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Physical exercise, sports, and lung function in smoking *versus* nonsmoking adolescents

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Physical exercise, sports, and lung function in smoking versus *nonsmoking adolescents. T.L. Holmen, E. Barrett-Connor, J. Clausen, J. Holmen, L. Bjermer. ©ERS Journals Ltd 2002.*

ABSTRACT: Associations between adolescent smoking habits and exercise, particularly participation in sports and lung function were studied.

All students aged 13–19 yrs in Nord-Trøndelag County, Norway, 1995–1997, were invited to join a cross-sectional study. Information on smoking habits and exercise was obtained by self-administered questionnaire. Spirometry was performed in accordance with American Thoracic Society standards.

Of the 6,811 students (aged 13–18 yrs, without asthma), 2,993 (44%) reported never-smoking, and 1,342 (20%) reported current smoking (10% daily). Frequency of physical exercise was inversely associated with smoking, but participants in individual sports with lesser endurance, especially body-building and fighting sports, were more likely to be daily smokers than nonparticipants. Both daily (53%) and occasional smokers (43%) were more likely to have quit sports than never-smokers (26%). Never-smokers showed a positive dose-response between physical exercise and lung function (forced vital capacity and forced expiratory volume in one second, adjusted for age and height). No similar significant association was observed in daily smokers.

These data suggest that smoking habits in different sports should be considered when promoting physical activity as smoking prevention, and sports organizations should include smoking prevention programmes. Adolescents with better lung function may self-select into sports; this possibility needs to be studied in a longitudinal design.

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Low physical activity is associated with increased morbidity and mortality in adulthood [1, 2]. An underlying premise for promotion of physical activity in youth is that it may persist through adulthood and may also reduce the risk for initiating unhealthy habits such as smoking [3].

Several cross-sectional studies have reported that physically active adolescents and those who participate in sports are less likely to be regular smokers [4–7] compared to sedentary youths. Encouraging participation in sports has been widely recommended for smoking cessation programmes [4, 8, 9]. AARON *et al.* [8] found female adolescents less likely to initiate smoking if they were more physically active or fit, but male adolescents showed a trend (not significant) towards being more active individuals and more likely to initiate cigarette use. Smoking habits, by different types of sports have received little attention.

Some studies report a positive association between physical activity and physical fitness and lung capacity [10–13], while others do not [14]. Whether physical activity increases lung function remains uncertain. Adult-smoking sportsmen exhibit some degree of lung-function impairment compared to nonsmoking sportsmen, but still have better lung function than smokers who are not sportsmen [15]. Young swimmers have been found to have better lung function than sedentary youths, as have participants of other sport activities [10, 16, 17]. An impact of training on lung growth in young swimmers has been suggested [17], but others have found no effect of physical activity on lung growth [18, 19]. Smoking in youth has been found to increase respiratory symptoms and decrease growth [4, 20, 21].

In this paper the cross-sectional association between smoking habit and physical exercise, participation in different types of sports, and lung function in adolescents is reported.

For editorial comments see page 1.

Material and methods

The population is from the YOUNG-HUNT study, the youth part of the large Nord-Trøndelag Health Study (HUNT), conducted from 1995–1997 in

Nord-Trøndelag County, Norway. All students, aged 13–19 yrs, in the county were invited to join the study. A self-administered questionnaire was completed during one school hour, in a setting with no opportunity to look at other's papers. The questionnaire did not include participants' names. Subjects were linked to the questionnaire by a bar code of the 11-digit personal number with which all Norwegians are registered at birth. Each student put their completed questionnaire in a blank envelope and sealed it. Project nurses collected the envelopes.

Questions used in this paper are shown in the Appendix. Exercise of higher intensity, defined as being short of breath and/or sweaty, was assessed by using questions from the World Health Organization cross-national survey of health behaviour in schoolchildren [22] and was divided into three groups: "exercising 4 days a week or more", "exercising 2 to 3 days a week" and "exercising 1 day a week or less". Sports were classified as individual sports or team sports. Because sports questions do not capture individual level of effort, sports were classified based on expected average intensity as follows: "Individual sports with higher endurance " including cross country skiing, cycling and running; "Individual sports with lesser endurance" including slalom skiing, horseback riding and gymnastics; "Swimming"; "Body-building and fight sports" including body-building, weightlifting, boxing, wrestling, Judo, Taekwondo and similar sports; and "Team sports" including football/soccer, handball, basketball and volleyball. In the text, physical exercise includes both organized and non-organized activities unless otherwise specified. Specific sports questions refer to organized sport.

Current smokers were defined as those who answered "yes" to ever having tried smoking (at least one cigarette) and in addition answered "yes, I smoke daily" (daily smokers) or "yes, I smoke occasionally, but not daily" (occasional smokers) to the question: "Do you smoke now?" Smokers were compared to those who answered "no" to ever having tried smoking one cigarette (never-smokers). Passive smoking was defined as exposure to smoking at home by mothers, fathers or siblings.

Within a month after completing the questionnaire, the students underwent a clinical examination, performed in schools, including spirometry and measurement of height and weight. Spirometry was performed by specially trained nurses, in accordance with American Thoracic Society (ATS) standards [23], using computerized pneumotachograph (Jaeger Masterscope, software version 4.15, Jaeger Inc., Wurtzberg, Germany). The acceptability of the spirometry results was assessed both during testing and data analysis, and included review of the computerized ATS error codes reported from the Masterscopes, and visual inspection of volume/time and flow/volume graphics. Achieving end-of-test acceptability was confirmed either from the computerized error code regarding flow plateaus or visual inspection of spirometry displays during testing.

Forced vital capacity (FVC), forced expiratory volume in one second (FEV_1), forced mid-expiratory flow (FEF_{50}) and FEV_1 per cent in relation to the maximal FVC (FEV_1%FVC) were registered. FVC was defined as whichever was largest of either forced expiratory or forced inspiratory vital capacity from technically acceptable curves. Standing height was registered without shoes with standardized metre measures.

All 1,005 students reporting a history of asthma were excluded from these analyses.

Ethics

Each student signed a written consent to participate in the study. Parents of students aged <16 yrs also gave written consent. The study was approved by the Regional Medicine Ethical Research Committee and the Norwegian Data Inspectorate Board.

Statistics

Comparisons of age at onset of smoking and leaving active sports were made by unpaired t-tests, and comparisons of categorical variables by Chi-squared analysis. Comparisons between daily smokers and those who had never tried smoking were performed using logistic regression with age, exposure to passive smoking and physical exercise in the model. Amount of exercise was adjusted for when comparing different types of sports activities. Separate models were used for both females and males and for the different types of sports.

Analyses of lung function were performed by linear regression models with FVC, FEV_1, FEV_1%FVC and FEF_{50} as dependent variables. Because of heteroscedasticity, logarithmic (ln) transformation of lung function (Y) was used to fit model assumptions. Separate models were made for daily smokers and for those who had never tried smoking, adjusted for age, standing height, weight, passive smoking, physical activity, rhinitis and acute bronchitis with cough in both males and females. Analyses of variance were used for comparisons between mean values of lung-function measures by different levels of exercise with the same variables, described earlier, as covariates. Estimates and confidence intervals (CI) are expressed as per cent differences from the logarithmic scale, with those who reported lowest level of exercise ($\leqslant$1 day a week) as reference. Comparisons of height within each level of physical exercise were carried out at all ages (13–18 yrs) using one way analysis of variance. Females and males were analysed separately, 95% CI are shown.

Results

Eighty-three per cent (8,305) completed both the questionnaire and spirometry. Included in these analyses were 6,811 students without asthma, aged 13–18 yrs, (50% males).

Smoking

As shown in table 1, 2,993 students (45% of males and 43% of females) had never tried smoking and 1,342 students (18% of males and 22% of females) reported current smoking (10% daily) (table 1). Daily smoking increased with age ($p<0.001$), and was marginally more common in girls ($p=0.09$). In daily smokers, mean age when smoking began was 13.9 yrs in both males and females. Overall, 52% males and 53% females reported being exposed to passive smoking at home.

Table 1. – Smoking status in adolescents, aged 13–18 yrs, participating in the YOUNG-HUNT study with both self-reported questionnaire and spirometry

	Males	Females	Total
Never tried smoking, not even one cigarette	1522 (45)	1471 (43)	2993 (44)
Tried smoking, but reported to be nonsmokers	929 (27)	898 (26)	1827 (27)
Previous smokers	199 (6)	238 (7)	437 (6)
Occasional smokers	282 (8)	383 (11)	665 (10)
Daily smokers	320 (10)	357 (11)	677 (10)
Missing data[#]	132 (4)	80 (2)	212 (3)
Total	3384 (100)	3427 (100)	6811 (100)

Data are presented as n (%). Adolescents who reported ever having asthma were excluded. [#]: students who did not answer the questions on smoking.

Physical exercise and sports participation

Most students (68%) exercised at least 2 days a week outside school hours (table 2). Males exercised more than females ($p<0.001$), and participated more in sports competitions ($p<0.001$). Compared to the younger age group (13–15 yrs), both males and females in the older age group (16–18 yrs) exercised less ($p<0.001$) and joined in less sports competitions ($p<0.001$). Compared to females, more males participated or had participated in "individual sports of higher endurance" ($p<0.001$) and "body-building and fight sports" ($p<0.001$), while females participated more in "individual sports with lesser endurance" ($p<0.001$) (table 2). Overall, 31% males and 34% females reported having previously participated in sports but not currently.

Physical exercise and smoking

Current smoking was more prevalent in students with lower levels of physical exercise (fig. 1). It was more common in "body-building and fighting sports", "swimming", and "individual sports of lesser endurance" compared to "team sports" and "individual sports of higher endurance", especially in females (table 3). More daily smokers (52% of males, 61% of females) and occasional smokers (43% of males, 39% of females) had dropped out of active sports compared to never-smokers (26% males, 27% females), $p<0.001$. Mean age for quitting sports was similar in daily smokers 15 yrs for both males and females and never-smokers (males 15 yrs, females 14 yrs). About 35% had started smoking before they quit sports; another 30% started smoking and quit sports in the same year.

Daily smokers reported less physical exercise and less participation in sports competitions than never-smokers (table 4). Both males and females currently participating in team sports and sports competitions (regardless of what type of sport) were less likely to be daily smokers than those who did not. In males, daily smoking was positively associated with both current and previous participation in body-building and fight sports and with present participation in swimming. Females who had previously participated in these types of sports and lesser endurance sports were more often daily smokers than those who had not participated. Few daily-smoking females however, were participating in body-building/fight sports and swimming, (table 3).

Lung function and physical exercise

A significant difference in mean height by exercise status was seen only between the highest and lowest

Table 2. – Physical activity and present and previous participation in different sports in adolescents, aged 13–18 yrs, attending both questionnaire and spirometry in the YOUNG-HUNT study

	Age 13–15 yrs		Age 16–18 yrs		Total
	Males	Females	Males	Females	
Exercise until sweaty $\geqslant$4 days·week^{-1} (outside school)	610 (33)	424 (23)	501 (32)	325 (21)	1860 (27)
Exercise until sweaty 2–3 days·week^{-1} (outside school)	765 (42)	895 (48)	509 (33)	601 (39)	2770 (41)
Exercise until sweaty $\leqslant$1 days·week^{-1} (outside school)	444 (24)	552 (29)	530 (34)	611 (40)	2137 (31)
Join in sports competitions	979 (53)	934 (50)	634 (41)	481 (31)	3028 (45)
Participate or previously participated in sports					
Individual high endurance sports (cross-country skiing, cycling, running)	583 (32)	451 (24)	496 (32)	355 (23)	1885 (28)
Individual low endurance sports (slalom, ski jumping, horseback riding, gymnastics)	340 (19)	717 (38)	209 (14)	584 (38)	1850 (27)
Body-building and fight sports (body-building, weight lifting, wrestling, judo, karate and similar fight sports)	243 (13)	75 (4)	271 (18)	123 (8)	712 (11)
Swimming	178 (10)	188 (10)	136 (9)	148 (10)	650 (10)
Team sports (football/soccer, handball, basket ball, volley ball)	1327 (72)	1354 (72)	1113 (72)	1083 (70)	4877 (72)

Data are presented as n (%). Adolescents who reported ever having asthma were excluded. n=6811. 25 males and 19 females did not answer the question of days with exercise·week^{-1}.

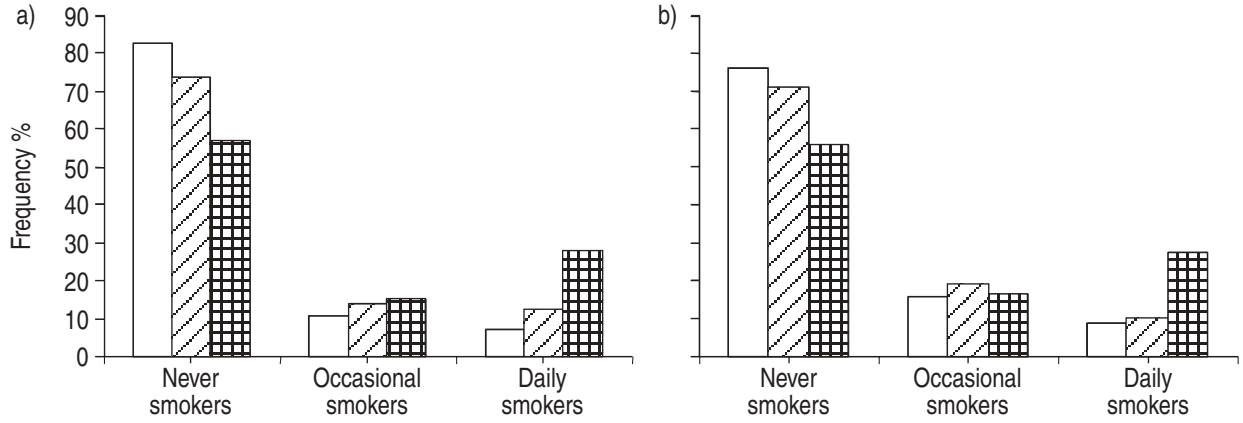

Fig. 1. – Frequency of exercise until sweaty or breathless outside school and smoking habits in adolescent a) males and b) females, aged 13–18 yrs, attending both questionnaire and spirometry in the YOUNG-HUNT study. Students who reported ever having asthma were excluded. N=6811 students. □: ⩾4 days·week^{-1}; ▨: 2–3 days·week^{-1}; ▦: 1 day·week^{-1}

level of exercise at age 13 yrs (mean difference 2.2 cm, p=0.01). Lung function was adjusted for age and height.

In never-smoking males and females there was a stepwise increase in levels of FVC and FEV1 with increasing level of exercise (fig. 2), with a statistically significant and clinical relevant mean difference between the highest and lowest level of exercise. Mean differences were for FVC: males 195 mL, p<0.001, females 122 mL, p<0.001; and for FEV1: males 154 mL, p<0.001, females 119 mL, p<0.001. The same dose-response relationship was observed in daily smokers, but this trend was not statistically significant (fig. 2). Daily-smoking males with medium level of exercise had significantly larger FEV1 compared to the lowest level of exercise. No significant associations were found between FEF50 and FEV1%FVC and frequency of exercise in never-smokers or daily smokers.

Both never-smoking males and females who participated in sports competitions (regardless of type of sport) had larger FVC, FEV1 and FEF50 compared to those who did not participate (adjusted for frequency of exercise). Mean differences in males: FVC 95 mL, p=0.01, FEV1 113 mL, p<0.001, FEF50 155 mL, p=0.03; and in females: FVC 65 mL, p=0.04, FEV1 70 mL, p=0.01, FEF50 156 mL, p=0.02. No such differences were found in daily smokers.

Lung function and different sports

Never-smoking males and females who presently participated in team sports had marginally higher FEF50 (mean difference: males 174 mL, p=0.05, females 15 mL, p=0.06) than those who did not. Females participating in team sports also had larger FEV1 (mean difference 80 mL, p=0.03) compared to non-participants. Daily-smoking males who presently participated in low-endurance sports had significantly lower FEV1 (p=0.05) and FEF50 (p=0.04) than nonparticipants. No other differences were found for other types of sports in never-smokers or daily smokers.

Table 3. – Present participation in different sports in never-, occasional- and daily-smoking adolescents, aged 13–18 yrs, attending both questionnaire and spirometry in the YOUNG-HUNT study

Type of sport	Males				Females			
	Never smokers	Occasional smokers	Daily smokers	Total	Never smokers	Occasional smokers	Daily smokers	Total
Individual high endurance sports (cross-country skiing, cycling, running)	392 (84)	44 (9)	30 (6)	466 (100)	252 (79)	50 (16)	18 (6)	320 (100)
Individual low endurance sports (slalom, ski jumping, horseback riding, gymnastics)	173 (81)	21 (10)	20 (9)	214 (100)	332 (71)	98 (21)	40 (9)	470 (100)
Body-building and fight sports (body-building, weight lifting, wrestling, judo, karate and similar fight sports)	117 (63)	37 (20)	32 (17)	186 (100)	39 (61)	17 (27)	8 (13)	64 (100)
Swimming	86 (74)	15 (13)	16 (14)	117 (100)	74 (71)	22 (21)	8 (8)	104 (100)
Team sports (football/soccer, handball, basket ball, volley ball)	758 (81)	114 (12)	68 (7)	940 (100)	704 (78)	146 (16)	56 (6)	906 (100)

Data are presented as n(%). Adolescents who reported ever having asthma were excluded. n=6,811 students.

Table 4. – Frequency of exercise and participation in different types of sports in never-smoking compared to daily-smoking adolescents attending both questionnaire and spirometry in the YOUNG-HUNT study

Exercise and sports	Males				Females			
	OR (CI)[¶]	p-value[¶]	OR (CI)[#]	p-value[#]	OR (CI)[¶]	p-value[¶]	OR (CI)[#]	p-value[#]
Exercise until breathless/sweaty 2–3 days·week^{-1}	0.4 (0.3–0.5)	<0.001			0.4 (0.3–0.5)	<0.001		
Exercise until breathless/sweaty ⩾4 days·week^{-1}	0.2 (0.1–0.3)	<0.001			0.3 (0.3–0.5)	<0.001		
Join in sports competitions	0.4 (0.3–0.8)	0.003			0.4 (0.2–0.7)	0.001		
Individual high endurance sports (cross-country skiing, cycling, running)	0.7 (0.4–1.1)	0.159	1.3 (0.8–2.0)	0.318	0.7 (0.4–1.3)	0.325	0.8 (0.5–1.3)	0.468
Individual low endurance sports (slalom, ski jumping, horseback riding, gymnastics)	1.3 (0.7–2.2)	0.404	1.4 (0.8–2.6)	0.199	1.6 (1.0–2.6)	0.065	2.0 (1.4–3.0)	<0.001
Body-building and fight sports (body-building, weight lifting, wrestling, judo, karate and similar fight sports)	3.0 (1.8–4.9)	<0.001	3.2 (1.9–5.3)	<0.001	1.4 (0.6–3.4)	0.412	3.8 (1.8–8.1)	<0.001
Swimming	1.9 (0.9–3.6)	0.038	0.7 (0.4–1.8)	0.694	1.2 (0.5–2.8)	0.625	3.0 (1.7–5.0)	<0.001
Team sports (football/soccer, handball, basket ball, volley ball)	0.5 (0.3–0.8)	0.003	1.7 (0.9–3.2)	0.132	0.5 (0.3–0.9)	0.013	0.9 (0.6–1.5)	0.725

Regression models are adjusted for age, passive smoking at home and frequency of exercise (competition and sports). Exercise 2–3 days and ⩾4 days a week are compared to exercise ⩽1 day a week. OR: Odds ratio; CI: 95% confidence intervals. Adolescents who reported ever having asthma were excluded. n=6811 students; [¶]: presently participating; [#]: formerly participating.

Never-smoking males and females who remained active in sports had better lung capacity compared to those who were no longer active. Mean difference in males: FVC: 135 mL, p<0.001, FEV1: 125 mL, p<0.001, and in females FVC: 69 mL, p=0.01, FEV1: 63 mL, p=0.01. No such difference was seen in daily smokers.

There were no important differences in the results when these analyses were repeated separately for the age groups 13–15 yrs and 16–18 yrs (data not shown).

Discussion

In this study of a large general population of adolescents, with a high participation rate and carefully supervised spirometry testing, higher levels of physical exercise were associated with less daily smoking overall. But daily smoking was more frequent in students who participated or had previously participated in some types of sports, most notably, individual sports of lesser endurance and body-building and fighting. Larger lung capacity (FVC and FEV1) independent of age and height was found in never-smokers with higher levels of physical exercise, no significant association was observed in daily smokers.

The inverse association between physical activity and current smoking is consistent with other studies [4, 5, 7, 8]. This observation, along with the finding that a much larger per cent of smokers than never-smokers had quit sports, suggests a role for promoting physical activity in smoking prevention. However, some types of sports were associated with more smoking, even after adjusting for the frequency of exercise. Daily smoking was more often associated with individual sports either demanding less endurance, or associated with less frequent participation in competitions. It is not clear whether these differences by type of sport are because smoking is perceived as less likely to impair performance or reflects peer influence, which plays an important part in adolescent smoking [4, 24, 25].

Difference in smoking habits among different types of sports has previously received little attention. If confirmed elsewhere, it suggests that type of sport should be considered when sports are recommended for smoking prevention or cessation. The importance of focusing on smoking prevention within sports organizations [26] is further supported by the observation that the age of smoking initiation either preceded or coincided with the age of quitting sports.

Whether physical exercise actually leads to better lung capacity cannot be determined in a cross-sectional study. In a prospective study, very young female competitive swimmers were found to increase their vital capacity and total lung capacity during a year of training [17], suggesting that the larger lung volumes in swimmers may be due to impact of training on lung growth. No impact of training on lung growth has been found in older swimmers or other youth [18, 19]. Being good in sports may depend on a better lung capacity, representing self-selection of adolescents who both join and continue with sports. Self-selection is a plausible explanation why never-smoking students who had discontinued sports had a lower lung capacity compared to never-smokers who were still active.

In this (data not shown) and other studies [20, 21, 27], daily smokers with a light smoke burden were found to have a larger lung capacity (FVC) than nonsmokers. If daily smokers with good lung function self-select into physical activity, this would tend to diminish the observed "effects" of exercise. This possibility is supported by the finding that, among less

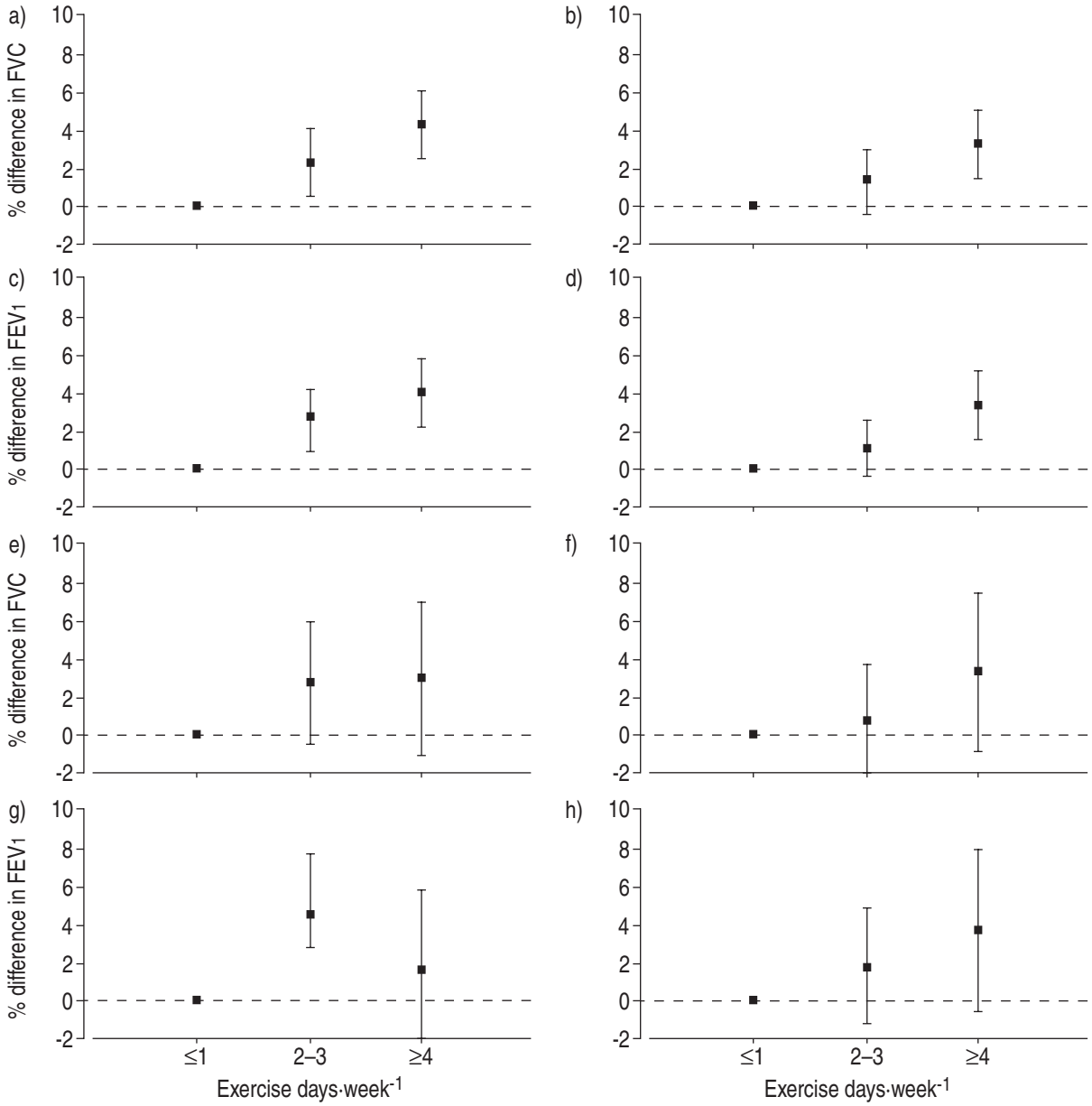

Fig. 2. – Effects of physical exercise on lung function in never-smoking and daily-smoking adolescents, aged 13–18 yrs, attending both questionnaire and spirometry in the Young-Hunt study. a, c) males, never-smokers (exercise: $\leqslant$1 day·week^{-1}, n=349; 2–3 days·week^{-1}, n=593; $\geqslant$4 days·week^{-1}, n=570); b, d) females, never-smokers (exercise: $\leqslant$1 day·week^{-1}, n=445; 2–3 days·week^{-1}, n=671; $\geqslant$4 days·week^{-1}, n=344); e, g) males, daily smokers (exercise: $\leqslant$1 day·week^{-1}, n=171; 2–3 days·week^{-1}, n=99; $\geqslant$4 days·week^{-1}, n=47); f, h) females, daily smokers (exercise: $\leqslant$1 day·week^{-1}, n=219; 2–3 days·week^{-1}, n=96; $\geqslant$4 days·week^{-1}, n=39). Students who reported ever having asthma were excluded. Per cent differences and 95% confidence intervals for differences were calculated on a logarithmic scale using those who had the lowest level of exercise ($\leqslant$1 day·week^{-1}) as a reference, and adjusting for age, height, weight, passive smoking at home, rhinitis and acute bronchitis with cough.

active students, daily smokers had a larger FVC than never-smokers, while no significant difference in lung capacity was found between daily and never-smokers who were more physically active. Few daily smokers exercised at high levels, however, and the fact that the absent significant association reflects the small number of daily-smoking athletes, cannot be excluded.

In this student population frequency of physical exercise, not type of sport, was associated with better lung capacity; this has been reported in some studies of athletes, particularly in swimmers [10, 12, 16, 17]. In the present study, swimmers did not have better lung capacity than nonswimmers, but there were few swimmers and none competed at a high level. The independent association between participation in sports competitions and larger lung function suggests that intensity of physical activity may be associated with larger lung function.

In spite of the computerized ATS error code warnings during testing, and careful assessment of the quality of the flow/volume curves by the nurses, a number of students did not meet the 1987 ATS criteria as judged by the ATS error-code messages from the Jaeger Masterscope. Because the ATS criteria in adolescents has been reported to be difficult [23–31], and excluding those not achieving ATS recommendations might exclude smokers, all students were included in the analysis. However, analyses were repeated excluding students not meeting the different Jaeger Masterscope ATS error codes with no significant differences in associations.

Rhinitis or bronchitis with cough was adjusted for in the regression analyses, as this might have had an impact on lung function, and all students who reported ever having asthma were excluded. The inclusion of adolescents reporting asthma in the analysis did not change the results (data not shown). Larger FEF_{50} and FEV_1 values in never-smoking participants in team sports may reflect less airway dysfunction (not diagnosed as asthma) in students participating in these sports.

In self-reported physical exercise there is always a question of validity. The exercise questions used were chosen because they have been extensively used to describe and compare large groups in previously published population studies in many countries, including Norway [32, 33]. The questions did not ask about seasonal exercise, but the majority of the adolescents who reported physical exercise were engaged in both winter and summer activities (data not shown). Substituting days per week with hours per week of exercise or using a combination of the two did not change the results (data not shown).

Smoking habits are also potentially subject to biased reporting. Confidentiality and consistency with other studies of adolescent smoking habits support the validity and generalizability of the results [4, 32]. The long dark winters of northern Norway may impact exercise preferences in youths, but do not appear to have impacted smoking patterns.

More frequent physical exercise was associated with less daily smoking, but daily smoking was more common in youths performing some individual sports. Smokers quit sports more often than never-smokers. A significant dose/response relationship between lung capacity (FVC and FEV_1) and levels of physical exercise was observed in never-smokers, but not in daily smokers.

These data provide indirect support for the promotion of physical activity as a smoking prevention strategy, and suggest that sports organizations should include smoking-prevention programmes. Initiation of sports programmes before the average age of smoking initiation (13 yrs in this study) could potentially yield long-term benefits in pulmonary function. Self-selection of adolescents with better lung function into sports is also suggested by these data, but causality will need to be studied prospectively.

APPENDIX: Questions and alternative answers used in this presentation from the YOUNG-HUNT study

Questions	Possible answers				
Have you ever tried smoking (at least one cigarette)?	Yes	No			
If yes, do you smoke?	Yes, I smoke _ cigarettes daily	Yes, I smoke occasionally, but not daily	No, previously I smoked daily	No, previously I smoked occasionally	No, I don't smoke
How old were you when you started smoking?	_ Age				
How many years all together have you been smoking daily?	_Number of years				
Does anyone in your home smoke?	No	Yes, mother	Yes, father	Yes, siblings	
Not during the average school day:					
How many days a week do you play sports or exercise to the point where you breath heavily and/or sweat?	Every day	4–6 days a week	2–3 days a week	1 day a week	
	At least once pr 14 days	At least once a month	Less than once a month	Never	
Not during the average school day:					
How many hours a week do you play sports or exercise to the point where you breath heavily and/or sweat?	None	About half an hour	About 1 hour	About 2–3 hours	
	About 4–6 hours	7 hours or more			
Are you actively involved in sports?	Yes	No, but I used to participate		No	
How old were you when you stopped participating?	_ Age				
Which sport(s) do/did you participate in?	Skiing (cross country)	Skiing (slalom/ski jump)	Soccer/football	Horse riding	Handball/basket/volleyball
	Fight sports/boxing	Body building	Weight lifting	Cycling	Track/field/orientation
	Swimming	Gymnastics			
Do you participate in competitive sports?	Yes	No, but I used to participate	No		

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References

1. Ellekjaer H, Holmen J, Ellekjaer E, Vatten L. Physical activity and stroke mortality in women. Ten-year follow-up of the Nord-Trondelag health survey, 1984–1986. *Stroke* 2000; 31: 14–18.
2. Sandvik L, Erikssen J, Thaulow E, Erikssen G, Mundal R, Rodahl K. Physical fitness as a predictor of mortality among healthy, middle-aged Norwegian men. *N Engl J Med* 1993; 328: 533–537.
3. Yang X, Telama R, Leino M, Viikari J. Factors explaining the physical activity of young adults: the importance of early socialization. *Scand J Med Sci Sports* 1999; 9: 120–127.
4. A report of the Surgeon General. 43. Preventing tobacco use among young peopleUS Department of Health and Human Services. Public Health Service, Center for Disease Control and Prevention, National Center for Chronic Disease Prevention and Health Promotion, Office of Smoking and Health. 1994.
5. Aarnio M, Kujala UM, Kaprio J. Associations of health-related behaviors, school type and health status to physical activity patterns in 16 year old boys and girls. *Scand J Soc Med* 1997; 25: 156–167.
6. Escobedo LG, Marcus SE, Holtzman D, Giovino GA. Sports participation, age at smoking initiation, and the risk of smoking among US high school students. *JAMA* 1993; 269: 1391–1395.
7. Rainey CJ, McKeown RE, Sargent RG, Valois RF. Patterns of tobacco and alcohol use among sedentary, exercising, nonathletic, and athletic youth. *J Sch Health* 1996; 66: 27–32.
8. Aaron DJ, Dearwater SR, Anderson R, Olsen T, Kriska AM, Laporte RE. Physical activity and the initiation of high-risk health behaviors in adolescents. *Med Sci Sports Exerc* 1995; 27: 1639–1645.
9. Escobedo LG, Reddy M, DuRant RH. Relationship between cigarette smoking and health risk and problem behaviors among US adolescents. *Arch Pediatr Adolesc Med* 1997; 151: 66–71.
10. Doherty M, Dimitriou L. Comparison of lung volume in Greek swimmers, land based athletes, and sedentary controls using allometric scaling. *Br J Sports Med* 1997; 31: 337–341.
11. MacAuley D, McCrum E, Evans A, Stott G, Boreham C, Trinick T. Physical activity, physical fitness and respiratory function-exercise and respiratory function. *Ir J Med Sci* 1999; 168: 119–123.
12. Mehrotra PK, Varma N, Tiwari S, Kumar P. Pulmonary functions in Indian sportsmen playing different sports. *Indian J Physiol Pharmacol* 1998; 42: 412–416.
13. Twisk JW, Staal BJ, Brinkman MN, Kemper HC, van Mechelen W. Tracking of lung function parameters and the longitudinal relationship with lifestyle. *Eur Respir J* 1998; 12: 627–634.
14. Biersteker MW, Biersteker PA. Vital capacity in trained and untrained healthy young adults in the Netherlands. *Eur J Appl Physiol* 1985; 54: 46–53.
15. De AK, Tripathi MM. Smoking and lung functions in sportsmen. *Br J Sports Med* 1988; 22: 61–63.
16. Courteix D, Obert P, Lecoq AM, Guenon P, Koch G. Effect of intensive swimming training on lung volumes, airway resistance and on the maximal expiratory flow-volume relationship in prepubertal girls. *Eur J Appl Physiol* 1997; 76: 264–269.
17. Zinman R, Gaultier C. Maximal static pressures and lung volumes in young female swimmers: one year follow-up. *Pediatr Pulmonol* 1987; 3: 145–148.
18. Engstrom I, Eriksson BO, Karlberg P, Saltin B, Thoren C. Preliminary report on the development of lung volumes in young girl swimmers. *Acta Paediatr Scand Suppl* 1971; 217: 73–76.
19. Lakhera SC, Kain TC, Bandopadhyay P. Changes in lung function during adolescence in athletes and non-athletes. *J Sports Med Phys Fitness* 1994; 34: 258–262.
20. Gold DR, Wang X, Wypij D, Speizer FE, Ware JH, Dockery DW. Effects of cigarette smoking on lung function in adolescent boys and girls. *N Engl J Med* 1996; 335: 931–937.
21. Tager IB, Munoz A, Rosner B, Weiss ST, Carey V, Speizer FE. Effect of cigarette smoking on the pulmonary function of children and adolescents. *Am Rev Respir Dis* 1985; 131: 752–759.
22. A WHO Cross-National Survey (HBSC). Health Behaviour in School-Aged Children. Research protocol for the 1993–94 study HEMIL-Report. Bergen, University of Bergen, Research Center for Health Promotion. 1994.
23. Statement of the American Thoracic Society. Standardization of spirometry-1987 update. *Am Rev Respir Dis* 1987; 136: 1285–1298.
24. Jackson C. Initial and experimental stages of tobacco and alcohol use during late childhood: relation to peer, parent, and personal risk factors. *Addict Behav* 1997; 22: 685–698.
25. Williams JG, Covington CJ. Predictors of cigarette smoking among adolescents. *Psychol Rep* 1997; 80: 481–482.
26. Epps RP, Lynn WR, Manley MW. Tobacco, youth, and sports. *Adolesc Med* 1998; 9: 483–490.
27. Tashkin DP, Clark VA, Coulson AH, *et al.* Comparison of lung function in young nonsmokers and smokers before and after initiation of the smoking habit. A prospective study. *Am Rev Respir Dis* 1983; 128: 12–16.
28. American Thoracic Society. Standardization of Spirometry, 1994 Update. *Am J Respir Crit Care Med* 1995; 152: 1107–1136.
29. Hankinson JL, Bang KM. Acceptability and reproducibility criteria of the American Thoracic Society as observed in a sample of the general population. *Am Rev Respir Dis* 1991; 143: 516–521.
30. Ng′Ang′a LW, Ernst P, Jaakkola MS, Gerardi G, Hanley JH, Becklake MR. Spirometric lung function. Distribution and determinants of test failure in a young adult population. *Am Rev Respir Dis* 1992; 145: 48–52.
31. Desmond KJ, Allen PD, Demizio DL, Kovesi T. Redefining End of Test (EOT) Criteria for Pulmonary Function Testing in Children. *Am J Respir Crit Care Med* 1997; 156: 542–545.
32. King A, Wold B, Tudor-Smith C, Harel Y. The health of youth. A cross-national survey. *WHO Reg Publ Eur Ser* 1996; 69: 1–222.
33. Nystad W. The physical activity level in children with asthma based on a survey among 7–16-year-old school children. *Scand J Med Sci Sports* 1997; 7: 331–335.