5	34.4	82.5	64.9	41.3

TABLE 2

Persistent physical activity at baseline (ages 16–18.5) and smoking and physical activity characteristics at follow-up (mean age 24.4).

	Baseline physical activity					
	Men			Women		
	Persistently active	Occasionally active	Persistently inactive	Persistently active	Occasionally active	Persistently inactive
	% *					
Follow-up characteristics						
Smoking daily at follow-up	15.6	33.7	47.7	11.3	22.3	42.8
Frequency of leisure physical activity						
4–5 times per week or more	53.8	20.0	8.6	61.6	23.2	12.3
3 times per month to 3 times per week	39.2	54.6	31.3	36.8	59.3	38.4
1–2 times per month or less	7.0	25.4	60.2	1.7	17.5	49.3
Average intensity of leisure physical activity corresponds at least to that of slow running or running	86.4	63.6	33.1	62.3	42.3	20.0
Duration of typical leisure physical activity session at least one hour	81.5	62.7	41.7	76.2	58.7	35.6
Spends time on sedentary hobbies at least two hours per day	48.3	53.2	65.4	33.8	49.5	58.0

* Of those who answered the specific question.

TABLE 3

Odds ratios of physical activity and daily smoking at follow-up (mean age 24.4) according to persistent physical activity frequency at baseline (ages 16–18.5).*

	Occasionally active			Persistently inactive			P for activity level * sex interaction†
	OR	95% CI	P	OR	95% CI	P	
Frequency of leisure physical activity 4–5 times per week or more	0.20	0.17, 0.24	<0.001	0.09	0.06, 0.13	<0.001	0.70
Daily smoking							
Whole cohort	2.54	1.98, 3.26	<0.001	5.53	3.88, 7.88	<0.001	0.28
(also adjusted for education 17)	2.02	1.56, 2.61	<0.001	3.65	2.53, 5.27	<0.001	0.33
(+ baseline smoking status††)	1.42	1.08, 1.87	0.011	1.80	1.21, 2.70	0.004	0.77
Non-smokers at baseline§	1.89	1.36, 2.57	<0.001	2.85	1.68, 4.84	<0.001	0.19
(also adjusted for education 17)	1.56	1.12, 2.16	0.008	2.15	1.24, 3.72	0.006	0.50

*Persistently active group at baseline is the reference group. OR denotes odds ratio. CI denotes confidence interval.

Results are adjusted for sex and follow-up age.

†P values for activity group*sex interaction are from global test over different activity levels.

††Baseline smoking status categories: never smoked (at most 1 cigarette), at least weekly smoker, occasional smoker, quit.

§Under 50 cigarettes lifetime.

TABLE 4

Odds ratios of physical activity and daily smoking at follow-up (mean age 24.4) among twin pairs discordant for leisure physical activity frequency at baseline (ages 16–18.5).*

	No. of discordant pairs	Occasionally active			Persistently inactive		
		OR	95% CI	P	OR	95% CI	P
Frequency of leisure physical activity 4–5 times per week or more	171	0.30	0.20, 0.45	<0.001	0.17	0.08, 0.35	<0.001
Daily smoking							
All pairs	119†	2.16	1.24, 3.76	0.007	3.39	1.56, 7.39	0.002
Both members non-smokers at baseline	50††	1.62	0.81, 3.23	0.17	1.62	0.49, 5.36	0.43

*Persistently active group at baseline is the reference group. OR denotes odds ratio. CI denotes confidence interval. The results of men and women are combined including opposite sex pairs, and adjusted for sex.

†Number of twin pairs who were discordant for baseline physical activity and also discordant for daily smoking at follow-up.

††Number of twin pairs who were non-smokers at baseline, discordant for baseline physical activity and also discordant for daily smoking at follow-up