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ORIGINAL ARTICLE

Cross-sectional study on the relationship between body mass index and smoking, and longitudinal changes in body mass index in relation to change in smoking status: The Tromsø Study

M. SNEVE[1] & R. JORDE[1,2]

[1]*Medical Department B, University Hospital of North Norway, Tromsø, Norway, and* [2]*Institute of Clinical Medicine, University of Tromsø, Tromsø, Norway*

Abstract

Aims: To evaluate the effects of smoking and other lifestyle factors on body mass index (BMI), and changes in BMI in relation to changes in smoking status. *Methods:* A cross-sectional study was performed on 10,920 males (3937 smokers) and 12,090 females (4343 smokers) who participated in the fourth Tromsø Study (performed in 1994–95). A longitudinal study was performed on 2364 males (732 smokers in 1994–95) and 2738 females (942 smokers in 1994–95) who participated in both the fourth and the fifth Tromsø studies (performed in 2001). *Results:* In the cross-sectional study, current smokers of both genders had a lower BMI (25.0 ± 3.4 vs. 25.5 ± 3.2 kg/m^2 in males, and 23.9 ± 3.9 vs. 25.3 ± 4.6 kg/m^2 in females, $p < 0.01$), a lower degree of physical activity, and a higher consumption of coffee and alcohol than never-smokers. We found a U-shaped relationship between number of cigarettes smoked per day and BMI, with the lowest BMI in those smoking 6–10 cigarettes per day. Heavy smokers and never-smokers had similar BMI. In the longitudinal study, continuing smokers had a smaller increase in BMI than those who gave up smoking. In those who gave up smoking, there was a significant, positive relationship between number of cigarettes smoked in 1994–95 and increase in BMI. ***Conclusions:*** **There is a U-shaped relationship between number of cigarettes smoked per day and BMI. Smoking cessation is associated with an increase in weight as compared to those who continue smoking.**

Key Words: *Alcohol, body mass index, cigarette smoking, coffee, obesity, physical activity*

Background

In the Western world there is an epidemic of obesity, and worldwide more than 1.6 billion adults are overweight and at least 400 million are obese according to World Health Organization criteria [1]. The cause is multifactorial, with changes in dietary habits and more sedentary lifestyles being the most important contributors. Body weight is also affected by smoking, and most [2–6], but not all [7], studies show that smokers are leaner than non-smokers. Furthermore, smokers appear to gain weight after smoking cessation [2,3,8], which for some is an argument for not quitting smoking [9].

If the effect on weight was due to a direct effect of smoking on food intake, metabolism and/or physical activity, one would expect to find the lowest body weight among those smoking the highest number of cigarettes daily. However, in some studies, a U-shaped relationship between smoking and body weight has been reported [10–13], and if this is true, it should be taken into consideration when relating smoking and body weight.

The Tromsø Study is a prospective follow-up study of entire birth cohorts and random samples in the municipality of Tromsø in northern Norway, with cardiovascular diseases and risk factors as the main focus [14]. The fourth Tromsø Study was conducted in 1994–95 (for simplicity, 1994 in the following) and the fifth in 2001. Body mass index (BMI) was measured, and a questionnaire on lifestyle factors, including smoking habits, was filled in. A large

Correspondence: Monica Sneve, Medical Department B, University Hospital of North Norway, PO Box 101, 9038 Tromsø, Norway. Tel: + 47 776 26000. Fax: + 47 776 26863. E-mail: monica.sneve@unn.no

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database was therefore available for evaluating relationships between smoking habits and BMI.

Aims

We wanted to evaluate the effects of smoking and other lifestyle factors on BMI, and to explore the effects on BMI of change in smoking status between the fourth and the fifth Tromsø studies.

Material and methods

Subjects

In the fourth Tromsø Study in 1994, all men and women born earlier than 1970 and, according to the population registry, living in the municipality of Tromsø were invited by letter to participate. In addition, all subjects aged 55–74 years and 5–10% random samples in the 25–54-year and 75–85-year age groups were invited to return for a second phase of the study, with comprehensive examinations including carotid ultrasound, echocardiography, and bone densitometry [15]. One reminder was sent to those who did not respond to the first invitation. In total, 35,443 subjects were invited and 27,158 attended, and complete data sets regarding the variables included in the present study were available for 23,010 subjects (Figure 1).

In the fifth Tromsø Study in 2001, all men and women older than 29 years, living in the municipality of Tromsø, and who had participated in the

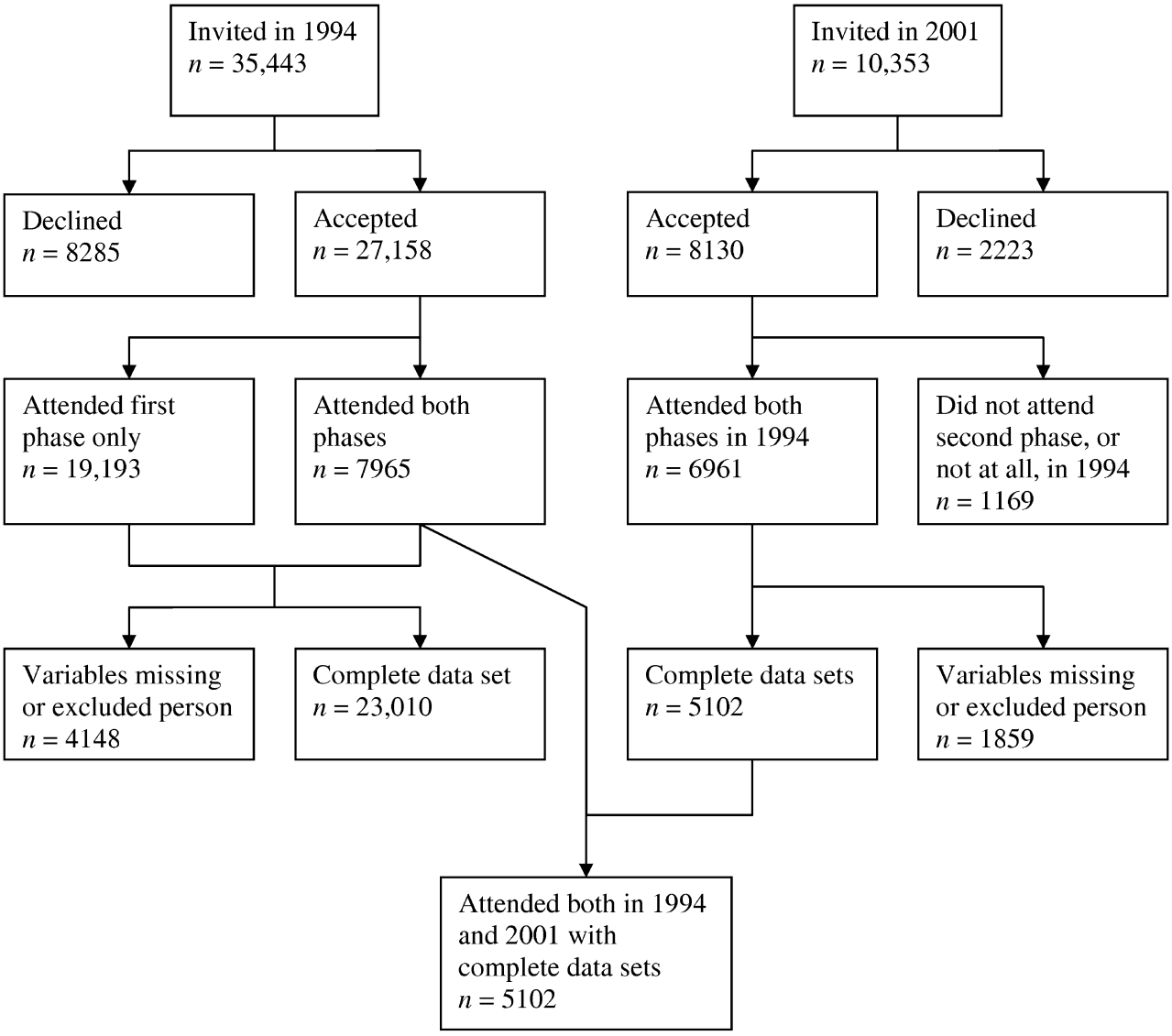

Figure 1. Flow chart of the study population in the fourth Tromsø Study in 1994 and the fifth Tromsø Study in 2001.

second phase of the fourth Tromsø Study in 1994, or who had reached 30, 40, 45, 60 or 70 years of age during 2001, were invited to participate. Thus, 10,353 persons were invited, of whom 8130 attended. Complete data sets were available for 5102 subjects who had participated in both the fourth (1994) and the fifth (2001) Tromsø studies (Figure 1).

All subjects filled in a questionnaire regarding health, smoking status, physical activity in spare time, and alcohol and coffee consumption [16]. The questions regarding smoking were: "Do you smoke cigarettes daily?"; "Do you smoke cigars/cigarillos daily?"; "Do you smoke a pipe daily?"; "If you smoked previously, how many years is it since you quitted?"; and "How many cigarettes do you or did you smoke daily?"

The Regional Ethics Committee approved the studies, and all participants gave written informed consent.

Variables

We classified the subjects in the cross-sectional study as current smokers, ex-smokers or non-smokers of cigarettes. In the longitudinal study, the subjects were classified as current smokers or current non-smokers. Those who were smokers in 1994 (according to the questionnaire in 1994) but not in 2001 were classified as "quitted smoking", and those who did not smoke in 1994 but were smoking in 2001 were classified as "started smoking". Those smoking cigars, cigarillos or a pipe only, or in addition to cigarettes, were excluded, as there were no questions regarding number of cigars, cigarillos or pipes smoked per day. A distinction between ordinary cigarettes and hand-rolled cigarettes was not made.

The physical activity score was calculated as the sum of hours of light and heavy physical activity in spare time per week, with heavy physical activity given double weight. Coffee consumption was calculated as the sum of cups of all types of coffee (boiled, filtered or other type) drunk per day. Alcohol consumption was calculated as the number of glasses of alcohol (adding glasses of spirits, beer and wine) consumed in 2 weeks, assuming an equal amount of alcohol in each glass. Thus, one glass of spirits (40 ml), one glass of beer (330 ml) or one glass of red wine (120 ml) is equivalent to 13 g of alcohol.

Height and weight were measured with the subject wearing light clothing and no shoes. BMI was defined as weight (kg) divided by height squared (m^2).

Statistical analyses

The normal distribution was evaluated by visual inspection of histograms with normal curves, normality plots (Q–Q plots), and determination of skewness and kurtosis. BMI and change in BMI (see below) were considered to be normally distributed, whereas the other variables were not, and nor did they assume a normal distribution after log transformation.

An initial regression analysis with a general linear model with BMI as the dependent variable and smoking status (current smoker and current non-smoker) and gender as factors, and age, physical activity score and coffee and alcohol consumption as independent variables, revealed a significant interaction ($p < 0.01$) between smoking status and gender. Where appropriate, the analyses are therefore done separately for each gender and for smokers/non-smokers.

When comparing current smokers, ex-smokers and never-smokers regarding BMI, we used a general linear model with variables similar to those used in the initial regression analysis. Linear trends across subgroups for BMI were evaluated with a similar regression model. For variables without a normal distribution, we used the Kruskal–Wallis test for k independent samples, and the Mann–Whitney test as post-hoc test. When comparing more than two groups, we always chose a reference group.

For evaluation of individual predictors of BMI in the cross-sectional data, we used a linear regression model with age, number of cigarettes smoked daily, physical activity score, coffee consumption and alcohol consumption as potential predictors. The appropriateness of the model was verified by plotting the residuals against each variable and inspecting the plot for even distribution throughout the variable range. Correlations between BMI and the predictor variables were evaluated by Spearman's rho (ρ).

In the analyses of the longitudinal data, change in variables was calculated as the value in 2001 minus the value in 1994.

When multiple comparisons were performed, a Bonferroni correction was used. Unless otherwise stated, all data are given as mean $\pm$ standard deviation. A p-value < 0.05 was considered to be statistically significant. The Statistical Package for Social Sciences (SPSS 13.0) was used for all analyses (SPSS Inc., Chicago, IL, USA).

Results

Cross-sectional data from the fourth Tromsø Study

The characteristics of the participants are shown in Table I. In both genders, current smokers had lower BMI, lower degrees of physical activity and higher consumption of coffee and alcohol than both ex-smokers and never-smokers. Among the males, ex-smokers had significantly higher BMI than

Table I. Characteristics of the subjects in the fourth Tromsø Study in 1994 in relation to smoking status and number of cigarettes smoked per day.

		Smoking status			Number of cigarettes smoked per day (current smokers)			
		Current smoker	Ex-smoker	Never smoker	1–5	6–10	11–20	>20
Males	*N*	3937	3600	3383	411	1215	1985	326
	Age (years)	45.5±13.3[a]	53.6±14.8[b]	41.9±12.7[c]	49.1±16.4[a]	45.9±14.5[d]	44.3±12.0[d]	46.4±10.3
	Body mass index (kg/m^2)	25.0±3.4[a,e]	26.3±3.3[b,f]	25.5±3.2[c,g]	24.9±3.3[a]	24.6±3.2	25.2±3.5	25.9±3.3[d,h]
	Number of cigarettes smoked daily	13.7±6.9	0	0	4.1±1.2	8.9±1.4	16.1±3.1	28.5±6.9
	Physical activity score	3.8±3.4[a]	4.1±3.4[b]	4.7±3.6[c]	4.0±3.3[a]	3.8±3.3	3.8±3.4	2.7±3.0[d]
	Coffee consumption (cups/day)	7.7±4.7[a]	5.6±3.5[b]	4.2±3.3[c]	4.9±2.8[a]	6.6±3.7[d]	8.5±4.6[d]	10.9±7.0[d]
	Alcohol consumption (glasses/2 weeks)	7.4±9.0[a]	5.4±6.8[b]	5.1±6.1	5.6±6.4	5.8±6.6	8.2±9.4[d]	11.1±13.6[d]
Females	*N*	4343	2932	4815	714	1970	1555	104
	Age (years)	44.7±13.1[a]	48.3±14.6[b]	50.0±17.5	45.9±15.5[a]	44.6±13.4	44.0±11.5	47.5±10.8
	Body mass index (kg/m^2)	23.9±3.9[a,e]	25.2±4.1[b,f]	25.3±4.6	24.1±3.9[a]	23.8±3.9	24.0±4.0	25.1±4.7
	Number of cigarettes smoked daily	10.7±5.3	0	0	4.1±1.2	8.7±1.5	15.0±3.0	28.2±5.8
	Physical activity score	3.2±2.7[a]	3.5±2.9[b]	3.5±2.9	3.2±2.7	3.3±2.8	3.1±2.8	2.4±2.6[d]
	Coffee consumption (cups/day)	6.2±3.5[a]	4.5±2.8[b]	3.4±2.6[c]	4.3±2.4[a]	5.9±3.1[d]	7.2±3.8[d]	9.0±5.8[d]
	Alcohol consumption (glasses/2 weeks)	3.3±4.5[a]	2.9±4.1[b]	1.2±3.1[c]	2.6±3.9[a]	3.0±3.9[d]	3.9±5.0[d]	6.5±7.7[d]

[a] $p<0.01$ vs. never-smokers; [b] $p<0.01$ vs. current smokers; [c] $p<0.01$ vs. ex-smokers; [d] $p<0.01$ vs. 1–5 cigarettes per day (Mann–Whitney Test); [e] $p<0.01$ vs. never-smokers; [f] $p<0.01$ vs. current smokers; [g] $p<0.01$ vs. ex-smokers; [h] $p<0.01$ vs. 1–5 cigarettes per day (general linear model with age, physical activity score, coffee consumption and alcohol consumption as covariates).

never-smokers. Regarding physical activity score, coffee consumption, and alcohol consumption, the ex-smokers had values in between those of the current smokers and never-smokers. In both genders, never-smokers had higher BMI than those smoking one to five cigarettes per day. Looking at current smokers separately, those smoking one to five cigarettes daily had lower BMI, were more physically active, and drank less coffee and alcohol than those smoking 21 or more cigarettes daily (Table I). There was a U-shaped relationship between BMI and the number of cigarettes smoked daily, where never-smokers and heavy smokers had BMI at the same level, as shown graphically in Figure 2.

In the multiple linear regression models with BMI as the dependent variable, we found, in both genders and in all smoking class subgroups, age and coffee consumption to be positively associated with BMI, and physical activity to be negatively associated with BMI. However, the relationship between alcohol consumption and BMI differed between the genders. When all subjects were evaluated together, non-smoking was positively associated with BMI. In the current smokers, the number of cigarettes smoked per day was significantly positively associated with BMI (Table II).

Relationship between BMI category and lifestyle factors

When current smokers, ex-smokers and never-smokers were grouped according to BMI level, those with normal weight (BMI 20–25 kg/m^2) were, as expected, younger and more physically active than

Figure 2. Mean body mass index (BMI) (error bars 95% confidence intervals) of males and females among never-smokers and current smokers in 1994 grouped in relation to the number of cigarettes smoked per day in 1994.

Table II. Spearman's correlation coefficient (ρ) and standardized regression coefficient β from the linear regression model with body mass index (BMI) as dependent variable in the fourth Tromsø Study in 1994.

	Current smokers				Ex-smokers				Never-smokers				Smokers and non-smokers			
	Males (n=3937)		Females (n=4343)		Males (n=3600)		Females (n=2932)		Males (n=3383)		Females (n=4815)		Males (n=10,920)		Females (n=12,090)	
	ρ	β	ρ	β	ρ	β	ρ	β	ρ	β	ρ	β	ρ	β	ρ	β
Age (years)	0.08[a]	0.04[c]	0.19[a]	0.14[e]	0.06[a]	0.03	0.31[a]	0.26[e]	0.16[a]	0.11[e]	0.34[a]	0.22[e]	0.14[a]	0.08[e]	0.30[a]	0.22[e]
Cigarettes smoked per day	0.12[a]	0.12[e]	0.03	0.05[d]												
Coffee (cups/day)	0.05[a]	0.00	0.05[a]	0.01	0.09[a]	0.09[e]	0.10[a]	0.09[e]	0.13[a]	0.08[e]	0.18[a]	0.09[e]	0.05[a]	0.08[e]	0.05[a]	0.06[e]
Physical activity score	−0.03	−0.02	−0.06[a]	−0.03[c]	−0.10[a]	−0.09[e]	−0.15[a]	−0.09[e]	−0.14[a]	−0.11[e]	−0.24[a]	−0.13[e]	−0.08[a]	−0.08[e]	−0.14[a]	−0.09[e]
Alcohol (glasses/2 weeks)	0.02	−0.02	−0.08[a]	−0.05[e]	−0.02	0.01	−0.16[a]	−0.06[e]	0	0.05[d]	−0.25[a]	−0.11[e]	−0.02	0.03[d]	−0.18[a]	−0.07[e]
Smoking status[b]													0.14[a]	0.16[e]	0.16[a]	0.14[e]
R^2	0.02		0.03		0.02		0.01		0.04		0.13		0.04		0.10	

[a]$p<0.01$, correlation with BMI (Spearman's correlation coefficient). [b]Smoker=1, non-smoker=2. [c]$p<0.05$. [d]$p<0.01$. [e]$p<0.001$.

Table III. Lifestyle factors in relation to body mass index (BMI) and gender in current smokers, ex-smokers and never-smokers in the fourth Tromsø Study in 1994.

	Males				Females			
	BMI ≤20.0	BMI 20.0–25.0	BMI 25.0–30.0	BMI ⩾30.0	BMI ≤20.0	BMI 20.0–25.0	BMI 25.0–30.0	BMI ⩾30.0
Current smokers								
N	180	1913	1536	308	510	2460	1036	337
Age (years)	48.9±16.8[b]	44.3±13.3	46.4±12.7[c]	46.5±12.4[c]	43.3±14.0	43.3±12.4	47.3±13.3[c]	48.9±13.7[c]
Cigarettes per day	11.7±5.9[b]	13.2±6.3	14.3±7.5[c]	15.0±7.0[c]	10.6±5.2	10.5±5.0	11.1±5.7	11.2±6.4
Physical activity score	3.1±2.9[a]	3.9±3.4	3.8±3.4	3.3±3.3[b]	3.2±2.9	3.3±2.8	3.0±2.6[b]	2.6±2.6[c]
Coffee (cups/day)	6.9±3.9	7.6±4.7	7.9±4.9	7.8±4.5	6.1±3.4	6.1±3.6	6.3±3.4	6.3±3.8
Alcohol (glasses/2 weeks)	6.1±8.3[b]	7.6±9.6	7.3±8.2	7.5±8.8	3.1±4.3[b]	3.6±4.5	3.2±4.7[c]	2.3±4.0[c]
Ex-smokers								
N	48	1220	1891	441	165	1471	923	373
Age (years)	61.7±17.9[b]	52.3±15.9	53.9±14.3[b]	54.6±13.2[b]	42.1±14.5[b]	45.2±13.4	51.3±14.4[b]	56.1±14.9[b]
Physical activity score	3.0±3.4[b]	4.6±3.5	4.0±3.4[b]	3.3±2.9[b]	3.3±2.9[b]	3.9±3.1	3.2±2.6[b]	2.6±2.4[b]
Coffee (cups/day)	4.9±4.0	5.2±3.3	5.9±3.5[b]	5.9±4.2[a]	3.6±2.6[b]	4.4±2.8	4.6±2.8	4.9±2.8[b]
Alcohol (glasses/2 weeks)	3.6±6.1[b]	5.4±6.2	5.4±7.1	5.5±7.1	2.9±4.2	3.3±4.4	2.7±3.7[b]	1.9±3.5[b]
Never-smokers								
N	55	1584	1440	304	326	2342	1451	696
Age (years)	40.4±13.9	40.2±12.1	43.3±12.8[b]	44.9±13.1[b]	41.9±15.8[b]	45.9±16.2	54.3±17.5[b]	58.3±16.4[b]
Physical activity score	4.8±3.8	5.1±3.7	4.5±3.5[b]	3.8±3.2[b]	4.2±3.2	4.0±3.0	3.1±2.7[b]	2.4±2.5[b]
Coffee (cups/day)	4.0±4.5	3.8±3.1	4.5±3.4[b]	4.6±3.6[b]	2.7±2.4[b]	3.2±2.5	3.7±2.5[b]	4.1±2.8[b]
Alcohol (glasses/2 weeks)	4.6±7.7	5.0±5.5	5.2±6.5	5.3±7.1	2.4±3.4	2.3±3.2	1.5±3.0[b]	0.8±2.0[b]

[a]$p<0.05$, [b]$p<0.01$, and [c]$p<0.001$, as compared to BMI 20.0–25.0; current smokers, ex-smokers and never-smokers separately (Mann–Whitney test).

Table IV. Lifestyle factors in 1994 in relation to smoking status in 2001 in males and females who participated in both the fourth (1994) and the fifth (2001) Tromsø studies.

	Males				Females			
	Smoker in 1994		Non-smoker in 1994		Smoker in 1994		Non-smoker in 1994	
	Smoker in 2001	Non-smoker in 2001	Non-smoker in 2001	Smoker in 2001	Smoker in 2001	Non-smoker in 2001	Non-smoker in 2001	Smoker in 2001
N	552	180	1570	62	727	215	1736	60
Age (years) in 1994	52.6±11.5[a]	54.7±11.2	55.8±11.5[c]	50.2±12.6	50.6±11.6	51.3±11.6	54.1±11.5[d]	47.2±11.7
Body mass index (kg/m^2) in 1994	25.3±3.3	25.4±3.3	26.3±3.0	26.3±2.4	24.0±3.4	24.8±4.4	25.6±4.0	25.2±3.1
Number of cigarettes per day in 1994	13.8±7.4	12.2±6.4	0	0	11.2±5.4	8.9±4.8	0	0
Physical activity score in 1994	3.7±3.1	3.6±3.1	4.3±3.3	3.5±2.9	3.1±2.8	3.0±2.6	3.5±2.7	3.9±2.6
Coffee consumption (cups/day) in 1994	8.0±4.2	7.6±5.1	5.2±3.1[d]	6.4±2.8	6.7±3.4[b]	5.8±2.9	4.2±2.4[d]	5.6±3.0
Alcohol consumption (glasses/2 weeks) in 1994	7.0±8.6[a]	5.4±6.0	5.0±5.8	5.4±4.9	3.6±4.5	2.9±3.7	2.6±3.3	3.8±6.3

[a]$p<0.05$, and [b]$p<0.001$, as compared to non-smokers in 2001 (Mann–Whitney test); [c]$p<0.01$, and [d]$p<0.001$, as compared to smokers in 2001 (Mann–Whitney test).

Table V. Change in lifestyle factors from 1994 to 2001 (value in 2001 minus value in 1994) in males and females in relation to smoking status in 2001.

	Males				Females			
	Unchanged smoker	Quitted smoking	Unchanged non-smoker	Started smoking	Unchanged smoker	Quitted smoking	Unchanged non-smoker	Started smoking
N	552	180	1570	62	727	215	1736	60
Change in body mass index (kg/m^2)	0.5±1.7[b,d]	1.6±2.0	0.8±1.5[c]	0±1.7	0.8±2.1[b,d]	2.3±2.3	1.2±1.9[c]	0.1±2.1
Change in number of cigarettes per day	−1.9±5.2	−12.2±6.4	0	10.8±5.4	−0.8±3.9	−8.9±4.8	0	8.5±4.5
Change in physical activity score	0.2±3.7	0.3±3.5	0.2±3.6	−0.1±2.9	0.3±3.2	0.4±2.7	0.4±3.0	−0.2±3.4
Change in coffee consumption (cups/day)	−0.6±5.6[b]	−2.0±4.5	−0.8±2.7	0±2.9	−0.9±2.8[a]	−1.4±2.6	−0.7±2.0	−0.4±2.9
Change in alcohol consumption (glasses/2 weeks)	−0.7±8.6	−0.9±4.8	−0.2±5.9	−0.9±4.7	0.1±4.4	−0.3±3.4	0.2±3.4	0.2±4.2

[a]$p<0.01$, [b]$p<0.001$, unchanged smoker vs. quitted smoking; [c]$p<0.001$, unchanged non-smoker vs. started smoking; [d]$p<0.01$, unchanged smoker vs. unchanged non-smoker (Mann–Whitney test).

Table VI. Change in lifestyle factors from 1994 to 2001 (value in 2001 minus value in 1994) in relation to number of cigarettes previously smoked daily in 1994 by those who quitted smoking and in relation to number of cigarettes smoked daily in 2001 by those who started smoking from 1994 to 2001.

		Quitted smoking			Started smoking		
		Previously >10 cigarettes daily	Previously 6–10 cigarettes daily	Previously 1–5 cigarettes daily	1–5 cigarettes daily	6–10 cigarettes daily	>10 cigarettes daily
Males	*N*	85	71	22	10	29	23
	Change in body mass index (kg/m^2)	$2.01 \pm 2.08^{a,d}$	1.37 ± 1.94	1.03 ± 1.45	0.18 ± 2.00	-0.37 ± 1.74	0.34 ± 1.58
	Change in physical activity score	0.54 ± 3.38	-0.05 ± 3.42	1.06 ± 3.90	0.07 ± 1.42	-0.39 ± 3.29	0.14 ± 3.02
	Change in coffee consumption (cups/day)	-2.64 ± 5.86	-1.64 ± 2.70	-0.72 ± 1.67	-1.29 ± 2.26	-0.37 ± 2.35	1.00 ± 3.56
	Change in alcohol consumption (glasses/2 weeks)	-0.97 ± 5.60	-1.01 ± 4.04	-0.49 ± 4.10	-3.43 ± 4.20	-0.85 ± 5.59	0.10 ± 3.33
Females	*N*	56	100	58	19	27	14
	Change in body mass index (kg/m^2)	$3.24 \pm 2.59^{c,d}$	2.37 ± 2.13^{b}	1.40 ± 1.97	0.53 ± 1.57	0.09 ± 2.01	-0.52 ± 2.69
	Change in physical activity score	0.43 ± 2.30	0.72 ± 2.85	-0.16 ± 2.60	0.99 ± 3.16	-0.71 ± 3.42	-0.61 ± 3.32
	Change in coffee consumption (cups/day)	-2.30 ± 3.40^{a}	-1.34 ± 2.21	-0.72 ± 1.97	0.80 ± 2.37	-0.81 ± 2.99	-1.43 ± 2.77^{a}
	Change in alcohol consumption (glasses/2 weeks)	-0.07 ± 3.00	-0.59 ± 3.09	0.19 ± 3.93	0.18 ± 4.27	0.09 ± 3.72	0.45 ± 5.37

[a]$p<0.05$, [b]$p<0.01$ and [c]$p<0.001$ vs. 1–5 cigarettes daily (those who quitted and those who started smoking separately) (Mann–Whitney test); [d]$p<0.05$, linear trend across number of cigarettes smoked per day categories.

those who were obese (BMI >30 kg/m^2) (Table III). In currently smoking males, there was an increase in number of cigarettes smoked with increasing BMI category, but, as in the linear regression model, this was less pronounced in smoking females (Table III).

Longitudinal study

The characteristics of the participants in 1994 in relation to smoking status in the fourth (1994) and in the fifth (2001) Tromsø studies are shown in Table IV.

In both genders, continuing non-smokers were older and drank less coffee in 1994 than those who had started smoking after 1994. Men who had quitted smoking were older and drank less alcohol in 1994 than continuing smokers. Women who had quitted smoking drank less coffee in 1994 than continuing smokers (Table IV).

Relationship between change in smoking status and lifestyle factors

In all subgroups of gender and smoking status, there was an increase in BMI from 1994 to 2001. However, in both genders, those who continued smoking had a smaller increase in BMI than those who quitted smoking after 1994. Furthermore, those who had started smoking after 1994 had a smaller increase in BMI than those who remained non-smokers. In both genders, the continuous smokers had a smaller increase in BMI than the continuous non-smokers. In all groups, there was a decrease in coffee consumption from 1994 to 2001, but the decrease was less in continuing smokers than in those who quitted smoking after 1994 (Table V).

Relationship between changes in number of cigarettes smoked and lifestyle factors

In those who quitted smoking after 1994, there was in both genders a positive relationship between number of cigarettes smoked in 1994 and increase in BMI. Furthermore, females who smoked more than 10 cigarettes in 1994 before quitting had a higher reduction in coffee consumption than those smoking one to five cigarettes in 1994 (Table VI).

In those who started smoking after 1994, there was in females a negative non-significant relationship between number of cigarettes smoked and change in BMI (Table VI).

Discussion

In the present study, we found current smokers to have lower BMI than ex-smokers and never-smokers, which is consistent with most other studies [2–6]. As expected [4,5,17], the current smokers had less healthy lifestyles, with lower physical activity, and higher consumption of coffee and alcohol than never-smokers, with the ex-smokers having values in between. However, adjusting for these covariates in a multiple linear regression model did not abolish smoking status as a strong predictor of BMI, and in this model current smoking appeared as a stronger predictor of BMI than physical activity.

When current smokers were considered separately, there was a U-shaped relationship between number of cigarettes smoked and BMI, with the lowest BMI being seen in those smoking 6–10 cigarettes per day, and the highest in those smoking more than 20 cigarettes per day. Heavy smokers had similar BMI as never-smokers. This U-shaped relationship has also been reported previously [10–13], and must be taken into account when considering the relationship between smoking and measures of body fat or its distribution. In this respect, smokers should not be considered as a homogeneous group, but should be divided into subgroups according to number of cigarettes smoked. Similarly, current non-smokers should be divided in ex-smokers and never-smokers.

In the longitudinal study, we found a few predictors of change in smoking status. Those who quitted smoking were older than those who continued smoking, and those who started smoking were younger than those who remained non-smokers. These changes were paralleled in coffee consumption, and if coffee consumption can be taken as an indictor of an unhealthy lifestyle, a healthy lifestyle in 1994 predicted a better smoking status in 2001.

As previously reported [2], those who quitted smoking had an increase in BMI as compared to those who continued smoking, and those who started smoking had a reduction in BMI compared to those who remained non-smokers. Furthermore, there was a significant, positive association between increase in BMI after quitting smoking and previous number of cigarettes smoked per day. Again, these changes in BMI were paralleled by changes in coffee consumption.

There is no simple explanation of why smokers tend to have lower BMI than non-smokers, why there is a U-shaped relationship between number of cigarettes smoked and BMI, why there is weight gain after smoking cessation, and why this weight gain is positively related to number of cigarettes previously smoked. One explanation could be that smoking, on the one hand, reduces appetite and increases the metabolic rate [18], and on the other, is associated

with an unhealthy lifestyle causing weight gain. Thus, in light smokers the first effect might be relatively unopposed by minor lifestyle changes, whereas in heavy smokers an unhealthy lifestyle outweighs the effects of smoking on appetite and metabolic rate.

For lifestyle, our data support this hypothesis, as the physical activity was inversely related to number of cigarettes smoked, and coffee and alcohol consumption were positively related to number of cigarettes smoked. In this respect, it is noteworthy that in those who quitted smoking, the subsequent increase in BMI, which was positively related to number of cigarettes previously smoked, was unopposed by an increase in physical activity or change in alcohol consumption. Furthermore, the ex-smoking males had higher BMI than the never-smokers, which again demonstrates that smoking is not just one single bad habit, but is a part of a generally unhealthy lifestyle.

At least in short-term experiments, nicotine appears to increase the metabolic rate by 5–7% [19,20]. Most studies also indicate an appetite-suppressant effect of nicotine [21,22], which may even lower the body weight set point [23]. Furthermore, caffeine augments the thermogenic effect [20,24,25] and appetite reduction [22] caused by nicotine. This is particularly relevant, as we found a striking parallel between number of cigarettes smoked and coffee consumption, including a reversal of the coffee-drinking pattern with smoking cessation.

Our study has several limitations. First, the study is based on smoking and lifestyle habits reported in a questionnaire, and for some of these variables, in particular alcohol consumption, underreporting may have occurred. Several of the subjects did not answer all questions in the questionnaires, and therefore had to be excluded from the analyses, which could have resulted in a selection bias favouring younger subjects and those with higher education. The number of smokers in the cross-sectional study from 1994 was 36% among men, whereas in the longitudinal study 31% of the men smoked at baseline. Accordingly, smokers were less likely to attend the fifth Tromsø study in 2001 than non-smokers were. However, as can be seen from Tables I and IV, the lifestyle factors (number of cigarettes smoked, physical activity score, coffee consumption, and alcohol consumption) were similar in the smokers in the cross-sectional and longitudinal studies. It is therefore unlikely that the selection bias, favouring non-smokers, has a major impact on the results. Furthermore, we did not include socioeconomic status in our analyses, which may be of relevance for the relationship between smoking and BMI [26]. It should also be emphasized that cross-sectional data can provide only weak evidence for associations, and thus conclusions regarding causality cannot be drawn. On the other hand, our study has considerable strength because of the large number of participants in the Tromsø Study and the high attendance rate.

Conclusions

We have found a strong relationship between smoking habits, lifestyle factors, and BMI. In particular, there was a U-shaped relationship between the number of cigarettes smoked per day and BMI, where the BMI of never-smokers and heavy smokers was similar. This U-shaped relationship should be taken into consideration when evaluating the relationship between BMI and smoking. In this respect, smokers cannot be considered as a homogeneous group.

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