Smoking and relative body weight: an international perspective from the WHO MONICA Project

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Abstract

***Study objective*—To investigate the magnitude and consistency of the associations between smoking and body mass index (BMI) in different populations.**

***Design*—A cross sectional study.**

***Setting and participants*—About 69 000 men and women aged 35–64 years from 42 populations participating in the first WHO MONICA survey in the early and mid 1980s.**

***Main results*—Compared to never smokers, regular smokers had significantly ($p<0.05$) lower median BMI in 20 (men) and 30 (women) out of 42 populations (range -2.9 to $0.5\,kg/m^2$). There was no population in which smokers had a significantly higher BMI than never smokers. Among men, the association between leanness and smoking was less apparent in populations with relatively low proportions of regular smokers and high proportions of ex-smokers. Ex-smokers had significantly higher BMI than never smokers in 10 of the male populations but in women no consistent pattern was observed. Adjustment for socioeconomic status did not affect these results.**

***Conclusions*—Although in most populations the association between smoking and BMI is similar, the magnitude of this association may be affected by the proportions of smokers and ex-smokers in these populations.**

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Numerous epidemiological studies have shown a consistent inverse relationship between smoking and body weight—smokers weigh relatively less than non-smokers,[1–11] and stopping smoking often leads to weight gain.[1–3 5 7 10 12–14] It has been shown that this is mainly because smoking increases energy expenditure.[15] Moreover, the inverse relationship between smoking and relative body weight becomes stronger with age,[4] which can be explained by longer duration of smoking.[5 16]

Among smokers a U-shaped relationship between the number of cigarettes smoked and relative body weight has been found in several studies—those smoking 10–20 cigarettes per day being the leanest.[1–5 7 9 17 18] Although this seems paradoxical given the metabolic effects of smoking, it has been suggested that heavy smokers may weigh more because of clustering of other unhealthy habits such as high intake of saturated fat, heavy use of alcohol, and little exercise. Indeed, a study in Finland found that a change in the association between smoking and body weight had occurred in the 1980s—smoking was no longer associated with leanness in this population but rather it was positively related to BMI, especially among younger middle aged men.[16]

Most studies of the relationship between smoking and relative body weight have looked at single populations or cohorts. Therefore we considered it important to examine whether associations are similar in populations with different histories of smoking habits and changes in body weight. We investigated this among men and women in 42 populations participating the WHO MONICA Project.

Given the findings of the Finnish study on changes in the relationship between smoking and relative body weight, it could be hypothesised that the "classical" inverse association between smoking and relative body weight might hold in populations with a high prevalence of smoking and comparatively few anti-smoking activities, while a "new" positive association between smoking and relative body weight may be more typical in populations with a previously high but currently falling prevalence of smoking due to anti-smoking programmes. While our data do not allow us to test this hypothesis directly, we will mainly focus on determining whether there are populations with the "new" association to warrant pursuing such a hypothesis.

Methods

The WHO MONICA Project was designed to measure trends in the incidence in and mortality from cardiovascular disease, and to assess the extent to which these trends are related to changes in known risk factors in 49 study populations in 26 countries. Risk factors in the WHO MONICA Project are monitored through up to three independent cross sectional population surveys.[19 20] The surveys included random samples of at least 200 people in each gender and 10 year age group, for the age range 35–64 years, and optionally 25–34 years. This study presents data from the baseline surveys. The survey periods range from May 1979 to February 1989 and are mostly concentrated in the early and mid 1980s. In this study, only the age range from 35–64 years is considered. The overall participation rates for the surveys varied from 54%–89%. The population sizes, participation rates, and survey periods have been described in more detail elsewhere.[21]

Height and body weight were measured with participants standing without shoes and heavy outer garments. Body mass index (BMI) was calculated as weight divided by height squared (kg/m^2) as a measure for relative weight. BMI categories were formed according to the WHO guidelines,[22] except for using 21 kg/m^2 instead of the WHO recommendation of 18 kg/m^2 as a cut off point for the leanest category. This cut off point was selected to ensure a sufficient number of subjects in each category and because of its use in some other studies.[23] The subjects were classified as follows:

- Lean persons—BMI less than 21 kg/m^2
- Persons of normal weight—BMI equal to or more than 21 but less than 25 kg/m^2
- Overweight persons—BMI equal to or more than 25 but less than 30 kg/m^2
- Obese persons—BMI equal to or more than 30 kg/m^2.

Data on smoking were obtained with a standard questionnaire.[24] In the analysis respondents were classified as follows:

- Regular cigarette smokers, those reporting smoking cigarettes every day. They were further classified in concordance with several other studies[2 3 8 9] as (a) light to moderate smokers, those smoking 1–19 cigarettes per day, and (b) heavy smokers, those smoking 20 or more cigarettes per day.
- Other current smokers, those reporting smoking cigarettes occasionally, or at least 1g of pipe tobacco per week, or at least one cigar per week.
- Ex-smokers, those reporting smoking cigarettes regularly in the past but not currently.
- Never smokers, those who were not current smokers and had never smoked cigarettes regularly.

The age group of the subject was obtained from the sampling frame at the time of sample selection. Tertiles of years of schooling within each population were used as a measure of socioeconomic status (SES). Years of schooling were obtained by asking—"How many years did you spent at school or in full-time study?". Tertiles of years of schooling were calculated for men and women in each 10 year age group separately.

KEY POINTS

- Cigarette smokers are leaner than never smokers in most of the populations studied – and more so in women than men.
- In some populations there was no association between smoking and body weight. In these populations, among men, there were fewer smokers and more ex-smokers than in populations in which smokers were leaner than never smokers.
- Ex-smoking men weighed on average more than never smokers, whereas in women no consistent pattern was found.

The quality of data on weight, height, smoking behaviour, and years of schooling has been centrally assessed. Any population with an unsatisfactory quality of data or response rate lower than 50% for any of the items has been omitted from this study. This left 42 populations, except for analyses involving years of schooling, where only a subset of 34 populations with full data was included.

STATISTICAL METHODS

In the first phase of data analysis, population level (ecological) data were analysed to estimate the strength of association between smoking and relative body weight. Pearson correlation coefficients between the proportions of regular cigarette smokers and the means and centiles of BMI were calculated for men and women for each 10 year age group. Correlations of age standardised values are given for the age group 35–64. Age standardised values were calculated using the world standard population,[25] as the reference population with weights 12, 11, and 8 for the 10 year age groups 35–44, 45–54, and 55–64 respectively.

In the second phase, individual data were used to examine the consistency and magnitude of the relation between smoking and BMI at the individual level. All analyses were carried out separately for men and women. Two types of analyses were performed—firstly, comparing medians or means of BMI between different categories of smoking, and secondly, comparing proportions of regular smokers between different categories of BMI within populations. Differences were reported to be statistically significant if the p value was less than 0.05.

To compare the levels of BMI between smoking categories, medians instead of means of BMI were used because of the distributions of BMI were skewed to the right. Confidence intervals for the differences in median BMIs in categories of smokers, compared with the never smoker category, were calculated using the Normal approximation as described by White *et al.*[26] Linear regression was used to control for potential confounding by SES. Mean BMIs and differences in mean BMIs in relation to smoking category were calculated using the general linear model (GLM) procedure of *SAS* statistical software,[27] adjusting for age group and population as categorical covariates. To assess the confounding effect of SES, regression analyses were performed both with and without adjusting for population specific tertiles of years of schooling. Confidence intervals for the estimates were calculated from the standard errors of the regression coefficients assuming that the sampling distributions of the coefficients were normal. The results of the linear regression were also used to give an overall estimate of the differences in the mean BMIs between smoking categories, summarising the results across all populations. In addition, the same overall estimates were calculated using non-parametric methods to confirm that the estimates based on the regression analysis did not differ from the estimates based on medians.

Table 1 Number of subjects, age standardised proportion (%) of regular cigarette smokers, and age standardised prevalence of obesity (BMI≥30 kg/m²) in first MONICA population survey. Men and women aged 35–64 years

			Men			Women		
Population	*Country*	*Abbreviation*	*No*	*Smokers %*	*Obese %*	*No*	*Smokers %*	*Obese%*
Newcastle	Australia	AUS-NEW	1218	34	15	1241	24	16
Perth	Australia	AUS-PER	631	33	9	661	22	11
Ghent	Belgium	BEL-GHE	539	43	11	495	25	15
Luxembourg Province	Belgium	BEL-LUX	989	43	13	959	18	18
Beijing	China	CHN-BEI	619	51	3	641	16	9
Czech Republic	Czech Rep.	CZE-CZE	948	44	21	990	21	32
Glostrup	Denmark	DEN-GLO	1456	45	11	1361	44	10
Kuopio Province	Finland	FIN-KUO	968	34	18	981	10	19
North Karelia	Finland	FIN-NKA	1125	30	17	1212	9	24
Turku/Loimaa	Finland	FIN-TUL	1194	30	19	1270	17	17
Lille	France	FRA-LIL	641	39	14	530	11	19
Strasbourg	France	FRA-STR	666	34	22	714	14	23
Toulouse	France	FRA-TOU	678	36	9	645	17	11
Augsburg rural	Germany	GER-AUR	846	30	20	857	12	22
Augsburg urban	Germany	GER-AUU	712	36	18	679	18	15
Bremen	Germany	GER-BRE	633	45	14	656	29	18
Cottbus County	Germany	GER-COT	460	31	17	543	11	23
Halle County	Germany	GER-HAC	816	38	18	859	14	27
Karl-Marx-Stadt County	Germany	GER-KMS	813	37	14	926	15	19
Rest of DDR-MONICA	Germany	GER-RDM	763	37	17	822	24	21
Rhein-Neckar Region	Germany	GER-RHN	1170	31	13	1266	23	12
Iceland	Iceland	ICE-ICE	657	26	11	704	40	11
Area Brianza	Italy	ITA-BRI	618	44	11	639	18	15
Friuli	Italy	ITA-FRI	719	35	16	724	26	19
Kaunas	Lithuania	LTU-KAU	728	38	22	735	4	45
Auckland	New Zealand	NEZ-AUC	1018	29	8	567	25	9
Tarnobrzeg Voivodship	Poland	POL-TAR	1250	58	13	1472	11	32
Warsaw	Poland	POL-WAR	1309	59	18	1337	33	26
Bucharest	Romania	ROM-BUC	524	38	20	632	15	31
Moscow control	Russia	RUS-MOC	770	48	13	645	12	33
Moscow intervention	Russia	RUS-MOI	1163	46	12	1234	9	35
Novosibirsk control	Russia	RUS-NOC	1061	59	15	1054	3	44
Novosibirsk interv.	Russia	RUS-NOI	601	53	13	646	3	43
Catalonia	Spain	SPA-CAT	993	47	9	994	7	24
Gothenburg	Sweden	SWE-GOT	517	33	7	557	34	9
Northern Sweden	Sweden	SWE-NSW	640	24	11	611	26	14
Ticino	Switzerland	SWI-TIC	781	38	20	769	24	15
Vaud/Fribourg	Switzerland	SWI-VAF	627	32	13	568	21	13
Belfast	UK	UNK-BEL	927	34	11	925	33	14
Glasgow	UK	UNK-GLA	502	52	11	480	50	16
Stanford	USA	USA-STA	427	40	10	516	36	15
Novi Sad	Yugoslavia	YUG-NOS	592	49	17	555	27	29

To compare the prevalence of regular cigarette smoking between BMI categories, age standardised proportions of regular cigarette smokers were calculated for the age group 35–64 using the same method for age standardisation as described above. The differences in the proportions of smokers between BMI categories within populations were tested by fitting a logistic regression model with regular cigarette smoking as the binary dependent variable and age group as the independent variable, with and without adjustment for indicator variables for BMI categories.

To estimate the overall difference in the age standardised proportions of regular cigarette smokers between BMI categories, the mean of the differences and a 95% confidence interval for this mean were calculated, summarising the results across all study populations. The normal weight category (BMI = 21.0–24.9 kg/m²) was used as the reference category when comparing proportions of regular smokers. The confidence intervals were calculated from standard errors of the means using t distribution with the number of populations minus one for the degrees of freedom.

Table 2 Pearson correlation coefficients between the proportion (%) of regular cigarette smokers and mean and centiles of body mass index (BMI) for 42 populations in the first MONICA survey

	Men		Women	
Age group	*r*	*(95% CI)*	*r*	*(95% CI)*
Mean				
35–44	−0.07	(−0.36, 0.24)	−0.45	(−0.66, −0.17)
45–54	−0.37	(−0.61, −0.08)	−0.65	(−0.79, −0.43)
55–64	−0.30	(−0.55, 0.01)	−0.63	(−0.79, −0.41)
Age standardised 35–64	−0.25	(−0.52, 0.05)	−0.59	(−0.76, −0.35)
Median				
35–44	0.00	(−0.30, 0.30)	−0.46	(−0.67, −0.18)
45–54	−0.34	(−0.59, −0.04)	−0.62	(−0.78, −0.39)
55–64	−0.30	(−0.55, 0.00)	−0.64	(−0.79, −0.41)
Age standardised 35–64	−0.22	(−0.49, 0.09)	−0.57	(−0.75, −0.33)
10th centile				
35–44	−0.16	(−0.44, 0.15)	−0.47	(−0.68, −0.19)
45–54	−0.54	(−0.73, −0.29)	−0.63	(−0.79, −0.41)
55–64	−0.50	(−0.70, −0.23)	−0.58	(−0.75, −0.33)
Age standardised 35–64	−0.43	(−0.65, −0.14)	−0.56	(−0.74, −0.31)
90th centile				
35–44	0.04	(−0.27, 0.34)	−0.37	(−0.61, −0.08)
45–54	−0.22	(−0.49, 0.09)	−0.58	(−0.75, −0.33)
55–64	−0.10	(−0.39, 0.21)	−0.60	(−0.76, −0.36)
Age standardised 35–64	−0.08	(−0.37, 0.23)	−0.54	(−0.72, −0.28)

Results

Table 1 gives the number of subjects, age standardised proportion of regular cigarette smokers and age standardised prevalence of obesity (BMI ≥ 30 kg/m²) in each population. The table shows considerable variation both in the prevalence of regular smoking and obesity across the study populations. The prevalence of regular cigarette smoking ranged from 24%–59% in men and from 3%–50% in women. In general, among men the prevalence of smoking was highest in some eastern European (Poland, Russia) populations and lowest in some Nordic (Sweden, Iceland) populations. Among women, however, smoking was relatively more common in some western European popu-

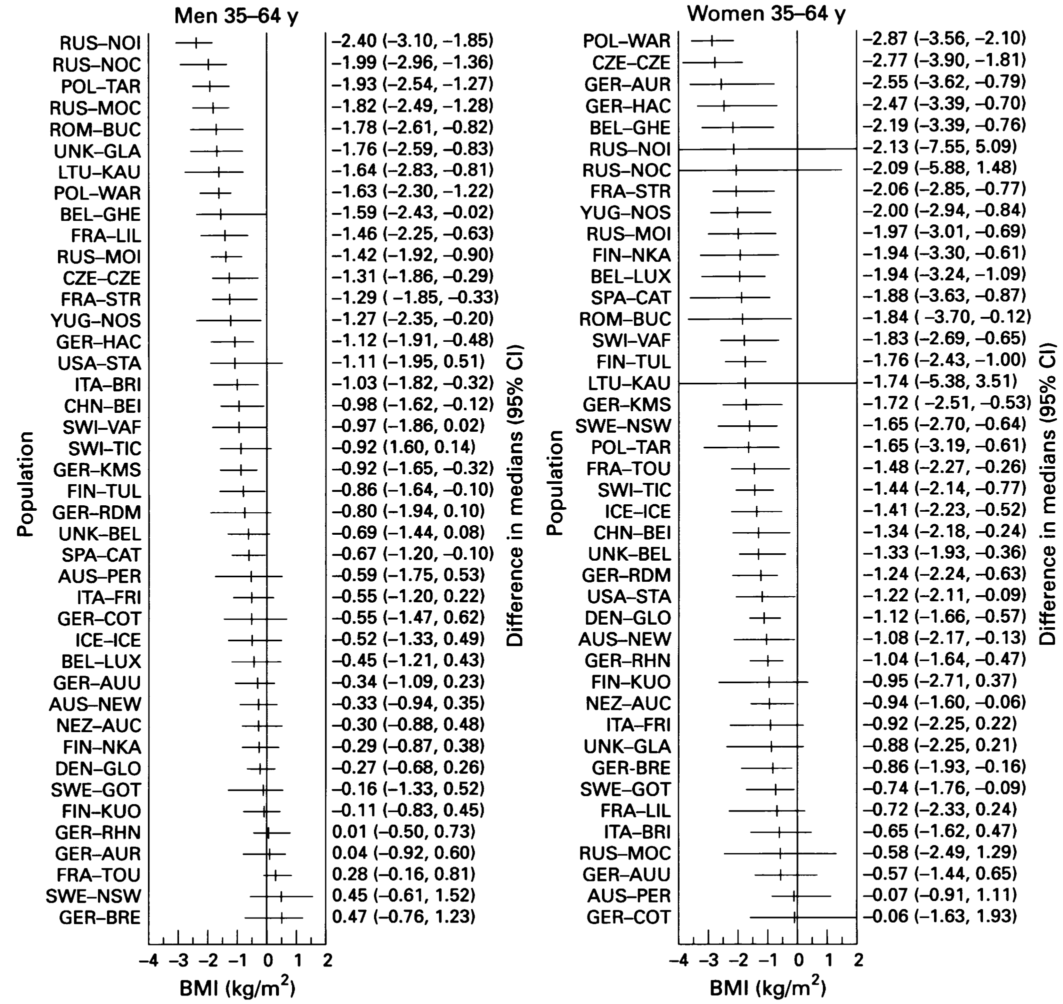

Figure 1 Difference in median BMI between regular cigarette smokers and never smokers in the first MONICA survey. Left, men aged 35–64; right, women aged 35–64.

lations and less common in eastern Europe. There were more female than male smokers only in Iceland (where 22% of men smoked pipes or cigars) and in Sweden. The prevalence of obesity ranged from 3%–22% in men and from 9%–45% in women and was relatively more common in populations with a low prevalence of smoking, especially among women.

Table 2 presents Pearson correlation coefficients between the proportion of regular cigarette smokers and BMI. These are ecological correlations where each population represents one observation. For women, smoking was significantly inversely related to BMI for all four measures—10th centile (leanness), mean and median BMI (average weight) or 90th centile (obesity). For men, the age standardised prevalence of smoking was significantly inversely related to the 10th centile only. For both men and women the weakest correlations were observed in the age group 35–44 years.

Figure 1 shows differences in median BMI between never smokers and regular cigarette smokers. In almost all populations smokers were leaner than never smokers—the difference was statistically significant in 20 out of 42 populations for men and in 30 out of 42 populations for women. The differences ranged from -2.4 to 0.5 kg/m^2 in men and from -2.9 to -0.1 kg/m^2 in women. When translated into kg for average heights of 1.72 m and 1.60 m for men and women respectively, they correspond to the range from -7.1 to 1.5 kg for men and from -7.4 to -0.3 kg for women. The largest differences were observed in populations with relatively high smoking rates (eg in some eastern European populations).

To elucidate further the difference between the populations where the smokers were considerably leaner than never smokers in comparison to populations where they were not, we compared the proportion of regular smokers in the 14 populations with the largest differences in BMI to the 14 populations with the smallest differences in BMI between smokers and never smokers with a non-parametric (Wilcoxon rank sum) test (table 3). Among men, there were significantly more regular smokers in the populations with the largest differences in BMI than in the populations with the smallest differences. In addition, the proportions of ex-smokers were statistically significantly lower in these populations. For women, however, there were fewer smokers in the group of populations with the largest differences in BMI than in the populations with the smallest differences but the difference in smoking prevalences was not statistically significant. The prevalence of ex-

Table 3 Proportions of regular smokers and ex-smokers in 14 populations with the largest difference in BMI between smokers and never smokers compared with 14 populations with the smallest difference. First MONICA survey, men and women aged 35–64

	Range for difference in BMI between smokers and never smokers (kg/m^2)	Median % of regular smokers	p value	Median % of ex-smokers	p value	No
Men						
Largest difference	−2.4, −1.3	47	<0.001	23	0.03	14
Smallest difference	−0.5, 0.5	33		29		14
Women						
Largest difference	−2.9, −1.8	14	0.07	7	0.02	14
Smallest difference	−1.1, −0.1	22		10		14

smokers was significantly lower in the populations with large differences in BMI.

Figure 2 shows the difference in median BMI between never smokers and ex-smokers. Ex-smokers had higher BMI than never smokers in 37 (and significantly so in 10) out of 42 populations among men, whereas for women there were differences in both directions but few were statistically significant. No systematic differences in BMI were observed between heavy and light smokers in most populations (data not shown).

Regression analysis was used to examine the potential confounding effects of SES using population specific tertiles of years of schooling as an indicator. The unadjusted (for SES) analysis was performed first for all populations and then for a subset of 34 populations, for which data on years of schooling were available, and then the SES adjusted analysis was performed for the 34 populations (table 4). The results were very similar whether adjusted for tertiles of years of schooling or not, indicating that SES had hardly any confounding effect on this association.

The mean BMI in the never smoking category was 26.6 g/m^2 for men and 26.8 kg/m^2 for women when adjusted for age group and population. In men, regular cigarette smokers were on average 0.9 kg/m^2 leaner than never smokers, which implies that a male smoker of average height of 1.72 m weighed 2.7 kg less

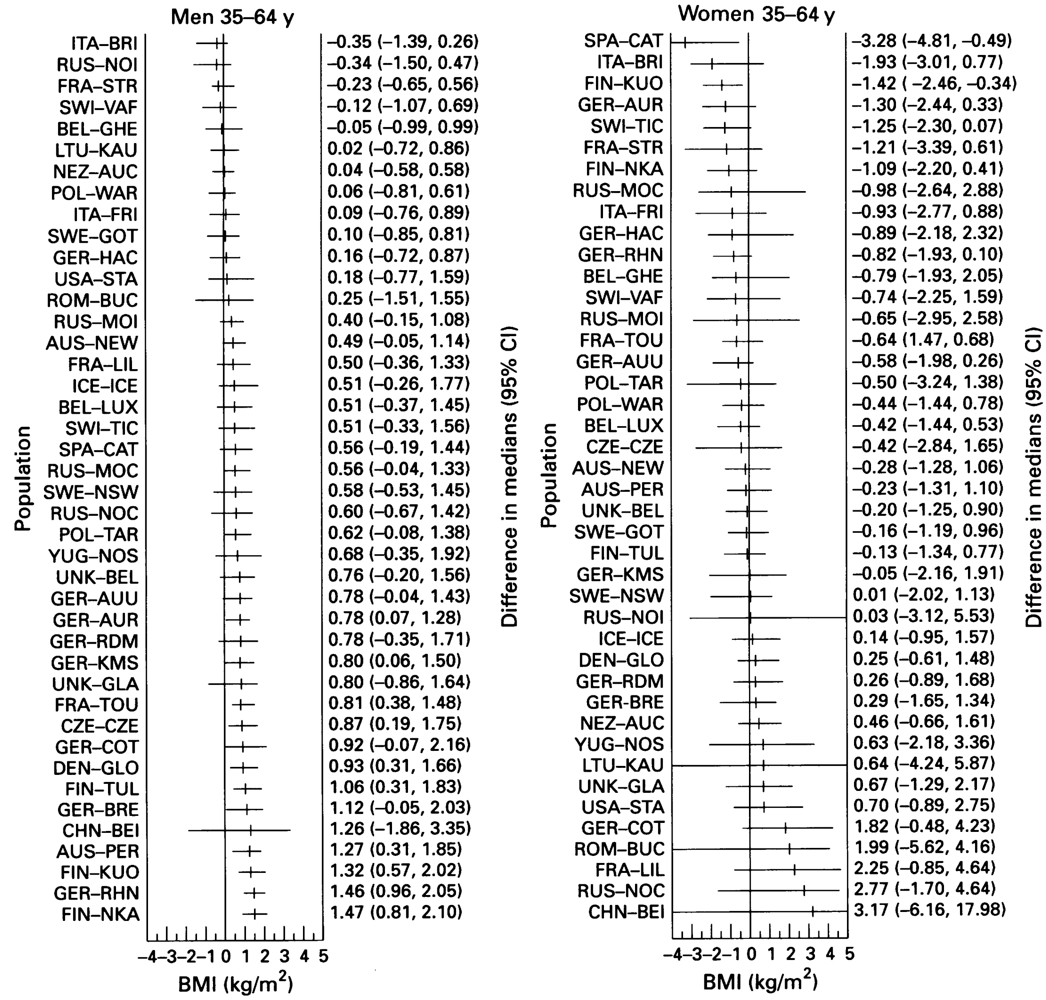

Figure 2 Difference in median BMI between ex-smokers and never smokers in the first MONICA survey. Left, men aged 35–64; right, women aged 35–64.

Table 4 Summary measures of BMI in relation to smoking category. Results from regression analysis. First MONICA survey, men and women aged 35–64

	Mean BMI (95% CI) adjusted for age group and population		
	Unadjusted for SES*	Unadjusted for SES†	Adjusted for SES†
Men			
Never smokers	26.6 (26.5,26.6)	26.6(26.5,26.7)	26.6(26.5,26.7)
Difference between never smokers and			
Regular cigarette smokers	−0.9 (−1.0,−0.8)	−0.9 (−1.0,−0.8)	−1.0 (−1.1,−0.9)
Light smokers	−0.9 (−1.0,−0.7)	−0.9 (−1.0,−0.8)	−0.9 (−1.1,−0.8)
Heavy smokers	−0.9 (−1.0,−0.7)	−0.9 (−1.1,−0.8)	−1.0 (−1.1,−0.9)
Ex-smokers	0.5 (0.4,0.6)	0.5 (0.4,0.6)	0.5 (0.4,0.6)
Women			
Never smokers	26.8 (26.7,26.9)	26.9 (26.9,27.0)	26.9 (26.8,26.9)
Difference between never smokers and			
Regular cigarette smokers	−1.1 (−1.3,−1.0)	−1.2 (−1.4,−1.1)	−1.2 (−1.3,−1.0)
Light smokers	−1.3 (−1.4,−1.1)	−1.4 (−1.5,−1.2)	−1.3 (−1.5,−1.1)
Heavy smokers	−0.8 (−1.0,−0.6)	−0.9 (−1.1,−0.7)	−0.9 (−1.1,−0.7)
Ex-smokers	−0.03 (−0.2,0.2)	−0.05 (−0.3,0.2)	0.1 (−0.1,0.3)

Socioeconomic status (SES) measured with population, gender, and age group specific tertiles of years of schooling
* Based on data from 42 populations
† Based on data from 34 populations

than a never smoker of the same height. Male ex-smokers had 0.5 kg/m^2 higher BMI than never smokers indicating that an ex-smoker of average height weighed 1.5 kg more than never smoker. In women, regular cigarette smokers were on average 1.1 kg/m^2 leaner than never smokers which implies a difference of 2.8 kg for a woman of average height of 1.60 m, but there was no significant difference between never and ex-smokers. For women, but not for men, light smokers had significantly lower BMIs than heavy smokers thus showing a U-shaped relationship between smoking and BMI.

The overall estimates of the differences in BMI between smoking categories were also calculated using non-parametric methods. The estimates based on medians were very similar to those produced by the regression analysis. Only the median BMIs for never smokers (26.3 and 26.1 kg/m^2 for men and women respectively) were somewhat lower than the means, especially for women, due to the skewness of the distributions.

The age standardized proportion of regular smokers decreased consistently with increasing BMI category (table 5). The difference between BMI categories was significant in 35 out of 42 populations among men and in 26 among women. In men the differences were larger than in women. Some exceptions to the general pattern were observed, for example among men in Auckland, Gothenburg, Toulouse, and northern Sweden there were more smokers in the obese than in the normal weight category, but the exceptions were usually not statistically significant.

On the basis of these results one could group the populations into two categories. In most populations for men and almost all for women the "classic" inverse association between smoking and BMI was observed. In some populations, there was no clear association. These include at least Auckland, Gothenburg, Toulouse, and northern Sweden for men and perhaps Cottbus County and Perth for women.

Table 5 Age standardised prevalence of regular cigarette smoking in relation to BMI category based on data from 42 populations. First MONICA survey, men and women aged 35–64

BMI category	Proportion (%) of smokers	95% CI
Men		
Lean (BMI<21.0)	61.8	(56.4, 67.2)
Normal weight (BMI=21.0–24.9)	45.6	(41.8, 49.3)
Overweight (BMI=25.0–29.9)	35.2	(32.8, 37.6)
Obese (BMI>=30.0)	31.8	(29.5, 34.1)
Women		
Lean (BMI<21.0)	30.0	(26.0, 34.0)
Normal weight (BMI=21.0–24.9)	22.8	(19.3, 26.4)
Overweight (BMI=25.0–29.9)	18.0	(14.8, 21.2)
Obese (BMI>=30.0)	13.9	(11.3, 16.5)

Discussion

The association between smoking and relative body weight is an important health issue because both smoking and increased body weight are independent risk factors for cardiovascular disease and quitting smoking is known to lead to weight gain. In addition, smoking is a potential confounder in the relationship between relative body weight and mortality.[8 23] Therefore the recent suggestion that the relationship might be changing from a negative association to a positive one,[16] especially among men, prompted us to explore this association in a wide range of populations. The data collected through the WHO MONICA project population surveys provided a unique opportunity to look at this relationship in a large number of populations from different parts of the world, based on common standardised survey methods for data collection and quality assurance, and centralised data analysis.

Our results show that the generally accepted finding that smokers weigh less than never smokers.[12] still prevails in most populations. This was especially true for women. Also, a U-shaped relationship between BMI and number of cigarettes smoked was found among women but not among men, whereas earlier investigations have generally found a stronger relationship in men.[4 9 16 18] This could be partly explained by the fact that we only used two categories for numbers of cigarettes smoked.

Among men, in some of the study populations there was no association between smoking and BMI and in these populations there were in general fewer smokers and more ex-smokers than in populations where smokers were considerably leaner than never smokers. This finding suggests that the magnitude of the inverse association between smoking and body weight may be related to the prevalence of smoking in the population. It also partly supports the original hypothesis that the "classical" inverse association might no longer be found in populations with extensive anti-smoking activities and reduced prevalence of smoking, eg in Australia, Finland, Sweden, the USA. However, no statistically significant positive association was found in any of these populations. Therefore it would be premature to draw any definitive conclusions about a change in the direction of the relationship, especially because this study was based on cross sectional data and reflects the situation in the early and mid 1980s. More recent data, covering a longer time period, will allow this hypothesis to be tested directly.

One mechanism by which the change from inverse to positive correlation between smoking and BMI observed in the Finnish study,[16] might act is through selection among smokers. As an increasing proportion of light smokers tend to quit smoking when smoking becomes regarded as socially undesirable behaviour, the group of smokers consists increasingly of heavy smokers, who on one hand have more difficulties in quitting,[17] and who on the other hand have higher BMIs than light smokers.[1 3 9 17] The change in the association from inverse to positive would therefore be only an ecological change at the population level since the relative body weight of the heavy smokers at individual level need not have changed. The lack of an inverse association between smoking and BMI is more often seen among younger men than among older men or women. This might be partly explained because the decline in body weight is a long term affect of smoking, whereas the slightly higher BMI observed in heavy smokers may be unrelated to the duration of smoking. This is, in fact, in agreement with the findings of the Finnish study where, in spite of the overall positive association, years of smoking was confirmed as a significant inverse predictor of BMI.[16] The effect of duration of smoking on body weight can however be an indirect one; it is better recognised in older people whose weights have a bigger range than in the young. The reasons for higher BMI of heavy smokers remain unclear. Clustering of unhealthy habits,[16] and use of smoking as a way to control body weight among obese people,[4] have been suggested as potential explanations, but no studies have been conducted specifically to explore this phenomenon.

When looking at the prevalence of smoking between different BMI categories, the most consistent inverse association was found in relation to leanness, especially among men. This is supported by earlier research,[8] and suggests that even if, in some populations, average body weight might be positively associated with smoking, leanness remains inversely associated with cigarette smoking. Our data did not allow us to investigate the association between BMI and duration of smoking. This might have further elucidated the differences between populations, because mean age of starting to smoke may differ among populations and this, too, could affect the distribution of BMI.

Some studies have found ex-smokers to be heavier than never smokers,[4 10] whereas others have not. [3 5] Our findings suggest that, among men, ex-smokers tend to have higher BMI than never smokers, but not among women and this finding is supported by one earlier study.[11] Also Flegal *et al*,[14] found that male ex-smokers were heavier than never smokers, but among women only those ex-smokers who had stopped smoking less than 10 years ago were heavier. The category of occasional cigarette smokers, pipe, and cigar smokers was not compared with never smokers in this study because of the small number of observations.

Socioeconomic status (SES) is a potential confounder in the relationship between smoking and body weight. Persons with lower SES tend to smoke more,[9 28] and to have higher BMIs,[9 11 18] than those with higher SES, the latter especially among women. The associations found in this study were not explained by the effects of SES measured in tertiles of years of schooling. This is consistent with the results of several other studies.[3 5 9 18] We did not measure such potential confounders as physical activity, caloric intake, and alcohol use, but in several studies they have not been found to be actual confounders,[3 5 18] for the BMI-smoking relationship.

This work is one example how large international multi-centre studies can be used to obtain an overview strengthened by standardised methods of data collection and quality assurance. One should, however, be cautious in applying quantitative measures obtained by combining data from heterogenous populations. Nevertheless, the consistency of associations observed among a large number of different populations gives considerably more weight to the findings than results based only on one cohort or study population which cannot be directly generalised to other populations.

In summary, in populations of the WHO MONICA project covering a wide range of smoking habits and prevalence of overweight, men and women who smoked generally had lower BMIs than never smokers. Among men, the difference was more pronounced in populations where smoking was relatively more common. Heavy smokers did not generally have lower BMIs than light smokers. Among men, but not among women, those who had stopped smoking had higher BMIs than those who never smoked. These results confirm that smoking is associated with relative body weight in individuals as well as in populations but that differences in smoking habits in a population can influence the magnitude of this association.

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Appendix 1

Sites and key personnel of contributing MONICA centres.

I MONICA COLLABORATING CENTRES

Australia

University of Western Australia, Nedlands
Principal Investigator—M.S.T. Hobbs
Key personnel—K Jamrozik, P L Thompson, BK Armstrong
University of Newcastle, Newcastle
Principal Investigator—A Dobson
Key personnel—H Alexander, R Heller

Belgium

Ghent State University, Ghent
Principal Investigator—G de Backer
Key personnel—I De Craene, P Van Onsem, L Van Parys
Interuniversity Association for the Prevention of Cardiovascular Diseases, Brussels
Principal Investigator—M Jeanjean
Key personnel—C Brohet, H Kulbertus, S Degre

China

Beijing Heart, Lung and Blood Vessel Research Institute, Beijing
Principal Investigator—Wu Zhaosu
Former Principal Investigator—Wu Ying-Kai
Key personnel for risk factor surveys—Yao Chonghua, Zhang Ruisong

Czech Republic

Institute for Clinical and Experimental Medicine, Prague
Principal Investigator—Z Skodová
Key personnel—Z Pisa, L Berka, Z Cicha, R Emrová, J Pikhartová, P Vojtisek, J Vorlicek, E Wiesner

Denmark

Copenhagen University Hospital, Glostrup
Principal Investigator—M Schroll
Key personnel—M Kirchhoff, A Sjøl, T Joergensen

Finland

National Public Health Institute, Helsinki
Principal Investigator—J Tuomilehto
Former Principal Investigator—P Puska
Key personnel for risk factor surveys—C-G Gref, H Korhonen, M Jauhiainen

France

Country Coordinator—J Richard
National Institute of Health and Medical Research (U258), Paris
Key personnel—A Bingham
National Institute of Health and Medical Research (INSERM 326), Toulouse
Principal Investigators—JP Cambou, J Ferrieres
Key personnel—J-B Ruidavets
Institute of Hygiene—Faculty of Medicine, Strasbourg
Principal Investigators—D Arveiler, P Schaffer
Key personnel—I Escudero, V Baas
Pasteur Institute and Study and Research Group on Myocardial Infarction, Lille
Principal Investigators—P Amouyel, M Montaye-Faivre
Former Principal Investigators—J-L Salomez, M-C Nuttens
Key personnel—N Marecaux, C Steclebout

Germany

GSF-Institute of Epidemiology, Neuherberg/Munich
Principal Investigator—U Keil
Key personnel—J Stieber, A Döring, B Filipiak, U Härtel, HW Hense
Centre for Epidemiology & Health Research, Berlin (from October 1990 Previously German Democratic Republic)
Principal Investigators—W Barth, L Heinemann
Key personnel—A Assmann, S Böthig, G Voigt, S Brasche, D Quietsch, E Classen

Bremer Institute for Prevention Research and Social Medicine, Bremen
Principal Investigator—E Greiser
Co-Principal Investigator—B Herman
Key personnel—G Studemann
Department of Clinical and Social Medicine of the University
Medical Clinic, Heidelberg
Principal Investigator—E Nussel
Former Co-Principal Investigator—E Ostor-Lamm
Key personnel—R Scheidt, W Morgenstern, M Stadler
Iceland
Heart Preventive Clinic, Reykjavik
Principal Investigator—N Sigfússon
Key personnel—II Gudmundsdóttir, I Stefánsdóttir, Th Thorsteinsson, H Sigvaldason
Italy
Institute of Cardiology, Regional Hospital, Udine
Principal Investigator—GA Feruglio
Key personnel—D Vanuzzo, L Pilotto, G Cignacco, M Scarpa, M Palmieri, M Spanghero, R Marini, G Zilio
University of Milan, Institute of Occupational Health, Milan
Principal Investigators—GC Cesana, M Ferrario
Key personnel—R Sega, P Mocarelli, G DeVito
Lthuania
Kaunas Medical Academy Institute of Cardiology, Kaunas
Principal Investigator—J Bluzhas
Key personnel for risk factor survey—S Domarkiene, A Tamosiunas, R Reklaitiene
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Principal Investigator—TA Varlamova
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Principal Investigator—YuP Nikitin
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Principal Investigator—L Wilhelmsen
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Umeå University Hospital, Luleå-Boden Hospital and Kalix Hospital, Departments of Medicine
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Key personnel—B Stegmayr, V Lundberg
Switzerland
University Institute of Social and Preventive Medicine, Lausanne
Principal Investigator—F Gutzwiller (Zürich)
Key personnel—M Rickenbach, V Wietlisbach, F Barazzoni, D Hausser
United Kingdom
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Principal Investigator—A Evans
Key personnel—E McCrum, T Falconer, S Cashman
University of Dundee, Dundee, Scotland
Principal Investigator—H Tunstall-Pedoe
Former Co-Principal Investigator (Population Surveys)—WCS Smith
Key personnel—R Tavendale, K Barrett, C Brown
Former key personnel—I Crombie, M Kenicer
USA
Stanford Center for Research in Disease Prevention, Stanford, California
Principal Investigator—SP Fortmann
Key personnel—A Varady, M Hull, JW Farquhar
Yugoslavia
Health Centre "Novi Sad", Novi Sad
Principal Investigator—M Planojevic
Former Principal Investigator—D Jakovljevic
Key personnel—A Svircevic, M Mirilov, T Strasser

II MONICA MANAGEMENT CENTRE—GENEVA
World Health Organization, Geneva
Responsible Officer—I Gyarfas
Former Responsible Officers—Z Pisa, SRA Dodu, S Böthig
Key personnel—I Martin, MJ Watson, M Hill

III MONICA DATA CENTRE—HELSINKI
National Public Health Institute, Helsinki, Finland
Responsible Officer—K Kuulasmaa
Former Responsible Officer—J Tuomilehto
Key personnel—A-M Koivisto, A Molarius, V Moltchanov, E Ruokokoski

IV MONICA STEERING COMMITTEE
A Evans (Chair), M Hobbs (Chair Publications SubCommittee), M Ferrario, H Tunstall-Pedoe (Rapporteur), I Gyarfas, K Kuulasmaa, A Shatchkute (WHO, Copenhagen),
Consultants—A Dobson, Z Pisa, and OD Williams

IV PREVIOUS STEERING COMMITTEE MEMBERS
S Sans, F Gutzwiller, SP Fortmann, A Menotti, P Puska, SL Rywik, U Keil, R Beaglehole, former chiefs of CVD/HQ, Geneva, V Zaitsev, J Tuomilehto
Former Consultants—MJ Karvonen, RJ Prineas, M Feinleib, FH Epstein