Long term effects of smoking on physical fitness and lung function: a longitudinal study of 1393 middle aged Norwegian men for seven years

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Abstract

Objective—To study association between smoking habits and long term decline in physical fitness and lung function in middle aged men who remained healthy.

Design—Baseline and follow up measurements performed during 1972–5 and 1980–2 respectively.

Setting—National University Hospital of Oslo, Norway.

Subjects—1393 men aged 40–59 at baseline who were all healthy at baseline and at follow up.

Main outcome measures—Forced expiratory volume in one second and physical fitness (defined as total work done during a symptom limited bicycle ergometer test divided by body weight).

Results—Initial fitness was substantially lower among 347 persistent smokers than among 791 persistent non-smokers (1349 J/kg v 1618 J/kg), as was initial forced expiratory volume (3341 ml v 3638 ml). Mean (95% confidence interval) decline in fitness over 7.2 years was 217 (185 to 249) J/kg among smokers compared with 86 (59 to 113) J/kg among non-smokers ($P < 0.001$). Corresponding declines in forced expiratory volume were 271 (226 to 316) ml in smokers and 116 (85 to 147) ml in non-smokers ($P < 0.001$). Differences between smokers and non-smokers remained practically unchanged after adjustment for age and level of physical activity. Changes in fitness and forced expiratory volume among 199 men who had stopped smoking mimicked the findings for persistent non-smokers, and 56 men who started smoking presented findings close to those of persistent smokers.

Conclusion—Decline in physical fitness and lung function among healthy middle aged men was considerably greater among smokers than among non-smokers and could not be explained by differences in age and physical activity.

Introduction

Physical performance is an important predictor of mortality from cardiovascular causes and from all causes in men^{1–3} and is mainly determined by the combined function of the cardiovascular and respiratory systems. Extensive data show that smoking considerably accelerates the sequential decline in lung function,⁴ but little is known about the long term effect

of smoking on physical performance. Thus, whereas cross sectional data indicate lower physical performance and response to training in smokers than in non-smokers,^{5–12} no study has to our knowledge reported prospective long term data on change in physical performance in relation to smoking habits.

The present study investigated the association between smoking habits and seven years' change in physical fitness and forced respiratory volume in one second in middle aged men who remained healthy.

Subjects and methods

All apparently healthy men aged 40–59 who were employed in five companies in Oslo, Norway, were invited to participate in a survey that entailed a cardiovascular examination (August 1972 to March 1975). "Apparently healthy" implied absence of any known or suspected heart diseases, diabetes, cancer, hypertension treated with drugs, and miscellaneous diseases described in detail elsewhere.¹³ Of 2341 eligible men, 2014 (882 smokers and 1132 non-smokers), accepted the invitation. An average of 7.2 years later (January 1980 to December 1982), 1757 of the 1933 men who were still alive by 31 December 1982 participated in an identical re-examination. Of these 1757 men, 364 were excluded because they had started treatment with antihypertensive drugs, developed symptoms or signs of coronary heart disease, had a stroke, developed diabetes, developed cancer, or were unable to conduct the second exercise test. This left 1393 men who were healthy according to the initial inclusion criteria and were eligible for the present study. Of the 176 men (1933–1757) who did not respond, 47 (29 smokers, 18 non-smokers) were severely diseased, 47 (24 smokers, 23 non-smokers) found their travelling distance too long, and 82 (51 smokers, 31 non-smokers) did not answer two mailing requests (later data indicated that most of these were diseased at the time of the second survey).

Examination

All examinations took place in the morning at the National University Hospital of Oslo (Rikshospitalet), and the subjects had fasted for 12 hours and had not smoked for at least eight hours beforehand. None was taking drugs, and none had intercurrent illnesses when examined. Table I shows the components of the examination. Detailed data on smoking and physical activity were obtained during interviews. The men were grouped as smokers or non-smokers—baseline non-smokers were labelled as such regardless of previous smoking habits. Men were labelled as physically active if they exercised for at least 30 minutes twice weekly to the level of breath shortness and sweating.¹ Combining baseline and follow up smoking data allowed subclassification of subjects as persistent non-smokers ($n=791$), persistent smokers ($n=347$), baseline smokers who had quit ($n=199$), and baseline non-smokers who had started ($n=56$).

The exercise test was conducted on an electrically braked Elema bicycle as described previously and was

TABLE I—Components of physical examination

1	Detailed case history, including questionnaire on physical activity and interview about physical activity during leisure hours
2	Complete clinical examination
3	Measurements of height and weight
4	Spirographic measurements (peak expiratory flow, forced expiratory volume in one second, and vital capacity)*
5	Series of blood tests (including a lipid profile)
6	X ray examination of heart and lungs
7	Resting electrocardiogram
8	Electrocardiogram during symptom limited exercise test on electrically braked Elema bicycle ergometer

*The highest value of two measurements (performed after careful instruction and one trial attempt).

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TABLE II—Mean (SD) values for some clinical, laboratory, and physiological variables at baseline and follow up by smoking habits among 1393 healthy middle aged men

	Unchanged smoking habits		Changed smoking habits	
	Non smokers (n=791)	Smokers (n=347)	Stopped smoking (n=199)	Started smoking (n=56)
Age (years):				
Baseline	49.1 (5.5)	49.4 (5.1)	49.4 (5.3)	49.1 (5.2)
Follow up	56.3 (5.5)	56.5 (5.0)	57.0 (5.3)	56.3 (5.3)
Body weight (kg):				
Baseline	76.8 (9.2)	75.6 (9.8)*	75.8 (9.3)	77.5 (9.2)
Follow up	77.4 (9.1)	75.8 (9.8)*	78.4 (9.4)	76.5 (9.1)
Body height (cm):				
Baseline	177.0 (6.3)	176.6 (6.0)	176.9 (5.8)	178.0 (5.8)
Follow up	176.8 (6.3)	176.4 (5.9)	176.7 (5.8)	177.8 (5.8)
Body mass index:				
Baseline	24.5 (2.8)	24.2 (2.7)	24.2 (2.7)	24.4 (2.5)
Follow up	24.7 (2.8)	24.3 (2.7)*	25.1 (2.8)	24.2 (2.5)
Blood pressure (mm Hg):				
Resting systolic:				
Baseline	129 (17)	125 (16)**	125 (17)	125 (16)
Follow up	131 (18)*	128 (16)*	133 (18)	127 (16)
Resting diastolic:				
Baseline	87 (10)	84 (10)**	84 (9)	84 (10)
Follow up*	88 (10)	86 (10)*	89 (10)	84 (10)
Maximal systolic:				
Baseline	215 (21)	211 (22)*	214 (21)	217 (20)
Follow up	216 (21)	215 (23)	220 (22)	213 (20)
Heart rate (beats/min):				
Resting:				
Baseline	62 (10)	59 (8)**	60 (9)	60 (9)
Follow up	63 (10)	62 (9)	63 (10)	62 (10)
Maximal:				
Baseline	167 (12)	160 (14)***	163 (13)	166 (13)
Follow up	161 (11)	152 (13)***	158 (13)	158 (12)
Serum lipid concentration (mmol/l):				
Cholesterol				
Baseline	6.6 (1.2)	6.7 (1.2)*	6.7 (1.2)	6.6 (1.2)
Follow up	6.4 (1.1)	6.6 (1.2)**	6.5 (1.1)	6.4 (1.2)
Triglycerides				
Baseline	1.22 (0.71)	1.35 (0.72)	1.30 (0.67)	1.22 (0.71)
Follow up	1.37 (0.81)	1.55 (0.74)***	1.49 (0.70)	1.29 (0.72)**

*P<0.05, **P<0.01, ***P<0.001 compared with persistent non-smokers.

TABLE III—Total work performed, duration of exercise test, and maximal work load of healthy middle aged men by smoking habit. Values are means (SD) unless stated otherwise

	Unchanged smoking habits		Changed smoking habits	
	Non-smokers (n=791)	Smokers (n=347)	Stopped smoking (n=199)	Started smoking (n=56)
Total work done (kJ)†:				
Baseline	124 (50)	102 (34)***	112 (43)	122 (41)
Follow up	118 (51)	86 (36)***	102 (47)	105 (42)
Difference	6 (29)	16 (23)***	10 (24)	17 (27)
95% Confidence interval of difference	4 to 8	13 to 19	7 to 13	10 to 24
Duration of exercise test (minutes):				
Baseline	14.8 (4.0)	12.9 (3.1)***	13.8 (3.7)	14.7 (3.4)
Follow up	14.1 (4.0)	11.3 (3.6)***	12.7 (4.0)	13.2 (3.7)
Difference	0.7 (2.5)	1.6 (2.3)***	1.1 (2.3)	1.5 (2.3)
95% Confidence interval of difference	0.5 to 0.9	1.4 to 1.8	0.8 to 1.4	0.9 to 2.1
Maximal working capacity (watts)‡:				
Baseline	186 (35)	174 (28)***	180 (31)	189 (27)
Follow up	190 (37)	166 (31)***	179 (36)	181 (32)
Difference	-4 (27)***	8 (26)	1 (25)	8 (24)
95% Confidence interval of difference	-6 to -2	5 to 11	-3 to 5	2 to 14

***P<0.001 compared with persistent non-smokers.

†Sum of all work performed at all exercise levels.

‡Maximal load tolerated for at least one minute.

continued until exhaustion if it was not stopped earlier for specified safety reasons.¹ The starting load was 5.87 kJ/min and the load was increased by 2.94 kJ/min at intervals of six minutes. Physical fitness was defined as working capacity divided by body weight, with working capacity defined as the cumulated work performed during the symptom limited exercise test. Forced expiratory volume in one second was measured with a Bernstein spirometer.¹⁴

STATISTICAL METHODS

Possible group differences were tested with two sided *t* tests at a 5% significance level. Multivariate regression analysis was applied for studying simultaneously the influence of several factors on change in physical fitness and forced expiratory volume in one second.

Results

Table II shows the values of clinical, laboratory, and physiological parameters for the groups of subjects at baseline and follow up. Body weight, systolic blood pressure, maximal heart rate during exercise, and serum triglyceride concentration showed small but significant and systematic differences between groups and sequential changes. Other differences were minor and not significant. All differences between smokers and non-smokers were graded according to the number of cigarettes smoked (detailed data not shown).¹⁴

FITNESS

Table III shows the results of the exercise tests, and table IV shows that baseline fitness was significantly higher among non-smokers than among smokers ($P<0.001$) and that the seven year drop in fitness was significantly lower in non-smokers (9% *v* 22%, $P<0.001$). This second difference was greater in the men aged 40-49 than in those aged 50-59.

For the 1138 men with unchanged smoking habits, multivariate regression analysis was used to test possible influence of age, smoking, level of physical activity and initial fitness on the seven year change in fitness. The analysis showed that high initial fitness and high age were associated with a high reduction in fitness ($P<0.001$) and that high physical activity was associated with a low reduction in fitness ($P=0.039$). When these three confounders had been accounted for, the seven year reduction in fitness was 13.6% higher among smokers than among non-smokers ($P<0.001$).

FORCED EXPIRATORY VOLUME

Table V shows that data for forced expiratory volume in one second showed a similar pattern in relation to smoking habits as physical fitness; that is, non-smokers had higher baseline values and a lower seven year decline.

Multivariate regression analysis of forced expiratory volume in men with unchanged smoking habits showed that high initial expiratory volume and high age were associated with a high reduction in expiratory volume ($P<0.001$) but physical activity was not associated with change in volume. When the two confounding factors were adjusted for, the seven year reduction in forced expiratory volume was 6.0% higher among smokers than among non-smokers ($P<0.001$).

Discussion

In the study non-smokers had substantially higher values for physical fitness and forced expiratory volume in one second at baseline than smokers, and these differences had increased at follow up seven years later. By addressing the effect of smoking on lung function and physical fitness only in men who remained healthy, this study grossly underestimates the negative health consequences of smoking. In fact, as we reported previously,¹ we found the same increased mortality and morbidity among smokers that has been reported generally.^{4,15} For example, smoking doubled the risk of dying from both cardiovascular and non-cardiovascular diseases,¹ and non-responders who were diseased were mostly smokers. The results of our present study, however, should be relevant for middle aged men who are generally healthy. In addition the 199 men who stopped smoking during the study and the 56 who started smoking offer a limited opportunity of assessing possible effects of changing smoking habits late in life.

Our data on physical fitness and lung function in relation to smoking are unlikely to be biased because other studies corroborate the smoking related differences we found for other physiological parameters—

for example, blood pressure,¹⁶ body weight,^{4,15} maximal heart rate response to exercise,^{12,16} and serum triglyceride concentration.^{17,18} Our spirographic results also agree with reports of more pronounced long term decline in forced expiratory volume in one second in smokers than in non-smokers.^{4,19,20} Moreover, we found that results for men who started smoking during the study mimicked those of persistent smokers while results for men who stopped smoking mimicked those for persistent non-smokers, suggesting that the smoking associated changes in the bronchi^{4,15,19,20} are at least partly reversible even in smokers aged 40-59.

PHYSICAL FITNESS

Various studies—none of which provide follow up data—have indicated a lower physical performance in smokers than in non-smokers.⁵⁻¹² One major cross sectional study, which addressed this aspect by means of symptom limited exercise testing,¹² produced results virtually identical to our baseline findings—that is, smoking being associated with lower heart rate response on all exercise levels, lower maximal heart rate, and lower maximal working capacity. By extrapolating from similar findings of submaximal heart rate (using the Åstrand-Ryhming nomogram²¹), one research group erroneously concluded that smokers seemed more fit than non-smokers.²² Our results show that healthy smokers showed a substantially larger

TABLE IV—Physical fitness (J/kg) of healthy middle aged men by smoking habit. Values are means (SD) unless stated otherwise

	Unchanged smoking habits		Changed smoking habits	
	Non-smokers	Smokers	Stopped smoking	Started smoking
All subjects:				
No of men	791	347	199	56
Baseline fitness	1618 (630)	1349 (413)***	1477 (520)	1565 (457)
Follow up fitness	1532 (639)	1132 (439)***	1307 (593)	1362 (471)
Difference	86 (384)	217 (307)***	170 (338)	203 (338)
95% Confidence interval of difference	59 to 113	185 to 249	123 to 217	114 to 292
Men aged 40-49 at baseline:				
No of men	437	182	95	32
Baseline fitness	1808 (653)	1488 (392)***	1645 (567)	1613 (391)
Follow up fitness	1761 (659)	1280 (430)***	1546 (654)	1473 (487)
Difference	47 (411)	208 (332)***	99 (355)	139 (351)
95% Confidence interval of difference	8 to 86	160 to 256	28 to 170	17 to 261
Men aged 50-59 at baseline:				
No of men	354	165	104	24
Baseline fitness	1384 (513)	1195 (380)***	1324 (423)	1501 (535)
Follow up fitness	1250 (483)	968 (389)***	1088 (430)	1214 (412)
Difference	134 (341)	227 (277)***	236 (308)	287 (307)
95% Confidence interval of difference	98 to 170	185 to 269	177 to 295	164 to 410

***P < 0.001 compared with persistent non-smokers.

TABLE V—Forced expiratory volume (ml) in one second of middle aged men by smoking habit. Values are means (SD) unless stated otherwise

	Unchanged smoking habits		Changed smoking habits	
	Non-smokers	Smokers	Stopped smoking	Started smoking
All subjects:				
No of men	781	344	198	56
Baseline volume	3638 (685)	3341 (698)***	3350 (733)	3571 (638)
Follow up volume	3522 (704)	3070 (738)***	3204 (791)	3325 (663)
Difference	116 (439)	271 (423)***	146 (426)	245 (553)
95% Confidence interval of difference	85 to 147	226 to 316	87 to 205	100 to 390
Men aged 40-49 at baseline:				
No of men	433	182	94	32
Baseline volume	3830 (679)	3579 (696)***	3537 (734)	3548 (645)
Follow up volume	3751 (690)	3354 (687)***	3458 (789)	3521 (638)
Difference	79 (449)	225 (409)***	78 (469)	127 (674)
95% Confidence interval of difference	37 to 121	166 to 284	-17 to 173	-107 to 361
Men aged 50-59 at baseline:				
No of men	348	162	104	24
Baseline volume	3401 (615)	3074 (599)***	3182 (695)	3467 (626)
Follow up volume	3238 (613)	2752 (660)***	2974 (724)	3064 (615)
Difference	162 (423)	322 (433)***	208 (375)	403 (269)
95% Confidence interval of difference	118 to 206	255 to 389	136 to 280	295 to 511

***P < 0.001 compared with persistent non-smokers.

Key messages

- Physical performance is an important predictor of mortality in men and is mainly determined by combined function of cardiovascular and respiratory systems
- There is much evidence that smoking accelerates decline in lung function, but little is known about its long term effects on physical fitness
- We studied changes in physical fitness and lung function in 1393 middle aged men who were healthy at the start of the study and at follow up seven years later
- Initial physical fitness was substantially lower in persistent smokers than in persistent non-smokers, and decline in fitness over time was considerably greater in smokers
- Smokers and non-smokers showed similar differences in lung function, but these differences cannot fully explain the effect of smoking on fitness

decline in physical performance than non-smokers. Men who started smoking seemed to mimic persistent smokers whereas, with due caution for small numbers, men who stopped smoking seemed to show slightly differing patterns depending on their age: those aged 40-49 seemed to benefit from stopping smoking while those aged 50-59 did so only marginally if at all.

Although our spirographic results agree with other reports of the negative effects of smoking,^{4,15,19,20} these observed differences in lung function alone can hardly explain the differences in fitness. Thus cardiovascular factors seem to be the main limiting factors in maximal exercise in healthy subjects, although respiratory muscle fatigue may be the limiting factor to endurance exercise even in athletes.²³ The explanation for our results from the exercise tests is therefore uncertain. One possible explanation might be that binding of carbon monoxide and cyanide to haemoglobin and cytochrome inhibited oxygen delivery and metabolism in smokers. We have no data to support this notion, but the half lives of bound carbon monoxide and cyanide are sufficiently long that the eight hours' abstinence from smoking that preceded exercise testing would not have eliminated this possible effect even if all the smokers had abstained from smoking. Conceivably, smoking associated impairment of pulmonary oxygen exchange may also in part explain lower maximum oxygen consumption in smokers than in non-smokers.^{4,16,24} Alternative but speculative explanations are down regulation of adrenergic receptors among smokers²⁵ and long term cardiac damage caused by stimulation of catecholamine by lifelong smoking.²⁶⁻³⁰ Such hypotheses could be tested in populations with a low prevalence of coronary heart disease and a high prevalence of smoking.

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Social cost of land mines in four countries: Afghanistan, Bosnia, Cambodia, and Mozambique

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Abstract

Objectives—To document the effects of land mines on the health and social conditions of communities in four affected countries.

Design—A cross design of cluster survey and rapid appraisal methods including a household questionnaire and qualitative data from key informants, institutional reviews, and focus groups of survivors of landmines from the same communities.

Setting—206 communities, 37 in Afghanistan, 66 in Bosnia, 38 in Cambodia, and 65 in Mozambique.

Subjects—174 489 people living in 32 904 households in the selected communities.

Main outcome measures—Effects of land mines on food security, residence, livestock, and land use; risk factors: extent of individual land mine injuries; physical, psychological, social, and economic costs of injuries during medical care and rehabilitation.

Results—Between 25% and 87% of households had daily activities affected by land mines. Based on expected production without the mines, agricultural production could increase by 88-200% in different regions of Afghanistan, 11% in Bosnia, 135% in Cambodia, and 3-6% in Mozambique. A total of 54 554 animals was lost because of land mines, with a minimum cash value of \$6.5m, or nearly \$200 per household. Overall, 6% of households (1964) reported a land mine victim; a third of victims died in the blast. One in 10 of the victims was a child. The most frequent activities associated with land mine incidents were agricultural or pastoral, except in Bosnia where more than half resulted from military activities, usually during patrols. Incidences have more than doubled between 1980-3 and 1990-3, excluding the incidents in Bosnia. Some 22% of victims (455/2100) were from households reporting attempts to remove land mines; in these households there was a greatly increased risk of injury (odds ratio 4.2 and risk difference 19% across the four countries). Lethality of the mines varied; in Bosnia each blast killed an average of 0.54 people and injured 1.4, whereas in Mozambique each blast

killed 1.45 people and wounded 1.27. Households with a land mine victim were 40% more likely to experience difficulty in providing food for the family. Family relationships were affected for around one in every four victims and relationships with colleagues in 40%.

Conclusions—Land mines seriously undermine the economy and food security in affected countries; they kill and maim civilians at an increasing rate. The expense of medical care and rehabilitation add economic disability to the physical burden. Awareness of land mines can be targeted at high risk attitudes, such as those associated with tampering with mines.

Introduction

The problems of land mines left after armed conflicts have been increasingly publicised in recent years and are now recognised as reaching crisis proportions in many countries.^{1,2} At the United Nations' conference in Geneva in July the Secretary General, Dr Boutros-Boutros Ghali, called for a total ban on the manufacture, trade, and use of land mines, akin to the ban on chemical warfare.

Immediate action is required to reduce the risks of existing land mines. Programmes to remove the devices, to increase the awareness of communities, and to rehabilitate the victims are running in Afghanistan, Bosnia, Cambodia, and Mozambique. But they are hampered by lack of resources and, sometimes, lack of knowledge of how best to focus efforts to tackle this plague.

It may cost as little as \$3 to produce a land mine.³ It costs \$300-\$1000 to remove one.⁴ Reliable international figures do not exist, but the Red Cross estimates that land mines kill about 800 people and injure thousands each month.⁵ Victims of land mine blasts often require extensive and prolonged medical care and rehabilitation, which is not usually available from already poorly funded and overstretched health services.⁶ Most data on land mine incidents come from

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