Cigarette Smoking Is Associated with Unhealthy Patterns of Nutrient Intake: a Meta-analysis[1,2]

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ABSTRACT The aim of this investigation was to assess the relationship between smoking status and nutrient intakes using a meta-analysis. Publications in English were sought through a Medline search using the following key words: food habits, eating, feeding behavior, diet, food, nutrition, nutritional status or assessment, tobacco use disorder, tobacco, nicotine and smoking. Scanning relevant reference lists of articles and hand searching completed the data collection. No attempt was made to search for unpublished results. Paper selection was based on nutritional surveys including comparisons of smokers with nonsmokers. Fifty-one published nutritional surveys from 15 different countries with 47,250 nonsmokers and 35,870 smokers were used in the analysis. The estimates of size effects were calculated with the mean and variance values of each nutrient intake and the size of the sample. Smokers declared significantly (all $P < 10^{-5}$) higher intakes of energy (+4.9%), total fat (+3.5%), saturated fat (+8.9%), cholesterol (+10.8%) and alcohol (+77.5%) and lower intakes of polyunsaturated fat (−6.5%), fiber (−12.4%), vitamin C (−16.5%), vitamin E (−10.8%) and β-carotene (−11.8%) than nonsmokers. Protein and carbohydrate intakes did not differ between smokers and nonsmokers. There was no evidence of heterogeneity among studies. In conclusion, the nutrient intakes of smokers differ substantially from those of nonsmokers. Some of these differences may exacerbate the deleterious effects of smoke components on cancer and coronary heart disease risk. J. Nutr. 128: 1450–1457, 1998.

KEY WORDS: • *nutrition* • *smoking* • *tobacco* • *coronary heart disease* • *cancer*

In industrialized countries, cigarette smoking is a major cause of preventable disease and premature death (Department of Health and Human Services 1989, Lakier 1992, Phillips et al. 1996, Thun et al. 1995). Several studies have shown anthropometric and biological heterogeneity between smokers and nonsmokers (Blair et al. 1980, Craig et al. 1989, Goldbourt and Medalie 1975, Klesges et al. 1989). These differences may be the consequence of the effects of smoke components on various metabolic reactions (Craig 1993, Jensen et al. 1995, Morrow et al. 1995) or may depend on different behaviors or lifestyles in smokers and nonsmokers (Blair et al. 1980, Goldbourt and Medalie 1975, Revicki et al. 1991, Woodward et al. 1994). The assessment of nutritional habits in population studies has demonstrated that smokers and nonsmokers differ in the way they select their food (Midgette et al. 1993, Preston 1991, Subar and Harlan 1993). These studies were conducted in countries with different cultures and lifestyles, thus adding to the already important variability of the nutrient intakes in the population. The aim of this analysis is to assess the relationship between smoking status and nutrient intake using the powerful tool of the meta-analysis. This technique absorbs part of the background variability and therefore, in our view, appears to be suitable for the transcultural comparisons of nutrient intakes.

MATERIALS AND METHODS

Studies. The publications included in this analysis were those that examined the association between energy and nutrient intakes and smoking status. The inclusion criteria were as follows: nutritional surveys including comparisons of smokers to nonsmokers. Nutrients had to be presented as quantitative variables in weight units. Only published articles written in English were recorded. Publications were sought through a Medline search, scanning relevant reference lists of articles and hand searching in published papers that were surveyed (list available on request). No attempt was made to search for unpublished results. Only the most recently published study with the largest number of subjects from the same survey was included in the analysis. When the values of heavy smokers were available for statistical calculations, they were used instead of those of unspecified groups of smoker. Similarly, the data

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from nonsmokers or never-smokers were selected as a control. Nutritional surveys were made with 3- to 7-d food records, 24-h recalls or records, food-frequency questionnaires or dietary histories. In certain studies, special questionnaires were used to assess alcohol consumption. Total energy intake was used where expressed in calories or Joules. The nutritional variables (protein, carbohydrate, lipid, alcohol, saturated fat, polyunsaturated fat, cholesterol, fiber, vitamin C, β-carotene, vitamin E, iron and calcium) were analyzed only when available in mass per unit time. Intakes of protein, lipids, carbohydrates and alcohol expressed as a percentage of total energy were not selected for statistical analysis. Mean values were adjusted for covariates in five studies. When necessary, the standard deviation was calculated from the standard error or 95% confidence interval of the mean for the purpose of the study.

The exclusion criteria included the following: unpublished papers, articles written in any language other than English, old data (updated in more recent selected publications) and repeated studies with a smaller number of subjects. Other publications were rejected because of missing information (variance or number of subjects) for the statistical analysis, or where data were presented in percentage of total energy or nonconventional units (drinks or frequency of intake). The list of the rejected papers is presented in the Appendix. In addition, in a subsample analysis, we excluded a total of 15 studies based on the following criteria: selected populations (pregnant women or adolescents) and dietary assessment based on a 24-h recall.

Data collected. A total of 51 studies (67 samples) was included and analyzed in the present meta-analysis. The following information was collected from each paper: population characteristics (gender, origin of the sample, age), sampling methodology, type of dietary investigation, statistical analysis, size of the sample, means and standard deviations of energy and nutrients, and smoking status (smokers, heavy smokers, never-smokers and nonsmokers).

Statistical method. Differences between nutrient intakes of smokers and non-smokers were expressed as the proportion of pooled SD:

$$Z_i = (M_{smoi} - M_{non\text{-}smoi})/SD_i$$

where M_{smoi} and $M_{non\text{-}smoi}$ represent the mean value of a given nutrient in smoker and nonsmoker groups of the same study. SD_i, the pooled standard deviation of each nutrient was calculated for each study as follows:

$$SD_i = [[((n_{non\text{-}smoi} - 1) \cdot SD^2_{non\text{-}smoi}) + ((n_{smoi} - 1) \cdot SD^2_{smoi})]/[n_{non\text{-}smoi} + n_{smoi} - 2]]^{1/2}$$

where n_{smoi} and $n_{non\text{-}smoi}$ represent the number of smokers and nonsmokers in each study for a given nutrient; SD_{smoi} and $SD_{non\text{-}smoi}$ are the standard deviations of the mean value of the given nutrient. The mean Z-score difference, 95% confidence interval and homogeneity of the data were assessed as previously described (Hedges and Olkin 1985). To this end, each study was weighted by W_i:

$$W_i = [(n_{smoi} \cdot n_{non\text{-}smoi})/(n_{smoi} + n_{non\text{-}smoi})]/\textstyle\sum_1^N[(n_{smoi} \cdot n_{non\text{-}smoi})/(n_{smoi} + n_{non\text{-}smoi})]$$

and the mean Z-score was calculated by the following:

$$\text{mean Z-score} = \textstyle\sum_1^N (Z_i \cdot W_i)$$

This strategy permits normalization of the data and statistical evaluation of the differences between smokers and nonsmokers.

To quantitatively assess the differences in nutrient intakes between smokers and nonsmokers, the mean percentage difference for a given nutrient was calculated after weighting each percentage difference by the number of subjects of the sample as follows:

$$\text{percentage difference} = [\textstyle\sum_1^N [((M_{smoi} - M_{non\text{-}smoi})/M_{non\text{-}smoi}) \times (n_{smoi} + n_{non\text{-}smoi})]]/[N_{smo} + N_{non\text{-}smo}]$$

where N_{smo} and $N_{non\text{-}smo}$ are the sum of n_i for a given nutrient.

RESULTS

The total number of subjects varied according to the nutrient that was analyzed (**Table 1**). Samples originated from 15 countries. In a few instances, samples were taken from selected groups of subjects: pregnant women ($n = 6$), adolescents ($n = 3$), manual and non-manual workers ($n = 1$).

The relationships between smoking status and total energy, fat, protein, carbohydrate, alcohol and fiber intakes are presented as Z-score differences for each individual study (**Fig. 1**). Smokers reported higher intakes of total energy, fat and alcohol than nonsmokers in 69.2% (36/52), 68.6% (24/35) and 100% (29/29) of the studies, respectively. This difference was particularly clear for alcohol. In all studies reporting alcohol intake, it was higher in smokers than in nonsmokers. In contrast, protein and carbohydrate consumption were evenly distributed around a Z-score of 0. Fiber intake was lower in smokers than in nonsmokers in 93.7% (30/32) of the studies. Saturated fat and cholesterol intakes were higher in smokers than in non-smokers in 87.5% (21/24) and 89.5% (17/19), respectively, and polyunsaturated fat intake was lower in smokers in 62.5% (10/16) of the studies, suggesting an association between fatty acid composition of the diet, cholesterol consumption and smoking status (**Fig. 2**). The intakes of vitamins C, E and β-carotene were lower in smokers than in nonsmokers in 88.9% (24/27), 61.5% (8/13) and 100% (15/15) of the studies, respectively (Fig. 2).

The mean Z-score difference was significant and positive ($P < 10^{-5}$) for total energy, fat, saturated fat, cholesterol and alcohol, suggesting that smokers declared significantly greater intakes of these nutrients than nonsmokers (**Table 2**). In contrast, the mean Z-score differences of polyunsaturated fat, fiber, vitamin C, vitamin E, β-carotene, iron ($P < 10^{-5}$) and calcium ($P = 0.0002$) intakes were significant and negative, indicating lower intakes of these nutrients in smokers compared with nonsmokers. Finally, the mean Z-score differences of total protein and carbohydrate were not significantly different from 0, suggesting that smokers reported an intake of these macronutrients similar to that of nonsmokers.

The weighted percentage difference in total energy equaled 4.9% between smokers and nonsmokers. This increase was accounted for by a 3.5 and 77.5% difference in total fat and alcohol intake, respectively, in smokers compared with nonsmokers. The consumption of fiber and antioxidant vitamins was on average between 10 and 20% lower in smokers than in nonsmokers (Table 2).

There was no evidence of heterogeneity among studies for each variable. In addition, to avoid the potential bias related to selected samples or to nutritional assessment methods, the analysis was repeated on a subsample (excluding pregnant women and adolescents) and intakes measured by the 24-h recall method. This analysis yielded qualitatively the same results as for the entire group for each nutrient. Finally, analyses were performed separately in men and women (excluding pregnant women) for energy, fat, protein, carbohydrate, alcohol, fiber and vitamin C. The mean Z-score differences in both genders were consistent with those of the whole group.

DISCUSSION

This study shows that smokers have unhealthy patterns of nutrient intake compared with nonsmokers and that these habits are homogeneous among studies despite extreme variability in food intake habits in different countries. On aver-

TABLE 1

Characteristics of studies for meta-analysis[1]

Author	Country	Dietary assessment	Alcohol assessment	Status	Number	Type of sample
Albanes et al. 1987	USA	24-h	—	non/smo	4959/4104	Men
Beser et al. 1995	Turkey	—	7-d quest.	non/hv	298/143	Men
Bolton-Smith et al. 1991	Scotland	FFQ	—	non/smo	117/79	Men
Bolton-Smith et al. 1993	Scotland	FFQ + weekly consumption	7-d recall	nev/smo	1122/1920	Men
″	″	″	″	″	2001/1844	Women
Bottoni et al. 1997	Italy	3-d FFQ	3-d FFQ	non/smo	71/49	Men
″	″	″	″	″	50/30	Women
Bui et al. 1992	Switzerland	Dietary history	—	non/smo	14/10	Men
Burke et al. 1997	Australia	2-d record	3-d record	non/smo	235/66	18-y-old men
″	″	″	″	″	214/72	18-y-old women
Cade and Margetts 1991	UK	24-h record	—	nev/smo	294/512	Men
″	″	″	″	″	574/427	Women
D'Avanzo et al. 1997	Italy	FFQ	—	nev/smo	1762/573	Women
Dallongeville et al. 1996	France	3-d record	3-d record	non/smo	89/82	Men
English et al. 1997	Australia	24-h recall	—	non/smo	1073/1024	Men
″	″	″	″	″	1894/785	Women
Facchini et al. 1992	USA	—	7-d quest	non/smo	20/20	Men/Women
Faruque et al. 1995	Bangladesh	7-d FFQ	—	nev/smo	44/44	Men
Fehily et al. 1984	Wales	7-d weighed	7-d weighed	non/smo	211/282	Men
Freeman et al. 1993	Scotland	—	Lifestyle quest.	nev/smo	90/66	Men/Women
Fulton et al. 1988	Scotland	7-d weighed	7-d weighed	non/smo	47/25	Men (non-manual)
″	″	″	″	″	38/52	Men (manual)
Giraud and Driskell 1994	USA	24-h recall + 2-d record	—	nev/smo	15/9	Men
Giraud et al. 1995 (a)	USA	24-h recall + 2-d record	—	nev/smo	11/23	Men
Giraud et al. 1995 (b)	USA	24-h recall + 2-d record	—	nev/smo	10/23	Men
Goldbourt and Medalie 1975	Israel	7-d FFQ + habits	—	nev/hv	3124/1916	Men
Haste et al. 1990	UK	7-d weighed	—	nev/smo	101/83	Pregnant
Jacobs et al. 1981	USA	24-h recall	—	nev/hv	51/22	Men 20–39 y
″	″	″		″	13/15	Men 40–59 y
″	″	″		″	83/9	Women 20–39 y
″	″	″		″	63/6	Women 40–59 y
Jensen et al. 1995	Switzerland	3-d FFQ	Daily self-report	nev/smo	13/14	Men
Keith and Mossholder 1986	USA	24-h recall ×2	—	non/smo	26/11	Adolescent girls
Klesges et al. 1990	USA	FFQ	—	non/smo	175/35	Men
Kos and Battig 1996	Switzerland	FFQ	—	non/smo	43/39	Men/Women
Larkin et al. 1990	USA	24-h recall	24-h recall	nev/smo	710/481	Women
Lupien et al. 1988	Canada	—	Standard quest.	nev/smo	200/524	Men
Margetts and Jackson 1993	UK	7-d weighed	7-day weighed	non/hv	631/153	Men
″	″	″	″	″	593/106	Women
Marks et al. 1991	USA	3-d record	—	nev/smo	21/29	Men
Marti et al. 1989	Finland	Fatty food quest.	7-d recall	non/smo	2779/1729	Men/Women 1982
″	″	″	″	″	1911/1002	Men/Women 1987
McKenzie-Parnell et al. 1993	New Zealand	3-d weighed	—	non/smo	68/27	Pregnant
Mc Phillips et al. 1994	USA	FFQ	FFQ	non/smo	402/230	Men
″	″	″	″	″	613/363	Women
Midgette et al. 1993	Australia	FFQ	FFQ	nev/hv	273/40	Women
Moffatt and Owens 1991	USA	3-d record	—	nev/smo	10/8	Men/Women
Muscati et al. 1996	Canada	Dietary history + 3 day weighed	—	non/smo	601/729	Pregnant
Nuttens et al. 1992	France	3-d record	3-d record	non/hv	687/95	Men
Papoz et al. 1982	France	7-d FFQ	—	nev/smo	334/103	Pregnant
Perkins et al. 1993	USA	24-h recall	7-d quest.	nev/smo	224/143	Women
Picone et al. 1982	USA	24-h recall ×5	—	non/smo	28/32	Pregnant
Robinson and York 1986	UK	7-d weighed ± 24h recall	—	non/smo	8/8	Women
Schectman et al. 1989	USA	24-h recall + 3 month FFQ	—	nev/hv	4815/1288	Men/Women
Stamford et al. 1984	USA	4-d record	4-d record	nev/smo	199/70	Men
Strain et al. 1991	Northern Ireland	7-d weighed	7-d weighed	non/smo	147/111	Men
″	″	″	″	″	200/132	Women
Ström et al. 1996	Sweden	Dietary history	—	non/smo	88/167	Men
Thompson et al. 1993	UK	FFQ	—	nev/smo	76/159	Men
″	″	″	″	″	217/228	Women
Tillotson et al. 1981	USA	24-h recall	—	non/smo	4460/7866	Men
Troisi et al. 1991	USA	FFQ	FFQ	nev/smo	235/81	Men
Trygg et al. 1995	Norway	3-d record	—	non/smo	370/451	Pregnant
Woodward et al. 1994	Scotland	FFQ	FFQ	non/smo	2152/2615	Men
″	″	″	″	″	2744/1980	Women
Zondervan et al. 1996	The Netherlands	FFQ	—	nev/hv	630/265	Men
″	″	″	″	″	924/270	Women

[1] Abbreviations used: FFQ, food-frequency questionnaire; quest., questionnaire; nev, never smokers; non, never smokers + ex-smokers; smo, smokers; hv, heavy smokers; manual, blue collar workers; non-manual, white collar workers.

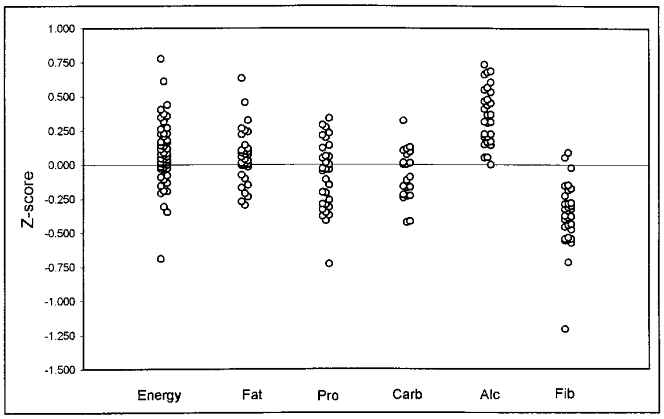

FIGURE 1 Standardized difference (Z-score) of energy, fat (Fat), protein (Pro), carbohydrate (Carb), alcohol (Alc) and fiber (Fib) intakes between smokers and nonsmokers. Each circle represents the Z-score of an individual study. Positive Z-score differences indicate higher and negative differences indicate lower reported intakes in smokers than in nonsmokers.

age, smokers declared consuming more fat (+3.5%) and more alcohol (+77.5%) than nonsmokers, resulting in a greater energy intake (+4.9%). Smokers also reported greater intakes of saturated fat (+8.9%) and cholesterol (+10.8%) and lesser intakes of polyunsaturated fat (−6.5%) and fiber (−12.4%). Moreover, the reported consumption of antioxidants, vitamin C (−16.5%), vitamin E (−10.8%) and β-carotene (−11.8%), was lower among smokers than nonsmokers. These associations were not different among studies. Such nutritional habits are compatible with a greater risk of cancer (Byers and Guerrero 1995, Shils and Young 1988) and coronary heart disease (Buring and Hennekens 1997, Kohlmeier and Hastings 1995, NCEP 1993, Willet 1990). Thus, smokers reported specific food intake patterns that may aggravate their smoking-related risk of cancer and coronary heart disease.

Several epidemiologic studies have shown anthropometric and biological differences between smokers and nonsmokers (Blair et al. 1980, Craig et al. 1989, Goldbourt and Medalie 1975, Klesges et al. 1989). These differences may result in part from behavioral differences such as peculiar food choices in smokers that have been described in a number of studies (Table 1). The present meta-analysis permits the overall estimation of the relationship between smoking status and nutritional intakes. Accordingly, the consistency of the difference in intake of a number of nutrients among population samples with different cultural environments suggests, although does not prove, a causal association between smoking and specific food choices. Alternatively, the associations reported in this study may be the consequence of publisher policy bias toward positive results (Chalmers and Altman 1995), although we believe that this effect is small in this study because many variables were assessed in the each survey.

Cigarette smoking is closely associated with the development and progression of cancer and coronary heart disease and increased mortality (Department of Health and Human Services 1989, Lakier 1992, Phillips et al. 1996, Thun et al. 1995). Such association is dependent on the effects of smoke components on cancer induction (Duthie et al. 1995), lipoprotein metabolism (Craig et al. 1989, Craig 1993) and lipid peroxidation (Morrow et al. 1995). This meta-analysis demonstrates that smokers also differ from nonsmokers in nutrient intake. Epidemiological evidence demonstrates a positive relationship between elevated alcohol, fat, saturated fat and cholesterol intakes and risk of cancer and/or coronary heart disease (NCEP 1993, Shils and Young 1988, Willet 1990). Inverse associations between antioxidant vitamin or fiber intakes and these diseases have also been shown (Buring and Hennekens 1997, Byers and Guerrero 1995, Kohlmeier and Hastings 1995, Shils and Young 1988). Thus, the observed differences between smokers and nonsmokers may exacerbate the effect of smoke components on the genesis and progression of cancer and coronary heart disease. Moreover, smoking by itself increases the requirements for various antioxidant vitamins such as vitamin C (Preston 1991), further compounding these risks.

The connection between smoking and dietary intake is extremely complex. Nicotine, the most characteristic of tobacco components, is a highly toxic alkaloid that is both a ganglionic stimulant and a depressant (Benowitz 1988). Many of its complex effects are mediated by the release of catecholamines. Recent studies have demonstrated that tobacco smoke exposure is associated with a marked reduction in monoamine oxidase, an enzyme that is associated with mood function (Fowler et al. 1996). It is conceivable that such effects result in dysregulation of appetite or attitudes toward food (Grunberg 1986). Others have suggested that modifications of taste related to smoking may lead smokers to prefer certain foods (Grunberg 1982). Particular food choices might also correspond to a generally unhealthy lifestyle a socio-economic status associated with smoking or a lack of nutrition knowledge (Goldbourt and Medalie 1975, Woodward et al. 1994). Finally, although it is possible that smokers and nonsmokers differ in the way in which they answer a food-frequency questionnaire, food record or dietary history, we believe that this hypothesis is unlikely.

In conclusion, the dietary habits of smokers are characterized by higher intakes of energy, total fat, saturated fat, cholesterol and alcohol and by lower intakes of antioxidant vitamins and fiber, compared with nonsmokers. Such a nutrient profile may exacerbate the risk of coronary heart disease and cancer associated with smoking. The results of this study indicate that any public health preventive action toward smokers should

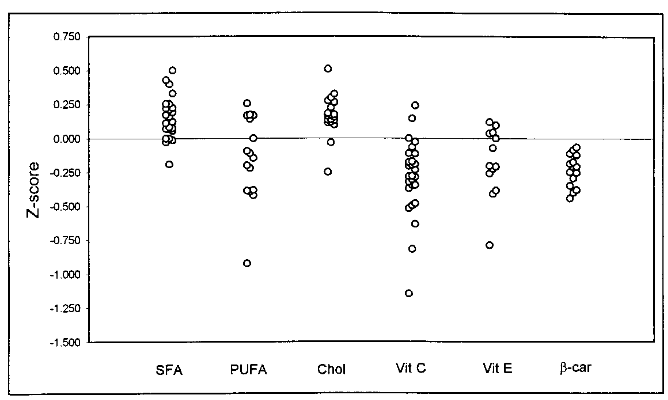

FIGURE 2 Standardized difference (Z-score) of saturated (SFA) and polyunsaturated (PUFA) fatty acids, cholesterol (Chol), vitamin C (Vit C), vitamin E (Vit E) and β-carotene (β-car) intakes between smokers and non-smokers. Each circle represents the Z-score of an individual study. Positive Z-score differences indicate higher and negative differences indicate lower reported intakes in smokers than in nonsmokers.

TABLE 2

Weighted difference in percentage of intakes between smokers and nonsmokers. Number of samples and subjects used in the meta-analysis and mean Z-score (95% confidence interval) of the various nutrient intakes

	% Difference smokers/nonsmokers	Number of samples	Smokers/Nonsmokers	Mean Z-score	95% Confidence interval	$P<$
Energy	4.9%	52	26435/30435	0.138	(0.122, 0.154)	10^{-5}
Fat	3.5%	31	13216/19685	0.072	(0.050, 0.094)	10^{-5}
Saturated fat	8.9%	27	11748/18644	0.170	(0.147, 0.193)	10^{-5}
Polyunsaturated fat	−6.5%	24	6286/9470	−0.143	(−0.175, −0.111)	10^{-5}
Cholesterol	10.8%	21	15211/15907	0.203	(0.180, 0.225)	10^{-5}
Protein	0.3%	35	10113/15583	0.001	(−0.024, 0.026)	NS[1]
Carbohydrate	−0.3%	32	5334/9907	−0.030	(−0.063, 0.003)	NS
Fiber	−12.4%	19	11640/18431	−0.338	(−0.362, −0.315)	10^{-5}
Vitamin C	−16.5%	18	10425/18248	−0.257	(−0.281, −0.233)	10^{-5}
Vitamin E	−10.8%	15	7099/9676	−0.185	(−0.216, −0.154)	10^{-5}
β-Carotene	−11.8%	16	7910/11760	−0.140	(−0.169, −0.111)	10^{-5}
Alcohol	77.5%	29	10756/16076	0.349	(0.325, 0.374)	10^{-5}
Iron	−7.5%	15	3783/7688	−0.205	(−0.244, −0.166)	10^{-5}
Calcium	−4.1%	13	3029/5183	−0.112	(−0.157, −0.067)	0.0002

[1] NS, nonsignificant, $P > 0.001$.

aim not only at suppressing tobacco use, but also at promoting better nutritional habits.

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APPENDIX: NONSELECTED PAPERS AND REASONS FOR EXCLUSION

Duplicate studies

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Aberrant value of alcohol in the sample of women

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