Association between cigarette smoking and abdominal obesity among Austrian bank employees

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Complete List of Authors:	de Oliveira Fontes Gasperin, Lizia; University of Vienna, Department of Nutritional Sciences Neuberger, Manfred; Inst Environmental Health, Preventive Medicine; Austrian Academy of Science, Clean Air Commission Tichy, Alexander; University of Veterinary Medicine, Platform Bioinformatics and Biostatistics Moshammer, Hans; Medical University Vienna, Inst. Environmental Health
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Title Page

Association between cigarette smoking and abdominal obesity among Austrian bank employees

Running title: Cigarette smoking and abdominal obesity

Authors:

1) de Oliveira Fontes Gasperin, Lizia (Dr.)

Department of Nutritional Sciences – University of Vienna, Vienna, Austria

2) Neuberger, Manfred (o. Univ. Prof. Dr.)

Institute of Environmental Health – Medical University of Vienna, Vienna, Austria

3) Tichy, Alexander (Dr.)

Platform Bioinformatics and Biostatistics

University of Veterinary Medicine, Vienna, Vienna, Austria

4) Moshammer, Hans (Priv. Doz. Dr.) (corresponding author)

Institute of Environmental Health – Medical University of Vienna, Vienna, Austria

Kinderspitalgasse 15

A-1090 Vienna, Austria

Phone: +43 1 40160 34935, fax: +43 1 40160 934903

E-mail: hanns.moshammer@meduniwien.ac.at

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ABSTRACT

Background: There is increasing evidence that smoking is associated with abdominal obesity and other risk factors for the metabolic syndrome. The aim of this study is to investigate these associations in a sample of healthy Austrian adults.

Methods: Data of 986 employees of an Austrian company (405 men and 581 women) obtained during their annual medical check-up at workplace were analysed. Information on body weight, height, body mass index (BMI), waist circumference, smoking status, education level, physical activity, diet, and biochemical parameters were obtained.

Results: No differences in total body fat and/or body fat distribution were found between non-smokers, smokers and former smokers; however among daily smokers the number of cigarettes smoked per day was significantly associated with higher body weight ($p = 0.001$) and BMI ($p = 0.009$). Male and female smokers had significantly higher counts of white blood cells (WBC) than non-smokers and former smokers. Heavy smokers also had a unhealthier lipid profile (lower HDL-cholesterol) and higher fasting glucose levels even after controlling for physical activity and calories intake.

Conclusion: Contrary to the beliefs of many smokers heavy smoking is associated with higher body weight and unfavourable metabolic changes.

Strengths and limitations of this study

- This is a cross-sectional study with all its inherent limitations. But the study included many participants with a similar occupational and socio-economic background and employed very detailed questionnaires on diet and physical activity. Dietary information was thoroughly checked by nutritional experts.
- Contrary to common believes smokers do not have less weight and smoking cessation does not necessarily lead to long-term weight gain.
- Heavy smokers even weigh more and display an unhealthy metabolic profile.
- Metabolic disorders in smokers could (partly) be explained by chronic systemic inflammation.

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INTRODUCTION

In Austria, approximately 27% of men and 19% of women aged 15 years and older are daily smokers. Whereas the smoking prevalence has decreased among men, it has increased among women and young people over the last 10 years.[1] Obesity and overweight have also increased over the last decade, reaching epidemic proportions.[2] The combination of smoking with obesity further increases the mortality, particularly from circulatory diseases.[3]

Adolescents, especially girls, often believe that smoking is an effective tool for weight control.[4] Similarly, smoking cessation has been associated with weight gain.[5] However, weight loss in smokers does not necessarily reflect a decrease in the fat mass, rather it may be caused by a reduction in the lean body mass [6] and heavy smokers were found to have higher body weight than light smokers.[7] Some studies reported that smoking is associated with abdominal obesity,[7] which would favour the development of metabolic syndrome, a cluster of risk factors for cardiovascular disease and type 2 diabetes mellitus (T2DM) that includes central obesity, dyslipidaemia, hyperglycaemia, and hypertension.[8, 9] Since other studies [10] failed to find a positive association between cigarette smoking and abdominal obesity, this issue is still controversial and remains to be elucidated.

The aim of this cross-sectional study was to investigate whether cigarette smoking is associated with increased abdominal obesity and related metabolic changes in a sample of healthy Austrian adults.

METHODS

Study population

Participants were recruited among employees in a financial institution based in Vienna. Once a year the employees undergo a health screening at the company. After information on the purpose of the study and its procedures, they were invited to participate. Two days before the medical examination they received a self-administered questionnaire, which was collected on the examination day. From 1 247 employees who filled in the questionnaires, 261 individuals were subsequently excluded: those who reported a history of cancer (20) or thyroid dysfunction (37), missing information on gender (3), age (1), anthropometric measurements (67), smoking status (80) and health status (24), pregnant women (3), individuals under nicotine replacement therapy at the time of the study (4), those with a body mass index (BMI)

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lower than 18.5 kg/m^2 or greater than 40 kg/m^2 (20), and those with a waist circumference (WC) lower than 60 cm (3). Data of 986 individuals (405 men and 581 women) aged 19–65 years were included in the final analyses. All participants signed an informed consent and the study protocol was in accordance with the Declaration of Helsinki. The study was approved by the Ethical Commission of the City of Vienna.

Anthropometric measurements

BMI was calculated as the ratio of weight in kilograms divided by the square of the height in meters (kg/m^2). WC and hip circumferences (HC) were measured using a non-elastic flexible tape, with participants in light clothing without shoes: WC at the top of the right iliac crest, at the end of a normal expiration; HC at the largest posterior extension of the buttocks.[11] Waist-to-hip ratio (WHR) was calculated as WC/HC, waist-to-height ratio (WHtR) as WC/height.

Lifestyle and Education

Participants who answered "no" to the following questions: "Have you ever smoked daily?", "Have you smoked at least 100 cigarettes, cigar, pipes or other tobacco products in your entire life?", "Do you smoke now?" were categorised as non-smokers. Individuals who reported smoking at the time of the enrolment or quitted less than one year before, where classified as smokers. Smokers included both occasional (<1 cigarette per day) and daily smokers (≥1 cigarette per day). Daily smokers were further sub-grouped into light smokers (1–10 cigarettes per day), moderate smokers (11–20 cigarettes per day), and heavy smokers (>20 cigarettes per day). Former smokers were defined as individuals who used to smoke and quitted at least one year prior to their recruitment.

Information on physical activity was obtained by the short form of the International Physical Activity Questionnaire – IPAQ.[12] MET-minutes per week were then calculated according to the IPAQ scoring protocol, and participants were categorised into three PA levels: low, moderate, and high.[13] Dietary intake of food and beverages was obtained by means of self-administered 24-hour recalls, supported by instructions and a validated photographic manual [14] describing portion sizes.

Education was classified as "low" for compulsory education (9 years of schooling in Austria), equivalent to levels 1 and 2 of the International Standard Classification of Education (ISCED),

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"middle" for at least three years of additional schooling (ISCED levels 3 and 4) and "high" for a university degree (ISCED level 5 and 6).

Blood samples

Blood samples were taken by venipuncture after an overnight fast and collected into heparinized tubes. Complete blood count was performed automatically (Sysmex XT 2000i); fasting glucose (FG), total cholesterol (TC), HDL-cholesterol (HDL-C) and triacylglycerides (TAG) were also analysed by automated methods (Roche Modular, Roche Diagnostics, Vienna, Austria). Plasma LDL-cholesterol (LDL-C) was calculated using the Friedewald formula, (LDL-C = TC - HDL-C - TAG/5) for TAG levels lower than 400 mg/dL.[15] Blood analyses were available for 88% of men and 91% of women.

Statistical Analyses

Metric scaled variables are expressed as mean ± standard deviation (SD). Chi-square tests were used to compare frequency distributions of categorical variables. Pearson's correlation coefficients were used to characterize relationships between BMI and WC. For the univariate analyses, factor levels were compared using the Least Significant Difference (LSD) post-hoc procedure.

Multivariate analyses of variances (MANOVA) were performed to evaluate the impact of smoking status or number of cigarettes on the anthropometric and biochemical parameters. Comparisons between non-smokers, smokers and former smokers were performed separately for men and women. Smoking status and level of education were used as fixed factors. In the models where number of cigarettes per day was used, gender was added as a fixed factor.

Several general linear models (GLM) were used to evaluate the influence of possible confounders in the results. The level of complexity was increased stepwise by adding specific variables such as age, physical activity level, total energy intake, and the two indices of diet quality as covariates to the model. The result of the simplest model is presented, when *p*-values remained unchanged after correcting for the different covariates.

For all analyses a two-tailed *p*-value less than 5% ($p < 0.05$) was considered statistically significant. All statistical analyses were performed using the IBM SPSS version 20 (SPSS Inc., Chicago, IL, USA).

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In the linear regression models "number of cigarettes" was included as a categorical variable. When visual inspection indicated deviance from linearity a General Additive Model (GAM) using splines with 4 degrees of freedom for number of cigarettes per day was tested. The latter analyses were performed with STATA SE 12.1 (StataCorp, College Station, Texas 77845 USA).

RESULTS

Smokers of both sexes were younger than non-smokers and former smokers. Among men, the average ages of non-smokers, smokers and former smokers were 43 ± 9.5, 38.3 ± 10.8, and 45.9 ± 8.2 years, respectively. Differences between the three groups were statistically significant (non-smokers *versus* smokers: $p < 0.001$; non-smokers *versus* former smokers: $p = 0.016$; smokers *versus* former smokers: $p < 0.001$). Among women, non-smokers, smokers and former smokers aged on average 40.5 ± 8.7, 37.6 ± 10.1, and 42.4 ± 8.5 years, respectively. Smokers differed significantly from non-smokers ($p = 0.001$) and former smokers ($p < 0.001$).

The baseline characteristic of the participants, according to gender and smoking status are presented in **Table 1**, for men and in **Table 2**, for women. There were only few participants (five men and nine women) with a low level of education, therefore the low and medium levels were combined.

The anthropometric indices were highly correlated in both men and women. Among men, 67.4% of the variance in BMI was explained by WC ($r = 0.82$, $p < 0.001$). Among women, 68.7% of the variance in BMI was accounted for WC ($r = 0.83$, $p < 0.001$). In the whole sample (male and female together), the Pearson's correlation between WHR and BMI was $r = 0.46$, between WHtR and BMI was $r = 0.82$, between WHR and body weight was $r = 0.54$, and between WHtR and body weight was $r = 0.71$ ($p < 0.001$ for all correlations).

Among both men and women, no statistically significant differences were found between the three smoking groups regarding the anthropometric indices. The results did not change after excluding occasional smokers (<1 cigarette per day) from the group of smokers (data not shown).

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Among both men and women, fasting glucose, total cholesterol, LDL-C, ratio of total cholesterol to HDL-C, and LDL-C, did not differ significantly between non-smokers, smokers and former smokers, after controlling for age, physical activity and energy intake.

Among men, total WBC counts were significantly elevated in smokers, compared with non-smokers ($p < 0.001$) and former smokers ($p < 0.001$). The differences between the groups remained statistically significant after controlling for age, physical activity and energy intake (**Table 1**).

Among women, the total WBC were significantly higher in smokers, compared with both, non-smokers ($p < 0.001$) and former smokers ($p < 0.001$), and the differences remained significant after controlling for confounders. No differences in the total or differential WBC counts were found between female non-smokers and female former smokers (**Table 2**).

Characteristics of daily smokers, according to the number of cigarettes smoked per day

The mean ± SD number of cigarettes per day was 6.3 ± 3.3 for light smokers, 17.3 ± 2.8 for moderate smokers, and 28.8 ± 5.5 for heavy smokers.

Mean ± SD age of light smokers, moderate smokers, and heavy smokers were 37 ± 10.7, 39.3 ± 10.2, and 43.8 ± 7.4, respectively. Heavy smokers were significantly older than light smokers ($p = 0.023$). No significant differences in the average age at which participants started smoking were observed between the groups. However, they differed significantly ($p = 0.020$) regarding the years of smoking (light smokers: 18.9 ± 9.8 years; moderate smokers: 21.8 ± 9.9 years; heavy smokers: 24.7 ± 7.3 years).

The characteristics of daily smokers, according to the number of cigarettes smoked per day, are shown in **Table 3**.

In the unadjusted model, heavy smokers had significantly greater values of body weight ($p = 0.030$), BMI ($p = 0.003$), WC ($p = 0.032$), and HC ($p = 0.036$) than light and moderate smokers. After controlling for age, physical activity and energy intake, the significance remained only for body weight ($p = 0.009$) and BMI ($p = 0.023$).

Overweight and obesity were observed in 84.6% of heavy smokers, compared with 35.6% of light smokers and 33% of moderate smokers ($\chi^2 = 13.5$, $p = 0.001$).

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The results of the linear regression models for selected end-points are shown in **Table 4** including also the impact of physical activity (low, moderate, and high activity level), reported consumption of calories, education, age, and gender. A non-linear association for the numbers of cigarettes was evident for body weight, TAG, HDL-C, and fasting glucose (**Figure 1**) with strong adverse effects usually only seen in heavy smokers.

DISCUSSION

In the present study, no statistical differences in the mean values of body weight and BMI were found between non-smokers, smokers and former smokers. Likewise, no statistically significant differences in the patterns of abdominal obesity—assessed by WC, WHR, or WHtR—were found between the three groups.

However, among the male participants, physical activity was found to be negatively and independently associated with body weight, BMI, WC, WHR and WHtR, after controlling for age, smoking and energy intake (data not shown). Previous studies have also reported an independent association between activity scores and body fat distribution among European men, after adjustment for smoking.[16]

Although several studies found that smokers have lower body weight and BMI than non-smokers,[17, 18] the results in the literature are inconclusive. Our data are in accordance with previous studies which found no significant differences between smokers and non-smokers regarding those anthropometric indices.[19, 20] Differently from other findings [21-23] and in agreement with others,[24, 25] in our study smoking status was not significantly associated with increased abdominal obesity.

Smoking cessation is often accompanied by weight gain, especially among heavy smokers.[5, 26] In the present study, former smokers were not found to have significantly higher body weight or BMI than non-smokers or smokers. Recent quitters in this study were not included among former smokers. So this study at least indicates that any weight gain after smoking cessation is not permanent.

While smoking status per se had only little effect on anthropometric parameters, heavy smokers (>20 cigarettes per day) had significantly higher values of both body weight and BMI, compared with light (1–10 cigarettes per day) and moderate (11–20 cigarettes per day)

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smokers. The significance remained even after controlling for age, physical activity, and energy intake.

Possible explanations for a higher body weight/BMI among heavy smokers, compared with light smokers, are differences in personality [27] and some lifestyle characteristics [28] that may increase their risk of becoming overweight and obese.[29] They were reported to consume more alcohol, be less active and have a poorer diet, compared with light and moderate smokers.[30] It is possible that the higher consumption of alcohol among heavy smokers leads to a weight gain which is not observed in light and moderate smokers.[31]

Regarding the laboratory analyses, differences in the lipid profile, according to the smoking status, were found only in men, after controlling for age, physical activity and energy intake. In women, although the analyses were not controlled for menstrual cycle, controlling for the use of hormonal contraceptive or hormonal replacement therapy did not change the results (data not shown). Male smokers presented higher levels of TAG and lower levels of HDL-C. Effects of smoking were generally more pronounced in heavy smokers. In addition, the levels of fasting glucose increased significantly with the number of cigarettes smoked per day, and the significance remained after controlling for age, physical activity and energy intake.

Overall, neither smoking status nor smoking intensity was positively associated with the levels of total cholesterol or LDL-C. These serum lipid parameters seem to be little influenced by smoking.[32] However, other authors found a clear association of cigarette smoking with low levels of total cholesterol and LDL-C.[33] In the present study, lower levels of HDL-C were associated with smoking status in men after controlling for several confounders. Also number of cigarettes smoked as well as pack years (data not shown) were significantly and negatively correlated with HDL-C.

With respect to the levels of fasting glucose, no differences were observed between smokers, non-smokers and former smokers. However, heavy smokers (>20 cigarettes per day) showed significantly higher levels of fasting glucose compared with both light and moderate smokers. The significance persisted after controlling for age, physical activity and energy intake. The absolute mean values of fasting glucose increased in a graded manner according to the smoking intensity. These findings are of relevance, because in a large number of prospective studies cigarette smoking has been associated with a higher risk of T2DM,[34] especially in heavy smokers.[35]

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The crude and adjusted mean values of total and differential WBC counts were significantly higher in male and female smokers, compared with their non-smoking and former smoking counterparts. No differences were observed between non-smokers and former smokers, indicating a decrease in the WBC count after smoking cessation, close to the levels found in never-smokers. Signs of inflammation in smokers are maybe not surprising considering the strong inflammatory impact on the airways. But also systemic inflammatory diseases are associated with smoking.[36]

When smokers were categorised according to the number of cigarettes smoked per day, statistically significant differences in the total WBC counts were found between light and moderate smokers, after controlling for confounders. Although no significant differences were found between light and heavy smokers, it is important to observe that the absolute differences between the means of the WBC counts in light and moderate smokers were the same of that between light and heavy smokers. The latter has not achieved statistical significance probably due to the small number or heavy smokers in the sample, in comparison to light and moderate smokers.

Cigarette smoking is a well-known risk factor for atherosclerosis and cardiovascular disease (CVD), as discussed before, and it has been recognized as the single most important factor known to influence the WBC count.[37] The WBC count has been correlated with CVD and is considered a biomarker of inflammatory processes that contribute to endothelial dysfunction and atherosclerosis progression.[38]

This study has strengths and limitations. The strengths are the large sample size with a wide age range (19–65 years), and the use of validated questionnaires for the assessment of smoking status and lifestyle—including diet, education level, and physical activity. Therefore adjustment for important confounders could be performed.

The limitations were the cross-sectional design of the study—which does not allow one to infer about cause and effect—and the use of self-reported weight and height as a routine in annual health checks, which were controlled by measurement only if deviant from earlier data, however, which could introduce bias to the study. Studies have demonstrated the validity and reliability of self-reported height and weight in different study populations.[39] Moreover, self-reported BMI and measured WC were highly correlated in the present study, which suggests good quality of the present data.

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Similarly, cigarette smoking was also self-reported, which could lead to some misclassification of smoking status. However, the reliability of self-reported smoking as a reliable tool for the assessment of smoking status has been confirmed in the literature.[40]

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CONTRIBUTORSHIP STATEMENT

LF led the study as part of her doctoral thesis and she wrote most of the paper. MN and HM acted as Supervisors. HM also helped with the statistics. Most of the statistics were done by AT

CONFLICT OF INTEREST

All authors declare no conflict of interest.

DATA SHARING STATEMENT

I am not Aware of any additional unpublished data relevant to that study.

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WHAT IS ALREADY KNOWN ON THIS SUBJECT?

Smoking is detrimental to health causing respiratory and systemic inflammation, and toxic damage to many body tissues. Systemic inflammation is linked to metabolic disorders. On the other hand nicotine reduces appetite and suppresses the feeling of hunger.

WHAT THIS STUDY ADDS?

In this sample of healthy employees in Vienna, smoking status was not associated with total adiposity (body weight and BMI) or with patterns of central body fat distribution. This contradicts the common belief that smoking reduces body weight. Even more, the number of cigarettes smoked per day showed a positive association with total adiposity. A positive and significant association of smoking with dyslipidaemia and higher counts of total WBC were observed. The levels of fasting glucose also increased significantly with the number of cigarettes smoked per day. This altered metabolic profile in smokers can lead to several diseases, including diabetes, coronary heart disease, and cancer.

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FIGURE 1

a: Non-linear influence of cigarettes smoked per day on body weight, results of general additive model, spline function with 4 degrees of freedom.

b: Non-linear influence of cigarettes smoked per day on TAG, results of general additive model, spline function with 4 degrees of freedom.

c: Non-linear influence of cigarettes smoked per day on HDL-C, results of general additive model, spline function with 4 degrees of freedom.

d: Non-linear influence of cigarettes smoked per day on fasting glucose, results of general additive model, spline function with 4 degrees of freedom.

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TABLES

Table 1. Baseline characteristics of male participants according to the smoking status.

	Non-Smokers	Smokers	Former Smokers	*p*-value
Sample size, n (%)	180 (44.4)	122 (30.1)	103 (25.4)	
Height, cm	179.8 ± 5.9	179 ± 5.7	179 ± 7.1	0.560 †
Body weight, kg	81.3 ± 10.9	81.5 ± 11.9	83.7 ± 11.2	0.777 †
BMI, kg/m^2	25.1 ± 3.0	25.3 ± 3.3	26.1 ± 3.5	0.634 †
WC, cm	92.2 ± 9.5	92.1 ± 10.1	94.6 ± 9.4	0.911 †
HC, cm	99.0 ± 7.4	98.6 ± 7.2	99.7 ± 7.6	0.895 †
WHR	0.931 ± 0.07	0.932 ± 0.06	0.950 ± 0.08	0.466 †
WHtR	0.524 ± 0.06	0.520 ± 0.06	0.540 ± 0.06	0.827 †
Fasting glucose, mMol	4.6 ± 0.6	4.5 ± 1.0	4.6 ± 0.5	0.217 †
Total cholesterol, mMol	5.6 ± 1.0	5.5 ± 1.1	5.6 ± 0.9	0.683 †
HDL-C, mMol	1.4 ± 0.3	1.4 ± 0.4	1.5 ± 0.3	0.025 †
LDL-C, mMol	3.6 ± 0.9	3.5 ± 0.9	3.6 ± 0.8	0.990 †
Triacylglycerols, mMol	1.3 ± 0.7	1.5 ± 1.0	1.4 ± 1.0	0.006 †
TC to HDL-C ratio	4.2 ± 1.2	4.3 ± 1.3	4.1 ± 1.2	0.098 †
Total WBC, G/L[(a,b)]	6.2 ± 1.4	7.1 ± 1.9	6.3 ± 1.2	0.009 †
Energy intake, kJ	9 306 ± 2 334	9 402 ± 1 865	9 411 ± 2 355	0.941 ‡
Physical activity (%)				
Low	33.5	33.0	29.1	0.902 §
Medium	46.5	48.9	47.7	
High	20.0	18.1	23.3	
Education level				
Medium	57.2	77.0	26	0.688 §
High	42.8	23.0	103	

BMI: body mass index; WC: waist circumference; HC: hip circumference; WHR: waist-to-hip ratio; WHtR: waist-to-height ratio. HDL-C: high-density lipoprotein cholesterol; LDL-C: low-density lipoprotein cholesterol WBC: white blood cells; G/L: 1x10^9 cells/L. Values are shown as mean ± SD; †p-value determined by multivariate ANOVA and adjusted for age, physical activity, and energy intake. ‡p-value determined by multivariate ANOVA and adjusted for age. LSD was the post-hoc procedure. (a): statistically significant differences between non-smokers and smokers; (b): statistically significant differences between smokers and former smokers; §p-values analysed using Chi-Square Test.

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Table 2. Baseline characteristics of female participants according to the smoking status.

	Non-Smokers	Smokers	Former Smokers	*p*-value
Sample size, n (%)	276 (47.5)	181 (31.2)	124 (21.3)	
Height, cm	166.8 ± 5.7	166.3 ± 6.0	167.6 ± 5.7	0.246 †
Body weight, kg	65.6 ± 11.0	65.3 ± 10.4	68.1 ± 12.7	0.610 †
BMI, kg/m^2	23.6 ± 3.8	23.6 ± 3.4	24.2 ± 4.2	0.637 †
WC, cm	83.4 ± 10.2	83.4 ± 9.9	85.2 ± 12.7	0.467 †
HC, cm	97.2 ± 9.5	96.6 ± 8.6	98.1 ± 11.4	0.857 †
WHR	0.858 ± 0.06	0.863 ± 0.06	0.867 ± 0.06	0.332 †
WHtR	0.494 ± 0.06	0.499 ± 0.06	0.505 ± 0.08	0.374 †
Fasting glucose, mMol	4.4 ± 0.9	4.3 ± 0.7	4.4 ± 0.7	0.097 †
Total cholesterol, mMol	5.5 ± 1.0	5.4 ± 1.0	5.4 ± 0.9	0.318 †
HDL-C, mMol	1.8 ± 0.4	1.7 ± 0.4	1.8 ± 0.4	0.177 †
LDL-C, mMol	3.2 ± 0.9	3.3 ± 0.9	3.2 ± 0.8	0.510 †
Triacylglycerols, mMol	1.0 ± 0.4	1.1 ± 0.6	1.0 ± 0.4	0.448 †
TC to HDL-C ratio	3.1 ± 0.8	3.5 ± 1.1	3.2 ± 0.8	0.083 †
Total WBC, G/L[(a,b)]	6.4 ± 1.5	7.7 ± 2.1	6.3 ± 1.8	<0.001 †
Energy intake, kJ	7 647 ± 1 777	6 989 ± 1 806	7 383 ± 1 999	0.008 ‡
Physical activity (%)				
low	33.3	26.5	24.2	0.019 §
medium	43.5	60.3	52.6	
high	23.1	13.2	23.2	
Education level (%)				
medium	75.3	90	82.1	0.046 §
high	24.7	10	17.9	

BMI: body mass index; WC: waist circumference; HC: hip circumference; WHR: waist-to-hip ratio; WHtR: waist-to-height ratio. HDL-C: high-density lipoprotein cholesterol; LDL-C: low-density lipoprotein cholesterol WBC: white blood cells; G/L: 1x10^9 cells/L. Values are shown as mean ± SD; †p-value determined by multivariate ANOVA and adjusted for age, physical activity, and energy intake. ‡p-value determined by multivariate ANOVA and adjusted for age. LSD was the post-hoc procedure. (a): statistically significant differences between non-smokers and smokers; (b): statistically significant differences between smokers and former smokers; §p-values analysed using Chi-Square Test.

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Table 3. Baseline characteristics of daily smokers, according to the smoking intensity.

	Smoking Intensity			
	Light Smokers	**Moderate Smokers**	**Heavy Smokers**	***p*-value**
	(*n* = 135)	(*n* = 106)	(*n* = 13)	
Body weight, kg[b,c]	71.3 ± 13.6	70.8 ± 12.8	81.3 ± 18.0	0.009
BMI, kg/m^2[b,c]	24.2 ± 3.5	24.1 ± 3.5	27.5 ± 3.4	0.023
WC, cm	86.0 ± 11.4	86.9 ± 10.2	94.3 ± 11.7	0.059
HC, cm	96.5 ± 8.6	97.7 ± 8.0	102.6 ± 8.5	0.163
WHR	0.890 ± 0.08	0.890 ± 0.07	0.920 ± 0.07	0.280
WHtR	0.502 ± 0.06	0.508 ± 0.06	0.545 ± 0.05	0.266
FG, mMol[b,c]	4.3 ± 0.6	4.4 ± 0.8	5.3 ± 2.6	0.010
TC, mMol	5.4 ± 1.1	5.4 ± 1.0	5.6 ± 0.7	0.399
HDL-C, mMol	1.6 ± 0.4	1.5 ± 0.4	1.1 ± 0.3	0.057
LDL-C, mMol	3.3 ± 1.1	3.3 ± 0.9	3.6 ± 0.6	0.515
TC to HDL-C ratio[b,c]	3.6 ± 1.2	3.9 ± 1.2	5.5 ± 1.8	0.033
TAG, mMol[b,c]	1.1 ± 0.6	1.3 ± 0.7	2.5 ± 1.9	0.006
Total WBC, G/L[a]	7.0 ± 1.8	8.0 ± 2.3	8.0 ± 2.2	0.035

BMI: body mass index; WC: waist circumference; HC: hip circumference; WHR: waist-to-hip ratio; WHtR: waist-to-height ratio; FG: fasting glucose; TC: total cholesterol; TAG: triacylglycerols. Values are shown as mean ± SD; *p*-value determined by multivariate ANOVA and adjusted for age, physical activity and energy intake; LSD was the post-hoc procedure; (a): statistically significant differences between light and moderate smokers; (b): statistically significant differences between light and heavy smokers; (c): statistically significant differences between moderate and heavy smokers. Light smokers: 1–10 cigarettes per day; moderate smokers: 11–20 cigarettes per day; heavy smokers: >20 cigarettes per day.

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Table 4. Results of the multiple linear regressions (also controlled for age and education, not shown).

Coefficient	Body weight kg	BMI, kg/m^2	WC, cm	Total WBC, G/L	Fasting glucose, mMol	HDL-C, mMol	TAG, mMol
Females	**-5.3**	*-0.7*	**-4.3**	0.5	**-0.18**	**0.35**	**-0.32**
Body height cm	**0.8**	n.a.	**0.3**	n.a.	n.a.	n.a.	n.a.
Occasional smokers	-0.3	-0.2	-0.9	0.1	-0.03	-0.05	0.05
Light smokers	0.2	-0.1	-0.2	0.6	-0.09	**-0.12**	0.11
Moderate smokers	-1.3	-0.2	-0.9	1.3	-0.04	**-0.13**	0.13
Heavy smokers	**9.5**	**3.5**	*7.1*	**1.7**	**0.74**	**-0.55**	**0.85**
Moderate physical activity	-1.0	-0.5	-0.5	*-0.8*	-	0.04	*-0.09*
High physical activity	**-3.4**	**-1.2**	**-2.8**	-0.8	-	**0.12**	**-0.14**
Calories kJ/day	**10.5**	**3.4**	*8.4*	1.7	0.4	-0.2	0.1

BMI: body mass index; WC: waist circumference; WBC: white blood cells; HDL-C: high-density lipoprotein cholesterol; TAG: triacylglycerides; Occasional smokers: less than 1 cigarette per day; Light smokers: 1–10 cigarettes per day; moderate smokers: 11–20 cigarettes per day; heavy smokers: >20 cigarettes per day. All smoking categories compared to non-smokers. **Bold coefficients**: $p<0.01$; *italic coefficients*: $p < 0.05$. n.a.: not applicable (body height in the case of BMI and lab parameters); -: dropped from the model

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ABBREVIATIONS

BMI:	body mass index
CVD:	cardiovascular disease
FG:	fasting glucose
HC:	hip circumferences
HDL-C:	HDL-cholesterol
LDL-C:	LDL-cholesterol
TAG:	triacylglycerides
TC:	total cholesterol
T2DM:	type 2 diabetes mellitus
WBC:	white blood cells
WC:	waist circumference
WHR:	waist-to-hip ratio
WHtR:	waist-to-height ratio

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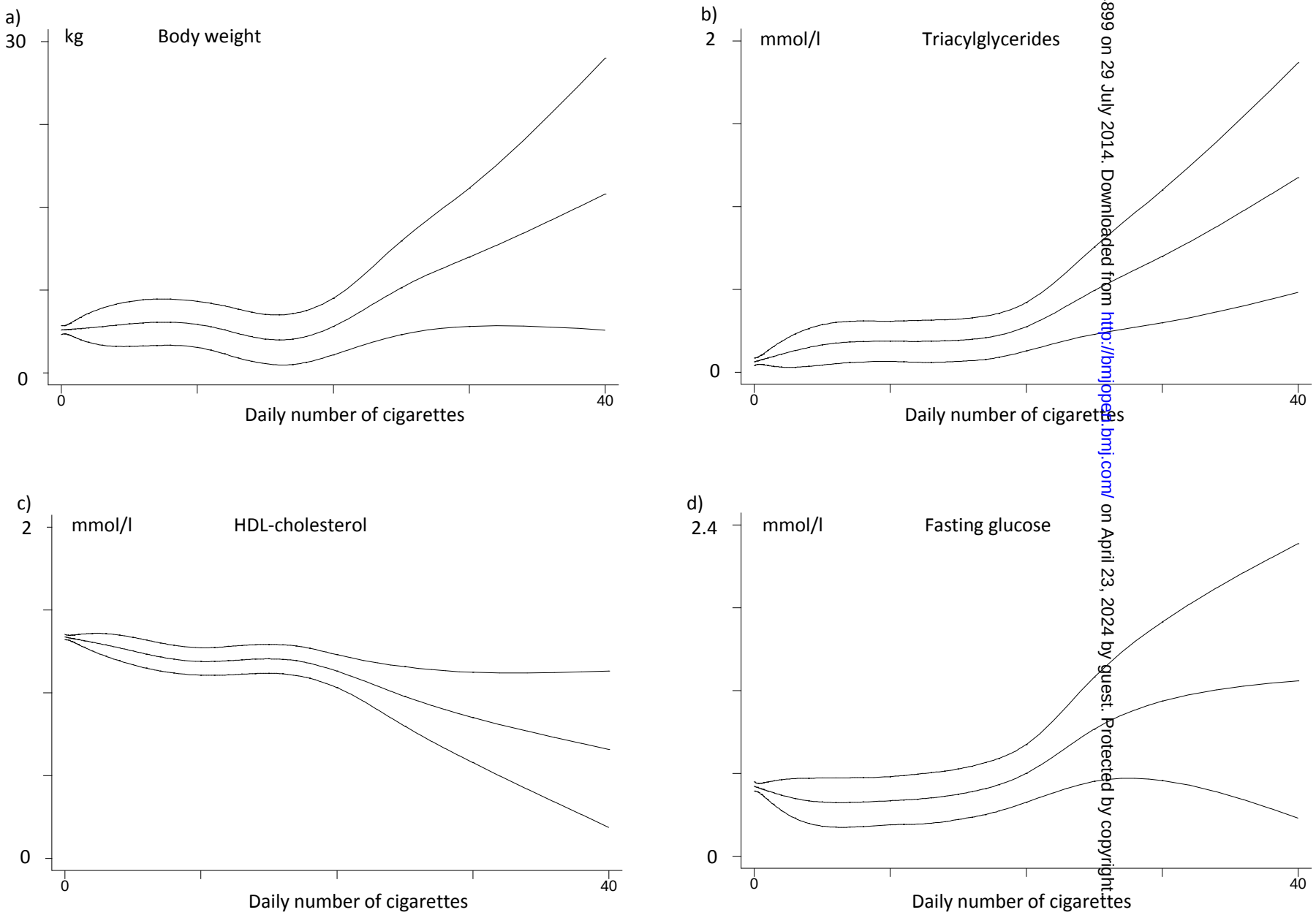

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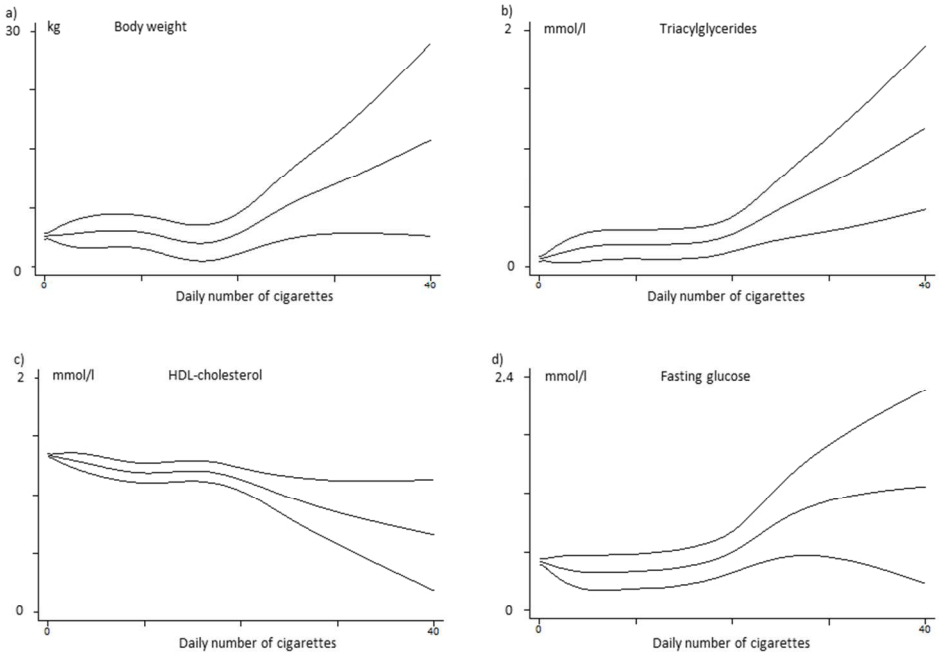

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STROBE Statement—checklist of items that should be included in reports of observational studies

	Item No	Recommendation
Title and abstract	1	(*a*) Indicate the study's design with a commonly used term in the title or the abstract - done
		(*b*) Provide in the abstract an informative and balanced summary of what was done and what was found- done
Introduction		
Background/rationale	2	Explain the scientific background and rationale for the investigation being reported- done
Objectives	3	State specific objectives, including any prespecified hypotheses- done
Methods		
Study design	4	Present key elements of study design early in the paper- done
Setting	5	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection
Participants	6	(*a*) *Cohort study*—Give the eligibility criteria, and the sources and methods of selection of participants. Describe methods of follow-up *Case-control study*—Give the eligibility criteria, and the sources and methods of case ascertainment and control selection. Give the rationale for the choice of cases and controls *Cross-sectional study*—Give the eligibility criteria, and the sources and methods of selection of participants- done
		(*b*) *Cohort study*—For matched studies, give matching criteria and number of exposed and unexposed *Case-control study*—For matched studies, give matching criteria and the number of controls per case
Variables	7	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable- done
Data sources/ measurement	8*	For each variable of interest, give sources of data and details of methods of assessment (measurement). Describe comparability of assessment methods if there is more than one group- done
Bias	9	Describe any efforts to address potential sources of bias- done
Study size	10	Explain how the study size was arrived at
Quantitative variables	11	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why- done
Statistical methods	12	(*a*) Describe all statistical methods, including those used to control for confounding- done
		(*b*) Describe any methods used to examine subgroups and interactions
		(*c*) Explain how missing data were addressed
		(*d*) *Cohort study*—If applicable, explain how loss to follow-up was addressed *Case-control study*—If applicable, explain how matching of cases and controls was addressed *Cross-sectional study*—If applicable, describe analytical methods taking account of sampling strategy
		(*e*) Describe any sensitivity analyses

Continued on next page

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Results		
Participants	13*	(a) Report numbers of individuals at each stage of study—eg numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analysed
		(b) Give reasons for non-participation at each stage
		(c) Consider use of a flow diagram
Descriptive data	14*	(a) Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders- done
		(b) Indicate number of participants with missing data for each variable of interest- done
		(c) *Cohort study*—Summarise follow-up time (eg, average and total amount)
Outcome data	15*	*Cohort study*—Report numbers of outcome events or summary measures over time
		Case-control study—Report numbers in each exposure category, or summary measures of exposure
		Cross-sectional study—Report numbers of outcome events or summary measures- done
Main results	16	(*a*) Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (eg, 95% confidence interval). Make clear which confounders were adjusted for and why they were included- done
		(*b*) Report category boundaries when continuous variables were categorized- done
		(*c*) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period
Other analyses	17	Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses
Discussion		
Key results	18	Summarise key results with reference to study objectives- done
Limitations	19	Discuss limitations of the study, taking into account sources of potential bias or imprecision. Discuss both direction and magnitude of any potential bias- done
Interpretation	20	Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence- done
Generalisability	21	Discuss the generalisability (external validity) of the study results
Other information		
Funding	22	Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based

*Give information separately for cases and controls in case-control studies and, if applicable, for exposed and unexposed groups in cohort and cross-sectional studies.

Note: An Explanation and Elaboration article discusses each checklist item and gives methodological background and published examples of transparent reporting. The STROBE checklist is best used in conjunction with this article (freely available on the Web sites of PLoS Medicine at http://www.plosmedicine.org/, Annals of Internal Medicine at http://www.annals.org/, and Epidemiology at http://www.epidem.com/). Information on the STROBE Initiative is available at www.strobe-statement.org.

In performing and reporting our cross-sectional study we have observed these guidelines (where applicable)

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BMJ Open

Cross-sectional association between cigarette smoking and abdominal obesity among Austrian bank employees

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Keywords:	Lipid disorders < DIABETES & ENDOCRINOLOGY, EPIDEMIOLOGY, NUTRITION & DIETETICS

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Title Page

Cross-sectional association between cigarette smoking and abdominal obesity among Austrian bank employees

Running title: Cigarette smoking and abdominal obesity

Authors:

1) de Oliveira Fontes Gasperin, Lizia (Dr.)

Department of Nutritional Sciences – University of Vienna

2) Neuberger, Manfred (o. Univ. Prof. Dr.)

Institute of Environmental Health – Medical University of Vienna

3) Tichy, Alexander (Dr.)

Platform Bioinformatics and Biostatistics

University of Veterinary Medicine, Vienna

4) Moshammer, Hans (Priv. Doz. Dr.) (corresponding author)

Institute of Environmental Health – Medical University of Vienna

Kinderspitalgasse 15/I

A-1090 Vienna, Austria

Phone: +43 1 40160 34935

E-mail: hanns.moshammer@meduniwien.ac.at

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Abstract

Objectives: There is increasing evidence that smoking is associated with abdominal obesity and other risk factors for the metabolic syndrome. The aim of this study is to investigate these associations in a sample of healthy Austrian adults.

Setting and Participants: Data of 986 employees of an Austrian company (405 men and 581 women; participation rate approx. 80%) obtained during their annual medical check-up at workplace were analysed.

Primary and secondary outcome measures: Information on smoking status, education level, physical activity, diet, body weight, height, body mass index (BMI), waist circumference, and biochemical parameters were obtained. Influence of smoking on health and anthropometric measures was investigated.

Results: No differences in total body fat and/or body fat distribution were found between non-smokers, smokers and former smokers; however among daily smokers the number of cigarettes smoked per day was significantly associated with higher body weight ($p = 0.001$) and BMI ($p = 0.009$). Male and female smokers had significantly higher counts of white blood cells (WBC) than non-smokers and former smokers. Heavy smokers also had a unhealthier lipid profile (lower HDL-cholesterol) and higher fasting glucose levels even after controlling for physical activity and calories intake.

Conclusion: Contrary to the beliefs of many smokers heavy smoking is associated with higher body weight and unfavourable metabolic changes.

Strengths and limitations of this study

- This is a cross-sectional study with all its inherent limitations.
- But the study included many participants with a similar occupational and socio-economic background and employed very detailed (and validated) questionnaires on diet and physical activity.
- Dietary information was thoroughly checked by nutritional experts.
- Dietary and smoking information (as well as most data on body weight) were provided by self-report only.
- No information on alcohol consumption was available.

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Keywords:

Abdominal obesity, cigarette smoking, dyslipidaemia, type 2 diabetes mellitus, leukocyte count, inflammation.

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Introduction

In Austria, approximately 27% of men and 19% of women aged 15 years and older are daily smokers. Whereas the smoking prevalence has decreased among men, it has increased among women and young people over the last 10 years.[1] Obesity and overweight have also increased over the last decade, reaching epidemic proportions.[2] The combination of smoking with obesity further increases the mortality, particularly from circulatory diseases.[3]

Adolescents, especially girls, often believe that smoking is an effective tool for weight control.[4] Similarly, smoking cessation has been associated with weight gain.[5] However, weight loss in smokers does not necessarily reflect a decrease in the fat mass, rather it may be caused by a reduction in the lean body mass [6] and heavy smokers were found to have higher body weight than light smokers.[7] Some studies reported that smoking is associated with abdominal obesity,[7] which would favour the development of metabolic syndrome, a cluster of risk factors for cardiovascular disease and type 2 diabetes mellitus (T2DM) that includes central obesity, dyslipidaemia, hyperglycaemia, and hypertension.[8, 9] Since other studies [10] failed to find a positive association between cigarette smoking and abdominal obesity, this issue is still controversial and remains to be elucidated.

The aim of this cross-sectional study was to investigate whether cigarette smoking is associated with increased abdominal obesity and related metabolic changes in a sample of healthy Austrian adults.

Methods

Study population

Participants were recruited among employees in a financial institution based in Vienna. Once a year the employees undergo a health screening at the company. After information on the purpose of the study and its procedures, they were invited to participate. Two days before the 2011 medical examination they received a self-administered questionnaire, which was collected on the examination day. From 1 247 employees who filled in the questionnaires (participation rate: approx. 80%), 261 individuals were subsequently excluded: those who reported a history of cancer (20) or thyroid dysfunction (37), missing information on gender (3), age (1), anthropometric measurements (67), smoking status (80) and health status (24), pregnant women (3), individuals under nicotine replacement therapy at the time of the study (4), those with a body mass index (BMI) lower than 18.5 kg/m^2 or greater than 40 kg/m^2 (20),

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and those with a waist circumference (WC) lower than 60 cm (3). Data of 986 individuals (405 men and 581 women) aged 19–65 years were included in the final analyses. All participants signed an informed consent and the study protocol was in accordance with the Declaration of Helsinki. The study was approved by the Ethical Commission of the City of Vienna.

Anthropometric measurements

BMI was calculated as the ratio of weight in kilograms divided by the square of the height in meters (kg/m^2). WC and hip circumferences (HC) were measured using a non-elastic flexible tape, with participants in light clothing without shoes: WC at the top of the right iliac crest, at the end of a normal expiration; HC at the largest posterior extension of the buttocks.[11] Waist-to-hip ratio (WHR) was calculated as WC/HC, waist-to-height ratio (WHtR) as WC/height.

Lifestyle and Education

Participants who answered "no" to the following questions: "Have you ever smoked daily?", "Have you smoked at least 100 cigarettes, cigar, pipes or other tobacco products in your entire life?", "Do you smoke now?" were categorised as non-smokers. Individuals who reported smoking at the time of the enrolment or quitted less than one year before, where classified as smokers. Smokers included both occasional (<1 cigarette per day) and daily smokers (≥1 cigarette per day). Daily smokers were further sub-grouped into light smokers (1–10 cigarettes per day), moderate smokers (11–20 cigarettes per day), and heavy smokers (>20 cigarettes per day). Former smokers were defined as individuals who used to smoke and quitted at least one year prior to their recruitment.

Information on physical activity was obtained by the short form of the International Physical Activity Questionnaire – IPAQ.[12] MET-minutes per week were then calculated according to the IPAQ scoring protocol, and participants were categorised into three PA levels: low, moderate, and high.[13] Dietary intake of food and beverages was obtained by means of self-administered 24-hour recalls, supported by instructions and a validated photographic manual [14] describing portion sizes.

Education was classified as "low" for compulsory education (9 years of schooling in Austria), equivalent to levels 1 and 2 of the International Standard Classification of Education

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(ISCED), "middle" for at least three years of additional schooling (ISCED levels 3 and 4) and "high" for a university degree (ISCED level 5 and 6).

Blood samples

Blood samples were taken by venipuncture after an overnight fast and collected into heparinized tubes. Complete blood count was performed automatically (Sysmex XT 2000i); fasting glucose (FG), total cholesterol (TC), HDL-cholesterol (HDL-C) and triacylglycerides (TAG) were also analysed by automated methods (Roche Modular, Roche Diagnostics, Vienna, Austria). Plasma LDL-cholesterol (LDL-C) was calculated using the Friedewald formula, (LDL-C = TC - HDL-C - TAG/5) for TAG levels lower than 400 mg/dL.[15] Blood analyses were available for 88% of men and 91% of women.

Statistical Analyses

Metric scaled variables are expressed as mean ± standard deviation (SD). Chi-square tests were used to compare frequency distributions of categorical variables. Pearson's correlation coefficients were used to characterize relationships between BMI and WC. For the univariate analyses, factor levels were compared using the Least Significant Difference (LSD) post-hoc procedure.

Multivariate analyses of variances (MANOVA) were performed to evaluate the impact of smoking status or number of cigarettes on the anthropometric and biochemical parameters. Comparisons between non-smokers, smokers and former smokers were performed separately for men and women. Smoking status and level of education were used as fixed factors. In the models where number of cigarettes per day was used, gender was added as a fixed factor.

Several general linear models (GLM) were used to evaluate the influence of possible confounders in the results. The level of complexity was increased stepwise by adding specific variables such as age, physical activity level, and total energy intake as covariates to the model. The result of the simplest model is presented, when p-values remained unchanged after correcting for the different covariates.

For all analyses a two-tailed p-value less than 5% ($p < 0.05$) was considered statistically significant. All statistical analyses were performed using the IBM SPSS version 20 (SPSS Inc., Chicago, IL, USA).

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In the linear regression models "number of cigarettes" was included as a categorical variable. When visual inspection indicated deviance from linearity a General Additive Model (GAM) using splines with 4 degrees of freedom for number of cigarettes per day was tested. The latter analyses were performed with STATA SE 12.1 (StataCorp, College Station, Texas 77845 USA).

Results

Smokers of both sexes were younger than non-smokers and former smokers. Among men, the average ages of non-smokers, smokers and former smokers were 43 ± 9.5, 38.3 ± 10.8, and 45.9 ± 8.2 years, respectively. Differences between the three groups were statistically significant (non-smokers *versus* smokers: $p < 0.001$; non-smokers *versus* former smokers: $p = 0.016$; smokers *versus* former smokers: $p < 0.001$). Among women, non-smokers, smokers and former smokers aged on average 40.5 ± 8.7, 37.6 ± 10.1, and 42.4 ± 8.5 years, respectively. Smokers differed significantly from non-smokers ($p = 0.001$) and former smokers ($p < 0.001$).

The baseline characteristic of the participants, according to gender and smoking status are presented in **Table 1**, for men and in **Table 2**, for women. There were only few participants (five men and nine women) with a low level of education, therefore the low and medium levels were combined.

The anthropometric indices were highly correlated in both men and women. Among men, 67.4% of the variance in BMI was explained by WC ($r = 0.82$, $p < 0.001$). Among women, 68.7% of the variance in BMI was accounted for WC ($r = 0.83$, $p < 0.001$). In the whole sample (male and female together), the Pearson's correlation between WHR and BMI was $r = 0.46$, between WHtR and BMI was $r = 0.82$, between WHR and body weight was $r = 0.54$, and between WHtR and body weight was $r = 0.71$ ($p < 0.001$ for all correlations).

Among both men and women, no statistically significant differences were found between the three smoking groups regarding the anthropometric indices. The results did not change after excluding occasional smokers (<1 cigarette per day) from the group of smokers (data not shown).

Among both men and women, fasting glucose, total cholesterol, LDL-C, ratio of total cholesterol to HDL-C, and LDL-C, did not differ significantly between non-smokers, smokers and former smokers, after controlling for age, physical activity and energy intake.

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Among men, total WBC counts were significantly elevated in smokers, compared with non-smokers ($p < 0.001$) and former smokers ($p < 0.001$). The differences between the groups remained statistically significant after controlling for age, physical activity and energy intake (**Table 1**).

Among women, the total WBC were significantly higher in smokers, compared with both, non-smokers ($p < 0.001$) and former smokers ($p < 0.001$), and the differences remained significant after controlling for confounders. No differences in the total or differential WBC counts were found between female non-smokers and female former smokers (**Table 2**).

Characteristics of daily smokers, according to the number of cigarettes smoked per day

The mean ± SD number of cigarettes per day was 6.3 ± 3.3 for light smokers, 17.3 ± 2.8 for moderate smokers, and 28.8 ± 5.5 for heavy smokers.

Mean ± SD age of light smokers, moderate smokers, and heavy smokers were 37 ± 10.7, 39.3 ± 10.2, and 43.8 ± 7.4, respectively. Heavy smokers were significantly older than light smokers ($p = 0.023$). No significant differences in the average age at which participants started smoking were observed between the groups. However, they differed significantly ($p = 0.020$) regarding the years of smoking (light smokers: 18.9 ± 9.8 years; moderate smokers: 21.8 ± 9.9 years; heavy smokers: 24.7 ± 7.3 years).

The characteristics of daily smokers, according to the number of cigarettes smoked per day, are shown in **Table 3**.

In the unadjusted model, heavy smokers had significantly greater values of body weight ($p = 0.030$), BMI ($p = 0.003$), WC ($p = 0.032$), and HC ($p = 0.036$) than light and moderate smokers. After controlling for age, physical activity and energy intake, the significance remained only for body weight ($p = 0.009$) and BMI ($p = 0.023$).

Overweight and obesity were observed in 84.6% of heavy smokers, compared with 35.6% of light smokers and 33% of moderate smokers ($\chi^2 = 13.5$, $p = 0.001$).

The results of the linear regression models for selected end-points are shown in **Table 4** including also the impact of physical activity (low, moderate, and high activity level), reported consumption of calories, education, age, and gender. A non-linear association for the numbers of cigarettes was evident for body weight, TAG, HDL-C, and fasting glucose (**Figure 1**) with strong adverse effects usually only seen in heavy smokers.

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Discussion

In the present study, no statistical differences in the mean values of body weight and BMI were found between non-smokers, smokers and former smokers. Likewise, no statistically significant differences in the patterns of abdominal obesity—assessed by WC, WHR, or WHtR—were found between the three groups.

However, among the male participants, physical activity was found to be negatively and independently associated with body weight, BMI, WC, WHR and WHtR, after controlling for age, smoking and energy intake (data not shown). Previous studies have also reported an independent association between activity scores and body fat distribution among European men, after adjustment for smoking.[16]

Although several studies found that smokers have lower body weight and BMI than non-smokers,[17, 18] the results in the literature are inconclusive. Our data are in accordance with previous studies which found no significant differences between smokers and non-smokers regarding those anthropometric indices.[19, 20] Differently from other findings [21-23] and in agreement with others,[24, 25] in our study smoking status was not significantly associated with increased abdominal obesity.

Smoking cessation is often accompanied by weight gain, especially among heavy smokers.[5, 26] In the present study, former smokers were not found to have significantly higher body weight or BMI than non-smokers or smokers. Recent quitters in this study were not included among former smokers. So this study at least indicates that any weight gain after smoking cessation is not permanent.

While smoking status per se had only little effect on anthropometric parameters, heavy smokers (>20 cigarettes per day) had significantly higher values of both body weight and BMI, compared with light (1–10 cigarettes per day) and moderate (11–20 cigarettes per day) smokers. The significance remained even after controlling for age, physical activity, and energy intake.

Possible explanations for a higher body weight/BMI among heavy smokers, compared with light smokers, are differences in personality [27] and some lifestyle characteristics [28] that may increase their risk of becoming overweight and obese.[29] They were reported to consume more alcohol, be less active and have a poorer diet, compared with light and

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moderate smokers.[30] It is possible that the higher consumption of alcohol among heavy smokers leads to a weight gain which is not observed in light and moderate smokers.[31]

Regarding the laboratory analyses, differences in the lipid profile, according to the smoking status, were found only in men, after controlling for age, physical activity and energy intake. In women, although the analyses were not controlled for menstrual cycle, controlling for the use of hormonal contraceptive or hormonal replacement therapy did not change the results (data not shown). Male smokers presented higher levels of TAG and lower levels of HDL-C. Effects of smoking were generally more pronounced in heavy smokers. In addition, the levels of fasting glucose increased significantly with the number of cigarettes smoked per day, and the significance remained after controlling for age, physical activity and energy intake.

Overall, neither smoking status nor smoking intensity was positively associated with the levels of total cholesterol or LDL-C. These serum lipid parameters seem to be little influenced by smoking.[32] However, other authors found a clear association of cigarette smoking with low levels of total cholesterol and LDL-C.[33] In the present study, lower levels of HDL-C were associated with smoking status in men after controlling for several confounders. Also number of cigarettes smoked as well as pack years (data not shown) were significantly and negatively correlated with HDL-C.

With respect to the levels of fasting glucose, no differences were observed between smokers, non-smokers and former smokers. However, heavy smokers (>20 cigarettes per day) showed significantly higher levels of fasting glucose compared with both light and moderate smokers. The significance persisted after controlling for age, physical activity and energy intake. The absolute mean values of fasting glucose increased in a graded manner according to the smoking intensity. These findings are of relevance, because in a large number of prospective studies cigarette smoking has been associated with a higher risk of T2DM,[34] especially in heavy smokers.[35]

The crude and adjusted mean values of total and differential WBC counts were significantly higher in male and female smokers, compared with their non-smoking and former smoking counterparts. No differences were observed between non-smokers and former smokers, indicating a decrease in the WBC count after smoking cessation, close to the levels found in never-smokers. Signs of inflammation in smokers are maybe not surprising considering the strong inflammatory impact on the airways. But also systemic inflammatory diseases are associated with smoking.[36]

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When smokers were categorised according to the number of cigarettes smoked per day, statistically significant differences in the total WBC counts were found between light and moderate smokers, after controlling for confounders. Although no significant differences were found between light and heavy smokers, it is important to observe that the absolute differences between the means of the WBC counts in light and moderate smokers were the same of that between light and heavy smokers. The latter has not achieved statistical significance probably due to the small number or heavy smokers in the sample, in comparison to light and moderate smokers.

Cigarette smoking is a well-known risk factor for atherosclerosis and cardiovascular disease (CVD), as discussed before, and it has been recognized as the single most important factor known to influence the WBC count.[37] The WBC count has been correlated with CVD and is considered a biomarker of inflammatory processes that contribute to endothelial dysfunction and atherosclerosis progression.[38]

This study has strengths and limitations. The strengths are the large sample size with a wide age range (19–65 years), and the use of validated questionnaires for the assessment of smoking status and lifestyle—including diet, education level, and physical activity. Therefore adjustment for important confounders could be performed.

The limitations were the cross-sectional design of the study—which does not allow one to infer about cause and effect—and the use of self-reported weight and height as a routine in annual health checks, which were controlled by measurement only if deviant from earlier data, however, which could introduce bias to the study. Studies have demonstrated the validity and reliability of self-reported height and weight in different study populations.[39] Moreover, self-reported BMI and measured WC were highly correlated in the present study, which suggests good quality of the present data.

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WHAT IS ALREADY KNOWN ON THIS SUBJECT?

Smoking is detrimental to health causing respiratory and systemic inflammation, and toxic damage to many body tissues. Systemic inflammation is linked to metabolic disorders. On the other hand nicotine reduces appetite and suppresses the feeling of hunger.

WHAT THIS STUDY ADDS?

In this sample of healthy employees in Vienna, smoking status was not associated with total adiposity (body weight and BMI) or with patterns of central body fat distribution. However, the number of cigarettes smoked per day showed a positive association with total adiposity. A positive and significant association of smoking with dyslipidaemia and higher counts of total WBC were observed. The levels of fasting glucose also increased significantly with the number of cigarettes smoked per day. This altered metabolic profile in smokers can lead to several diseases, including diabetes, coronary heart disease, and cancer.

Contributorship statement

LdOFG collected and sorted the data as part of her thesis work. The thesis paper formed the key basis of this paper. AT helped her with the statistical analysis. MN advised her with the original study concept and later helped her to formulate the paper. This was partly a task of re-wording and of shortening the original thesis. Thesis papers tend to be rather long and turning this into a paper fit for a journal is a rather tough job. HM did additional statistical analyses (regression analyses, GAM) and also helped with the wording and the submission work.

Competing interests

All authors declare no conflict of interest.

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The research for this paper was done as part of the thesis work of the first author. No (external) funding was provided for that study.

Data sharing

The raw data (excel file) and additional analyses results are available upon e-mail request (hanns.moshammer@meduniwien.ac.at)

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FIGURE (1 a-d)

a: Non-linear influence of cigarettes smoked per day on body weight, results of general additive model, spline function with 4 degrees of freedom.

b: Non-linear influence of cigarettes smoked per day on TAG, results of general additive model, spline function with 4 degrees of freedom.

c: Non-linear influence of cigarettes smoked per day on HDL-C, results of general additive model, spline function with 4 degrees of freedom.

d: Non-linear influence of cigarettes smoked per day on fasting glucose, results of general additive model, spline function with 4 degrees of freedom.

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TABLES

Table 1. Baseline characteristics of male participants according to the smoking status.

	Non-Smokers	Smokers	Former Smokers	*p*-value
Sample size, n (%)	180 (44.4)	122 (30.1)	103 (25.4)	
Age, years	43.0 ± 9.5	38.3 ± 10.8	45.9 ± 9.2	0.032
Height, cm	179.8 ± 5.9	179 ± 5.7	179 ± 7.1	0.560 †
Body weight, kg	81.3 ± 10.9	81.5 ± 11.9	83.7 ± 11.2	0.777 †
BMI, kg/m^2	25.1 ± 3.0	25.3 ± 3.3	26.1 ± 3.5	0.634 †
WC, cm	92.2 ± 9.5	92.1 ± 10.1	94.6 ± 9.4	0.911 †
HC, cm	99.0 ± 7.4	98.6 ± 7.2	99.7 ± 7.6	0.895 †
WHR	0.931 ± 0.07	0.932 ± 0.06	0.950 ± 0.08	0.466 †
WHtR	0.524 ± 0.06	0.520 ± 0.06	0.540 ± 0.06	0.827 †
Fasting glucose, mMol	4.6 ± 0.6	4.5 ± 1.0	4.6 ± 0.5	0.217 †
Total cholesterol, mMol	5.6 ± 1.0	5.5 ± 1.1	5.6 ± 0.9	0.683 †
HDL-C, mMol	1.4 ± 0.3	1.4 ± 0.4	1.5 ± 0.3	0.025 †
LDL-C, mMol	3.6 ± 0.9	3.5 ± 0.9	3.6 ± 0.8	0.990 †
Triacylglycerols, mMol	1.3 ± 0.7	1.5 ± 1.0	1.4 ± 1.0	0.006 †
TC to HDL-C ratio	4.2 ± 1.2	4.3 ± 1.3	4.1 ± 1.2	0.098 †
Total WBC, G/L[(a,b)]	6.2 ± 1.4	7.1 ± 1.9	6.3 ± 1.2	0.009 †
Energy intake, kJ	9 306 ± 2 334	9 402 ± 1 865	9 411 ± 2 355	0.941 ‡
Physical activity (%)				
Low	33.5	33.0	29.1	0.902 §
Medium	46.5	48.9	47.7	
High	20.0	18.1	23.3	
Education level				
Medium	56.9	77.0	74.5	<0.001 §
High	43.1	23.0	25.5	

BMI: body mass index; WC: waist circumference; HC: hip circumference; WHR: waist-to-hip ratio; WHtR: waist-to-height ratio. HDL-C: high-density lipoprotein cholesterol; LDL-C: low-density lipoprotein cholesterol WBC: white blood cells; G/L: 1x10^9 cells/L. Values are shown as mean ± SD; †p-value determined by multivariate ANOVA and adjusted for age, physical activity, and energy intake. ‡p-value determined by multivariate ANOVA and adjusted for age. LSD was the post-hoc procedure. (a): statistically significant differences between non-smokers and smokers; (b): statistically significant differences between smokers and former smokers; §p-values analysed using Chi-Square Test.

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Table 2. Baseline characteristics of female participants according to the smoking status.

	Non-Smokers	Smokers	Former Smokers	*p*-value
Sample size, n (%)	276 (47.5)	181 (31.2)	124 (21.3)	
Age, years	40.5 ± 8.7	37.6 ± 10.1	42.4 ± 8.5	0.256
Height, cm	166.8 ± 5.7	166.3 ± 6.0	167.6 ± 5.7	0.246 †
Body weight, kg	65.6 ± 11.0	65.3 ± 10.4	68.1 ± 12.7	0.610 †
BMI, kg/m^2	23.6 ± 3.8	23.6 ± 3.4	24.2 ± 4.2	0.637 †
WC, cm	83.4 ± 10.2	83.4 ± 9.9	85.2 ± 12.7	0.467 †
HC, cm	97.2 ± 9.5	96.6 ± 8.6	98.1 ± 11.4	0.857 †
WHR	0.858 ± 0.06	0.863 ± 0.06	0.867 ± 0.06	0.332 †
WHtR	0.494 ± 0.06	0.499 ± 0.06	0.505 ± 0.08	0.374 †
Fasting glucose, mMol	4.4 ± 0.9	4.3 ± 0.7	4.4 ± 0.7	0.097 †
Total cholesterol, mMol	5.5 ± 1.0	5.4 ± 1.0	5.4 ± 0.9	0.318 †
HDL-C, mMol	1.8 ± 0.4	1.7 ± 0.4	1.8 ± 0.4	0.177 †
LDL-C, mMol	3.2 ± 0.9	3.3 ± 0.9	3.2 ± 0.8	0.510 †
Triacylglycerols, mMol	1.0 ± 0.4	1.1 ± 0.6	1.0 ± 0.4	0.448 †
TC to HDL-C ratio	3.1 ± 0.8	3.5 ± 1.1	3.2 ± 0.8	0.083 †
Total WBC, G/L[(a,b)]	6.4 ± 1.5	7.7 ± 2.1	6.3 ± 1.8	<0.001 †
Energy intake, kJ	7 647 ± 1 777	6 989 ± 1 806	7 383 ± 1 999	0.008 ‡
Physical activity (%)				
low	33.3	26.5	24.2	0.019 §
medium	43.5	60.3	52.6	
high	23.1	13.2	23.2	
Education level (%)				
medium	75.3	90	82.3	<0.001 §
high	24.7	10	17.1	

BMI: body mass index; WC: waist circumference; HC: hip circumference; WHR: waist-to-hip ratio; WHtR: waist-to-height ratio. HDL-C: high-density lipoprotein cholesterol; LDL-C: low-density lipoprotein cholesterol WBC: white blood cells; G/L: 1x10^9 cells/L. Values are shown as mean ± SD; †p-value determined by multivariate ANOVA and adjusted for age, physical activity, and energy intake. ‡p-value determined by multivariate ANOVA and adjusted for age. LSD was the post-hoc procedure. (a): statistically significant differences between non-smokers and smokers; (b): statistically significant differences between smokers and former smokers; §p-values analysed using Chi-Square Test.

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Table 3. Baseline characteristics of daily smokers, according to the smoking intensity.

	Smoking Intensity			
	Light Smokers	**Moderate Smokers**	**Heavy Smokers**	***p*-value**
	(*n* = 135)	(*n* = 106)	(*n* = 13)	
Body weight, kg[b,c]	71.3 ± 13.6	70.8 ± 12.8	81.3 ± 18.0	0.009
BMI, kg/m^2[b,c]	24.2 ± 3.5	24.1 ± 3.5	27.5 ± 3.4	0.023
WC, cm	86.0 ± 11.4	86.9 ± 10.2	94.3 ± 11.7	0.059
HC, cm	96.5 ± 8.6	97.7 ± 8.0	102.6 ± 8.5	0.163
WHR	0.890 ± 0.08	0.890 ± 0.07	0.920 ± 0.07	0.280
WHtR	0.502 ± 0.06	0.508 ± 0.06	0.545 ± 0.05	0.266
FG, mMol[b,c]	4.3 ± 0.6	4.4 ± 0.8	5.3 ± 2.6	0.010
TC, mMol	5.4 ± 1.1	5.4 ± 1.0	5.6 ± 0.7	0.399
HDL-C, mMol	1.6 ± 0.4	1.5 ± 0.4	1.1 ± 0.3	0.057
LDL-C, mMol	3.3 ± 1.1	3.3 ± 0.9	3.6 ± 0.6	0.515
TC to HDL-C ratio[b,c]	3.6 ± 1.2	3.9 ± 1.2	5.5 ± 1.8	0.033
TAG, mMol[b,c]	1.1 ± 0.6	1.3 ± 0.7	2.5 ± 1.9	0.006
Total WBC, G/L[a]	7.0 ± 1.8	8.0 ± 2.3	8.0 ± 2.2	0.035

BMI: body mass index; WC: waist circumference; HC: hip circumference; WHR: waist-to-hip ratio; WHtR: waist-to-height ratio; FG: fasting glucose; TC: total cholesterol; TAG: triacylglycerols. Values are shown as mean ± SD; *p*-value determined by multivariate ANOVA and adjusted for age, physical activity and energy intake; LSD was the post-hoc procedure; (a): statistically significant differences between light and moderate smokers; (b): statistically significant differences between light and heavy smokers; (c): statistically significant differences between moderate and heavy smokers. Light smokers: 1–10 cigarettes per day; moderate smokers: 11–20 cigarettes per day; heavy smokers: >20 cigarettes per day.

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Table 4. Results of the multiple linear regressions (also controlled for age and education, not shown).

Coefficient	Body weight kg	BMI, kg/m^2	WC, cm	Total WBC, G/L	Fasting glucose, mMol	HDL-C, mMol	TAG, mMol
Females	**-5.3**	*-0.7*	**-4.3**	0.5	**-0.18**	**0.35**	**-0.32**
Body height cm	**0.8**	n.a.	**0.3**	n.a.	n.a.	n.a.	n.a.
Occasional smokers	-0.3	-0.2	-0.9	0.1	-0.03	-0.05	0.05
Light smokers	0.2	-0.1	-0.2	0.6	-0.09	**-0.12**	0.11
Moderate smokers	-1.3	-0.2	-0.9	1.3	-0.04	**-0.13**	0.13
Heavy smokers	**9.5**	**3.5**	*7.1*	**1.7**	**0.74**	**-0.55**	**0.85**
Moderate physical activity	-1.0	-0.5	-0.5	*-0.8*	-	0.04	*-0.09*
High physical activity	**-3.4**	**-1.2**	**-2.8**	-0.8	-	**0.12**	**-0.14**
Calories kJ/day	**10.5**	**3.4**	*8.4*	1.7	0.4	-0.2	0.1

BMI: body mass index; WC: waist circumference; WBC: white blood cells; HDL-C: high-density lipoprotein cholesterol; TAG: triacylglycerides; Occasional smokers: less than 1 cigarette per day; Light smokers: 1–10 cigarettes per day; moderate smokers: 11–20 cigarettes per day; heavy smokers: >20 cigarettes per day. All smoking categories compared to non-smokers. **Bold coefficients**: $p<0.01$; *italic coefficients*: $p < 0.05$. n.a.: not applicable (body height in the case of BMI and lab parameters); -: dropped from the model

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Abbreviations

BMI:	body mass index
CVD:	cardiovascular disease
FG:	fasting glucose
HC:	hip circumferences
HDL-C:	HDL-cholesterol
LDL-C:	LDL-cholesterol
TAG:	triacylglycerides
TC:	total cholesterol
T2DM:	type 2 diabetes mellitus
WBC:	white blood cells
WC:	waist circumference
WHR:	waist-to-hip ratio
WHtR:	waist-to-height ratio

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Title Page

Cross-sectional association between cigarette smoking and abdominal obesity among Austrian bank employees

Running title: Cigarette smoking and abdominal obesity

Authors:

1) de Oliveira Fontes Gasperin, Lizia (Dr.)

Department of Nutritional Sciences – University of Vienna

2) Neuberger, Manfred (o. Univ. Prof. Dr.)

Institute of Environmental Health – Medical University of Vienna

3) Tichy, Alexander (Dr.)

Platform Bioinformatics and Biostatistics

University of Veterinary Medicine, Vienna

4) Moshammer, Hans (Priv. Doz. Dr.) (corresponding author)

Institute of Environmental Health – Medical University of Vienna

Kinderspitalgasse 15/I

A-1090 Vienna, Austria

Phone: +43 1 40160 34935

E-mail: hanns.moshammer@meduniwien.ac.at

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Abstract

Background: There is increasing evidence that smoking is associated with abdominal obesity and other risk factors for the metabolic syndrome. The aim of this study is to investigate these associations in a sample of healthy Austrian adults.

Methods: Data of 986 employees of an Austrian company (405 men and 581 women) obtained during their annual medical check-up at workplace were analysed. Information on body weight, height, body mass index (BMI), waist circumference, smoking status, education level, physical activity, diet, and biochemical parameters were obtained.

Results: No differences in total body fat and/or body fat distribution were found between non-smokers, smokers and former smokers; however among daily smokers the number of cigarettes smoked per day was significantly associated with higher body weight ($p = 0.001$) and BMI ($p = 0.009$). Male and female smokers had significantly higher counts of white blood cells (WBC) than non-smokers and former smokers. Heavy smokers also had a unhealthier lipid profile (lower HDL-cholesterol) and higher fasting glucose levels even after controlling for physical activity and calories intake.

Conclusion: Contrary to the beliefs of many smokers heavy smoking is associated with higher body weight and unfavourable metabolic changes.

Strengths and limitations of this study

- This is a cross-sectional study with all its inherent limitations.
- But the study included many participants with a similar occupational and socio-economic background and employed very detailed (and validated) questionnaires on diet and physical activity.
- Dietary information was thoroughly checked by nutritional experts.
- Dietary and smoking information (as well as most data on body weight) were provided by self-report only.
- No information on alcohol consumption was available.

Keywords:

Abdominal obesity, cigarette smoking, dyslipidaemia, type 2 diabetes mellitus, leukocyte count, inflammation.

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Introduction

In Austria, approximately 27% of men and 19% of women aged 15 years and older are daily smokers. Whereas the smoking prevalence has decreased among men, it has increased among women and young people over the last 10 years.[1] Obesity and overweight have also increased over the last decade, reaching epidemic proportions.[2] The combination of smoking with obesity further increases the mortality, particularly from circulatory diseases.[3]

Adolescents, especially girls, often believe that smoking is an effective tool for weight control.[4] Similarly, smoking cessation has been associated with weight gain.[5] However, weight loss in smokers does not necessarily reflect a decrease in the fat mass, rather it may be caused by a reduction in the lean body mass [6] and heavy smokers were found to have higher body weight than light smokers.[7] Some studies reported that smoking is associated with abdominal obesity,[7] which would favour the development of metabolic syndrome, a cluster of risk factors for cardiovascular disease and type 2 diabetes mellitus (T2DM) that includes central obesity, dyslipidaemia, hyperglycaemia, and hypertension.[8, 9] Since other studies [10] failed to find a positive association between cigarette smoking and abdominal obesity, this issue is still controversial and remains to be elucidated.

The aim of this cross-sectional study was to investigate whether cigarette smoking is associated with increased abdominal obesity and related metabolic changes in a sample of healthy Austrian adults.

Methods

Study population

Participants were recruited among employees in a financial institution based in Vienna. Once a year the employees undergo a health screening at the company. After information on the purpose of the study and its procedures, they were invited to participate. Two days before the 2011 medical examination they received a self-administered questionnaire, which was collected on the examination day. From 1 247 employees who filled in the questionnaires (participation rate: approx. 80%), 261 individuals were subsequently excluded: those who reported a history of cancer (20) or thyroid dysfunction (37), missing information on gender (3), age (1), anthropometric measurements (67), smoking status (80) and health status (24), pregnant women (3), individuals under nicotine replacement therapy at the time of the study (4), those with a body mass index (BMI) lower than 18.5 kg/m^2 or greater than 40 kg/m^2 (20),

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and those with a waist circumference (WC) lower than 60 cm (3). Data of 986 individuals (405 men and 581 women) aged 19–65 years were included in the final analyses. All participants signed an informed consent and the study protocol was in accordance with the Declaration of Helsinki. The study was approved by the Ethical Commission of the City of Vienna.

Anthropometric measurements

BMI was calculated as the ratio of weight in kilograms divided by the square of the height in meters (kg/m^2). WC and hip circumferences (HC) were measured using a non-elastic flexible tape, with participants in light clothing without shoes: WC at the top of the right iliac crest, at the end of a normal expiration; HC at the largest posterior extension of the buttocks.[11] Waist-to-hip ratio (WHR) was calculated as WC/HC, waist-to-height ratio (WHtR) as WC/height.

Lifestyle and Education

Participants who answered "no" to the following questions: "Have you ever smoked daily?", "Have you smoked at least 100 cigarettes, cigar, pipes or other tobacco products in your entire life?", "Do you smoke now?" were categorised as non-smokers. Individuals who reported smoking at the time of the enrolment or quitted less than one year before, where classified as smokers. Smokers included both occasional (<1 cigarette per day) and daily smokers (≥1 cigarette per day). Daily smokers were further sub-grouped into light smokers (1–10 cigarettes per day), moderate smokers (11–20 cigarettes per day), and heavy smokers (>20 cigarettes per day). Former smokers were defined as individuals who used to smoke and quitted at least one year prior to their recruitment.

Information on physical activity was obtained by the short form of the International Physical Activity Questionnaire – IPAQ.[12] MET-minutes per week were then calculated according to the IPAQ scoring protocol, and participants were categorised into three PA levels: low, moderate, and high.[13] Dietary intake of food and beverages was obtained by means of self-administered 24-hour recalls, supported by instructions and a validated photographic manual [14] describing portion sizes.

Education was classified as "low" for compulsory education (9 years of schooling in Austria), equivalent to levels 1 and 2 of the International Standard Classification of Education

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(ISCED), "middle" for at least three years of additional schooling (ISCED levels 3 and 4) and "high" for a university degree (ISCED level 5 and 6).

Blood samples

Blood samples were taken by venipuncture after an overnight fast and collected into heparinized tubes. Complete blood count was performed automatically (Sysmex XT 2000i); fasting glucose (FG), total cholesterol (TC), HDL-cholesterol (HDL-C) and triacylglycerides (TAG) were also analysed by automated methods (Roche Modular, Roche Diagnostics, Vienna, Austria). Plasma LDL-cholesterol (LDL-C) was calculated using the Friedewald formula, (LDL-C = TC - HDL-C - TAG/5) for TAG levels lower than 400 mg/dL.[15] Blood analyses were available for 88% of men and 91% of women.

Statistical Analyses

Metric scaled variables are expressed as mean ± standard deviation (SD). Chi-square tests were used to compare frequency distributions of categorical variables. Pearson's correlation coefficients were used to characterize relationships between BMI and WC. For the univariate analyses, factor levels were compared using the Least Significant Difference (LSD) post-hoc procedure.

Multivariate analyses of variances (MANOVA) were performed to evaluate the impact of smoking status or number of cigarettes on the anthropometric and biochemical parameters. Comparisons between non-smokers, smokers and former smokers were performed separately for men and women. Smoking status and level of education were used as fixed factors. In the models where number of cigarettes per day was used, gender was added as a fixed factor.

Several general linear models (GLM) were used to evaluate the influence of possible confounders in the results. The level of complexity was increased stepwise by adding specific variables such as age, physical activity level, and total energy intake as covariates to the model. The result of the simplest model is presented, when *p*-values remained unchanged after correcting for the different covariates.

For all analyses a two-tailed *p*-value less than 5% ($p < 0.05$) was considered statistically significant. All statistical analyses were performed using the IBM SPSS version 20 (SPSS Inc., Chicago, IL, USA).

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In the linear regression models "number of cigarettes" was included as a categorical variable. When visual inspection indicated deviance from linearity a General Additive Model (GAM) using splines with 4 degrees of freedom for number of cigarettes per day was tested. The latter analyses were performed with STATA SE 12.1 (StataCorp, College Station, Texas 77845 USA).

Results

Smokers of both sexes were younger than non-smokers and former smokers. Among men, the average ages of non-smokers, smokers and former smokers were 43 ± 9.5, 38.3 ± 10.8, and 45.9 ± 8.2 years, respectively. Differences between the three groups were statistically significant (non-smokers *versus* smokers: $p < 0.001$; non-smokers *versus* former smokers: $p = 0.016$; smokers *versus* former smokers: $p < 0.001$). Among women, non-smokers, smokers and former smokers aged on average 40.5 ± 8.7, 37.6 ± 10.1, and 42.4 ± 8.5 years, respectively. Smokers differed significantly from non-smokers ($p = 0.001$) and former smokers ($p < 0.001$).

The baseline characteristic of the participants, according to gender and smoking status are presented in **Table 1**, for men and in **Table 2**, for women. There were only few participants (five men and nine women) with a low level of education, therefore the low and medium levels were combined.

The anthropometric indices were highly correlated in both men and women. Among men, 67.4% of the variance in BMI was explained by WC ($r = 0.82$, $p < 0.001$). Among women, 68.7% of the variance in BMI was accounted for WC ($r = 0.83$, $p < 0.001$). In the whole sample (male and female together), the Pearson's correlation between WHR and BMI was $r = 0.46$, between WHtR and BMI was $r = 0.82$, between WHR and body weight was $r = 0.54$, and between WHtR and body weight was $r = 0.71$ ($p < 0.001$ for all correlations).

Among both men and women, no statistically significant differences were found between the three smoking groups regarding the anthropometric indices. The results did not change after excluding occasional smokers (<1 cigarette per day) from the group of smokers (data not shown).

Among both men and women, fasting glucose, total cholesterol, LDL-C, ratio of total cholesterol to HDL-C, and LDL-C, did not differ significantly between non-smokers, smokers and former smokers, after controlling for age, physical activity and energy intake.

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Among men, total WBC counts were significantly elevated in smokers, compared with non-smokers ($p < 0.001$) and former smokers ($p < 0.001$). The differences between the groups remained statistically significant after controlling for age, physical activity and energy intake (**Table 1**).

Among women, the total WBC were significantly higher in smokers, compared with both, non-smokers ($p < 0.001$) and former smokers ($p < 0.001$), and the differences remained significant after controlling for confounders. No differences in the total or differential WBC counts were found between female non-smokers and female former smokers (**Table 2**).

Characteristics of daily smokers, according to the number of cigarettes smoked per day

The mean ± SD number of cigarettes per day was 6.3 ± 3.3 for light smokers, 17.3 ± 2.8 for moderate smokers, and 28.8 ± 5.5 for heavy smokers.

Mean ± SD age of light smokers, moderate smokers, and heavy smokers were 37 ± 10.7, 39.3 ± 10.2, and 43.8 ± 7.4, respectively. Heavy smokers were significantly older than light smokers ($p = 0.023$). No significant differences in the average age at which participants started smoking were observed between the groups. However, they differed significantly ($p = 0.020$) regarding the years of smoking (light smokers: 18.9 ± 9.8 years; moderate smokers: 21.8 ± 9.9 years; heavy smokers: 24.7 ± 7.3 years).

The characteristics of daily smokers, according to the number of cigarettes smoked per day, are shown in **Table 3**.

In the unadjusted model, heavy smokers had significantly greater values of body weight ($p = 0.030$), BMI ($p = 0.003$), WC ($p = 0.032$), and HC ($p = 0.036$) than light and moderate smokers. After controlling for age, physical activity and energy intake, the significance remained only for body weight ($p = 0.009$) and BMI ($p = 0.023$).

Overweight and obesity were observed in 84.6% of heavy smokers, compared with 35.6% of light smokers and 33% of moderate smokers ($\chi^2 = 13.5$, $p = 0.001$).

The results of the linear regression models for selected end-points are shown in **Table 4** including also the impact of physical activity (low, moderate, and high activity level), reported consumption of calories, education, age, and gender. A non-linear association for the numbers of cigarettes was evident for body weight, TAG, HDL-C, and fasting glucose (**Figure 1**) with strong adverse effects usually only seen in heavy smokers.

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Discussion

In the present study, no statistical differences in the mean values of body weight and BMI were found between non-smokers, smokers and former smokers. Likewise, no statistically significant differences in the patterns of abdominal obesity—assessed by WC, WHR, or WHtR—were found between the three groups.

However, among the male participants, physical activity was found to be negatively and independently associated with body weight, BMI, WC, WHR and WHtR, after controlling for age, smoking and energy intake (data not shown). Previous studies have also reported an independent association between activity scores and body fat distribution among European men, after adjustment for smoking.[16]

Although several studies found that smokers have lower body weight and BMI than non-smokers,[17, 18] the results in the literature are inconclusive. Our data are in accordance with previous studies which found no significant differences between smokers and non-smokers regarding those anthropometric indices.[19, 20] Differently from other findings [21-23] and in agreement with others,[24, 25] in our study smoking status was not significantly associated with increased abdominal obesity.

Smoking cessation is often accompanied by weight gain, especially among heavy smokers.[5, 26] In the present study, former smokers were not found to have significantly higher body weight or BMI than non-smokers or smokers. Recent quitters in this study were not included among former smokers. So this study at least indicates that any weight gain after smoking cessation is not permanent.

While smoking status per se had only little effect on anthropometric parameters, heavy smokers (>20 cigarettes per day) had significantly higher values of both body weight and BMI, compared with light (1–10 cigarettes per day) and moderate (11–20 cigarettes per day) smokers. The significance remained even after controlling for age, physical activity, and energy intake.

Possible explanations for a higher body weight/BMI among heavy smokers, compared with light smokers, are differences in personality [27] and some lifestyle characteristics [28] that may increase their risk of becoming overweight and obese.[29] They were reported to consume more alcohol, be less active and have a poorer diet, compared with light and

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moderate smokers.[30] It is possible that the higher consumption of alcohol among heavy smokers leads to a weight gain which is not observed in light and moderate smokers.[31]

Regarding the laboratory analyses, differences in the lipid profile, according to the smoking status, were found only in men, after controlling for age, physical activity and energy intake. In women, although the analyses were not controlled for menstrual cycle, controlling for the use of hormonal contraceptive or hormonal replacement therapy did not change the results (data not shown). Male smokers presented higher levels of TAG and lower levels of HDL-C. Effects of smoking were generally more pronounced in heavy smokers. In addition, the levels of fasting glucose increased significantly with the number of cigarettes smoked per day, and the significance remained after controlling for age, physical activity and energy intake.

Overall, neither smoking status nor smoking intensity was positively associated with the levels of total cholesterol or LDL-C. These serum lipid parameters seem to be little influenced by smoking.[32] However, other authors found a clear association of cigarette smoking with low levels of total cholesterol and LDL-C.[33] In the present study, lower levels of HDL-C were associated with smoking status in men after controlling for several confounders. Also number of cigarettes smoked as well as pack years (data not shown) were significantly and negatively correlated with HDL-C.

With respect to the levels of fasting glucose, no differences were observed between smokers, non-smokers and former smokers. However, heavy smokers (>20 cigarettes per day) showed significantly higher levels of fasting glucose compared with both light and moderate smokers. The significance persisted after controlling for age, physical activity and energy intake. The absolute mean values of fasting glucose increased in a graded manner according to the smoking intensity. These findings are of relevance, because in a large number of prospective studies cigarette smoking has been associated with a higher risk of T2DM,[34] especially in heavy smokers.[35]

The crude and adjusted mean values of total and differential WBC counts were significantly higher in male and female smokers, compared with their non-smoking and former smoking counterparts. No differences were observed between non-smokers and former smokers, indicating a decrease in the WBC count after smoking cessation, close to the levels found in never-smokers. Signs of inflammation in smokers are maybe not surprising considering the strong inflammatory impact on the airways. But also systemic inflammatory diseases are associated with smoking.[36]

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When smokers were categorised according to the number of cigarettes smoked per day, statistically significant differences in the total WBC counts were found between light and moderate smokers, after controlling for confounders. Although no significant differences were found between light and heavy smokers, it is important to observe that the absolute differences between the means of the WBC counts in light and moderate smokers were the same of that between light and heavy smokers. The latter has not achieved statistical significance probably due to the small number or heavy smokers in the sample, in comparison to light and moderate smokers.

Cigarette smoking is a well-known risk factor for atherosclerosis and cardiovascular disease (CVD), as discussed before, and it has been recognized as the single most important factor known to influence the WBC count.[37] The WBC count has been correlated with CVD and is considered a biomarker of inflammatory processes that contribute to endothelial dysfunction and atherosclerosis progression.[38]

This study has strengths and limitations. The strengths are the large sample size with a wide age range (19–65 years), and the use of validated questionnaires for the assessment of smoking status and lifestyle—including diet, education level, and physical activity. Therefore adjustment for important confounders could be performed.

The limitations were the cross-sectional design of the study—which does not allow one to infer about cause and effect—and the use of self-reported weight and height as a routine in annual health checks, which were controlled by measurement only if deviant from earlier data, however, which could introduce bias to the study. Studies have demonstrated the validity and reliability of self-reported height and weight in different study populations.[39] Moreover, self-reported BMI and measured WC were highly correlated in the present study, which suggests good quality of the present data.

Acknowledgements

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Conflict of interest

All authors declare no conflict of interest.

WHAT IS ALREADY KNOWN ON THIS SUBJECT?

Smoking is detrimental to health causing respiratory and systemic inflammation, and toxic damage to many body tissues. Systemic inflammation is linked to metabolic disorders. On the other hand nicotine reduces appetite and suppresses the feeling of hunger.

WHAT THIS STUDY ADDS?

In this sample of healthy employees in Vienna, smoking status was not associated with total adiposity (body weight and BMI) or with patterns of central body fat distribution. However, the number of cigarettes smoked per day showed a positive association with total adiposity. A positive and significant association of smoking with dyslipidaemia and higher counts of total WBC were observed. The levels of fasting glucose also increased significantly with the number of cigarettes smoked per day. This altered metabolic profile in smokers can lead to several diseases, including diabetes, coronary heart disease, and cancer.

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FIGURE (1 a-d)

a: Non-linear influence of cigarettes smoked per day on body weight, results of general additive model, spline function with 4 degrees of freedom.

b: Non-linear influence of cigarettes smoked per day on TAG, results of general additive model, spline function with 4 degrees of freedom.

c: Non-linear influence of cigarettes smoked per day on HDL-C, results of general additive model, spline function with 4 degrees of freedom.

d: Non-linear influence of cigarettes smoked per day on fasting glucose, results of general additive model, spline function with 4 degrees of freedom.

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TABLES

Table 1. Baseline characteristics of male participants according to the smoking status.

	Non-Smokers	Smokers	Former Smokers	*p*-value
Sample size, n (%)	180 (44.4)	122 (30.1)	103 (25.4)	
Age, years	43.0 ± 9.5	38.3 ± 10.8	45.9 ± 9.2	0.032
Height, cm	179.8 ± 5.9	179 ± 5.7	179 ± 7.1	0.560 †
Body weight, kg	81.3 ± 10.9	81.5 ± 11.9	83.7 ± 11.2	0.777 †
BMI, kg/m^2	25.1 ± 3.0	25.3 ± 3.3	26.1 ± 3.5	0.634 †
WC, cm	92.2 ± 9.5	92.1 ± 10.1	94.6 ± 9.4	0.911 †
HC, cm	99.0 ± 7.4	98.6 ± 7.2	99.7 ± 7.6	0.895 †
WHR	0.931 ± 0.07	0.932 ± 0.06	0.950 ± 0.08	0.466 †
WHtR	0.524 ± 0.06	0.520 ± 0.06	0.540 ± 0.06	0.827 †
Fasting glucose, mMol	4.6 ± 0.6	4.5 ± 1.0	4.6 ± 0.5	0.217 †
Total cholesterol, mMol	5.6 ± 1.0	5.5 ± 1.1	5.6 ± 0.9	0.683 †
HDL-C, mMol	1.4 ± 0.3	1.4 ± 0.4	1.5 ± 0.3	0.025 †
LDL-C, mMol	3.6 ± 0.9	3.5 ± 0.9	3.6 ± 0.8	0.990 †
Triacylglycerols, mMol	1.3 ± 0.7	1.5 ± 1.0	1.4 ± 1.0	0.006 †
TC to HDL-C ratio	4.2 ± 1.2	4.3 ± 1.3	4.1 ± 1.2	0.098 †
Total WBC, G/L[(a,b)]	6.2 ± 1.4	7.1 ± 1.9	6.3 ± 1.2	0.009 †
Energy intake, kJ	9 306 ± 2 334	9 402 ± 1 865	9 411 ± 2 355	0.941 ‡
Physical activity (%)				
Low	33.5	33.0	29.1	0.902 §
Medium	46.5	48.9	47.7	
High	20.0	18.1	23.3	
Education level				
Medium	56.9	77.0	74.5	<0.001 §
High	43.1	23.0	25.5	

BMI: body mass index; WC: waist circumference; HC: hip circumference; WHR: waist-to-hip ratio; WHtR: waist-to-height ratio. HDL-C: high-density lipoprotein cholesterol; LDL-C: low-density lipoprotein cholesterol WBC: white blood cells; G/L: 1x10^9 cells/L. Values are shown as mean ± SD; †p-value determined by multivariate ANOVA and adjusted for age, physical activity, and energy intake. ‡p-value determined by multivariate ANOVA and adjusted for age. LSD was the post-hoc procedure. (a): statistically significant differences between non-smokers and smokers; (b): statistically significant differences between smokers and former smokers; §p-values analysed using Chi-Square Test.

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Table 2. Baseline characteristics of female participants according to the smoking status.

	Non-Smokers	Smokers	Former Smokers	*p*-value
Sample size, n (%)	276 (47.5)	181 (31.2)	124 (21.3)	
Age, years	40.5 ± 8.7	37.6 ± 10.1	42.4 ± 8.5	0.256
Height, cm	166.8 ± 5.7	166.3 ± 6.0	167.6 ± 5.7	0.246 †
Body weight, kg	65.6 ± 11.0	65.3 ± 10.4	68.1 ± 12.7	0.610 †
BMI, kg/m^2	23.6 ± 3.8	23.6 ± 3.4	24.2 ± 4.2	0.637 †
WC, cm	83.4 ± 10.2	83.4 ± 9.9	85.2 ± 12.7	0.467 †
HC, cm	97.2 ± 9.5	96.6 ± 8.6	98.1 ± 11.4	0.857 †
WHR	0.858 ± 0.06	0.863 ± 0.06	0.867 ± 0.06	0.332 †
WHtR	0.494 ± 0.06	0.499 ± 0.06	0.505 ± 0.08	0.374 †
Fasting glucose, mMol	4.4 ± 0.9	4.3 ± 0.7	4.4 ± 0.7	0.097 †
Total cholesterol, mMol	5.5 ± 1.0	5.4 ± 1.0	5.4 ± 0.9	0.318 †
HDL-C, mMol	1.8 ± 0.4	1.7 ± 0.4	1.8 ± 0.4	0.177 †
LDL-C, mMol	3.2 ± 0.9	3.3 ± 0.9	3.2 ± 0.8	0.510 †
Triacylglycerols, mMol	1.0 ± 0.4	1.1 ± 0.6	1.0 ± 0.4	0.448 †
TC to HDL-C ratio	3.1 ± 0.8	3.5 ± 1.1	3.2 ± 0.8	0.083 †
Total WBC, G/L[(a,b)]	6.4 ± 1.5	7.7 ± 2.1	6.3 ± 1.8	<0.001 †
Energy intake, kJ	7 647 ± 1 777	6 989 ± 1 806	7 383 ± 1 999	0.008 ‡
Physical activity (%)				
low	33.3	26.5	24.2	0.019 §
medium	43.5	60.3	52.6	
high	23.1	13.2	23.2	
Education level (%)				
medium	75.3	90	82.3	<0.001 §
high	24.7	10	17.1	

BMI: body mass index; WC: waist circumference; HC: hip circumference; WHR: waist-to-hip ratio; WHtR: waist-to-height ratio. HDL-C: high-density lipoprotein cholesterol; LDL-C: low-density lipoprotein cholesterol WBC: white blood cells; G/L: 1x10^9 cells/L. Values are shown as mean ± SD; †p-value determined by multivariate ANOVA and adjusted for age, physical activity, and energy intake. ‡p-value determined by multivariate ANOVA and adjusted for age. LSD was the post-hoc procedure. (a): statistically significant differences between non-smokers and smokers; (b): statistically significant differences between smokers and former smokers; §p-values analysed using Chi-Square Test.

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Table 3. Baseline characteristics of daily smokers, according to the smoking intensity.

	Smoking Intensity			
	Light Smokers	**Moderate Smokers**	**Heavy Smokers**	***p*-value**
	(*n* = 135)	(*n* = 106)	(*n* = 13)	
Body weight, kg[b,c]	71.3 ± 13.6	70.8 ± 12.8	81.3 ± 18.0	0.009
BMI, kg/m^2[b,c]	24.2 ± 3.5	24.1 ± 3.5	27.5 ± 3.4	0.023
WC, cm	86.0 ± 11.4	86.9 ± 10.2	94.3 ± 11.7	0.059
HC, cm	96.5 ± 8.6	97.7 ± 8.0	102.6 ± 8.5	0.163
WHR	0.890 ± 0.08	0.890 ± 0.07	0.920 ± 0.07	0.280
WHtR	0.502 ± 0.06	0.508 ± 0.06	0.545 ± 0.05	0.266
FG, mMol[b,c]	4.3 ± 0.6	4.4 ± 0.8	5.3 ± 2.6	0.010
TC, mMol	5.4 ± 1.1	5.4 ± 1.0	5.6 ± 0.7	0.399
HDL-C, mMol	1.6 ± 0.4	1.5 ± 0.4	1.1 ± 0.3	0.057
LDL-C, mMol	3.3 ± 1.1	3.3 ± 0.9	3.6 ± 0.6	0.515
TC to HDL-C ratio[b,c]	3.6 ± 1.2	3.9 ± 1.2	5.5 ± 1.8	0.033
TAG, mMol[b,c]	1.1 ± 0.6	1.3 ± 0.7	2.5 ± 1.9	0.006
Total WBC, G/L[a]	7.0 ± 1.8	8.0 ± 2.3	8.0 ± 2.2	0.035

BMI: body mass index; WC: waist circumference; HC: hip circumference; WHR: waist-to-hip ratio; WHtR: waist-to-height ratio; FG: fasting glucose; TC: total cholesterol; TAG: triacylglycerols. Values are shown as mean ± SD; *p*-value determined by multivariate ANOVA and adjusted for age, physical activity and energy intake; LSD was the post-hoc procedure; (a): statistically significant differences between light and moderate smokers; (b): statistically significant differences between light and heavy smokers; (c): statistically significant differences between moderate and heavy smokers. Light smokers: 1–10 cigarettes per day; moderate smokers: 11–20 cigarettes per day; heavy smokers: >20 cigarettes per day.

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Table 4. Results of the multiple linear regressions (also controlled for age and education, not shown).

Coefficient	Body weight kg	BMI, kg/m^2	WC, cm	Total WBC, G/L	Fasting glucose, mMol	HDL-C, mMol	TAG, mMol
Females	**-5.3**	*-0.7*	**-4.3**	0.5	**-0.18**	**0.35**	**-0.32**
Body height cm	**0.8**	n.a.	**0.3**	n.a.	n.a.	n.a.	n.a.
Occasional smokers	-0.3	-0.2	-0.9	0.1	-0.03	-0.05	0.05
Light smokers	0.2	-0.1	-0.2	0.6	-0.09	**-0.12**	0.11
Moderate smokers	-1.3	-0.2	-0.9	1.3	-0.04	**-0.13**	0.13
Heavy smokers	**9.5**	**3.5**	*7.1*	**1.7**	**0.74**	**-0.55**	**0.85**
Moderate physical activity	-1.0	-0.5	-0.5	*-0.8*	-	0.04	*-0.09*
High physical activity	**-3.4**	**-1.2**	**-2.8**	-0.8	-	**0.12**	**-0.14**
Calories kJ/day	**10.5**	**3.4**	*8.4*	1.7	0.4	-0.2	0.1

BMI: body mass index; WC: waist circumference; WBC: white blood cells; HDL-C: high-density lipoprotein cholesterol; TAG: triacylglycerides; Occasional smokers: less than 1 cigarette per day; Light smokers: 1–10 cigarettes per day; moderate smokers: 11–20 cigarettes per day; heavy smokers: >20 cigarettes per day. All smoking categories compared to non-smokers. **Bold coefficients**: $p<0.01$; *italic coefficients*: $p < 0.05$. n.a.: not applicable (body height in the case of BMI and lab parameters); -: dropped from the model

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Abbreviations

BMI:	body mass index
CVD:	cardiovascular disease
FG:	fasting glucose
HC:	hip circumferences
HDL-C:	HDL-cholesterol
LDL-C:	LDL-cholesterol
TAG:	triacylglycerides
TC:	total cholesterol
T2DM:	type 2 diabetes mellitus
WBC:	white blood cells
WC:	waist circumference
WHR:	waist-to-hip ratio
WHtR:	waist-to-height ratio

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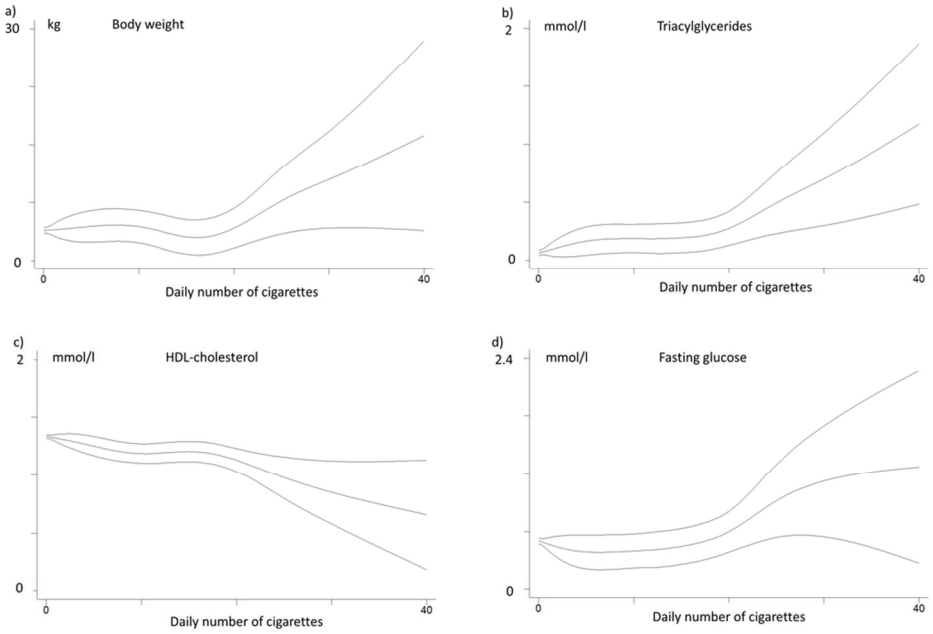

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STROBE Statement—checklist of items that should be included in reports of observational studies

	Item No	Recommendation
Title and abstract	1	(*a*) Indicate the study's design with a commonly used term in the title or the abstract - done
		(*b*) Provide in the abstract an informative and balanced summary of what was done and what was found- done
Introduction		
Background/rationale	2	Explain the scientific background and rationale for the investigation being reported- done
Objectives	3	State specific objectives, including any prespecified hypotheses- done
Methods		
Study design	4	Present key elements of study design early in the paper- done
Setting	5	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection
Participants	6	(*a*) *Cohort study*—Give the eligibility criteria, and the sources and methods of selection of participants. Describe methods of follow-up *Case-control study*—Give the eligibility criteria, and the sources and methods of case ascertainment and control selection. Give the rationale for the choice of cases and controls *Cross-sectional study*—Give the eligibility criteria, and the sources and methods of selection of participants- done
		(*b*) *Cohort study*—For matched studies, give matching criteria and number of exposed and unexposed *Case-control study*—For matched studies, give matching criteria and the number of controls per case
Variables	7	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable- done
Data sources/ measurement	8*	For each variable of interest, give sources of data and details of methods of assessment (measurement). Describe comparability of assessment methods if there is more than one group- done
Bias	9	Describe any efforts to address potential sources of bias- done
Study size	10	Explain how the study size was arrived at
Quantitative variables	11	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why- done
Statistical methods	12	(*a*) Describe all statistical methods, including those used to control for confounding- done
		(*b*) Describe any methods used to examine subgroups and interactions
		(*c*) Explain how missing data were addressed
		(*d*) *Cohort study*—If applicable, explain how loss to follow-up was addressed *Case-control study*—If applicable, explain how matching of cases and controls was addressed *Cross-sectional study*—If applicable, describe analytical methods taking account of sampling strategy
		(*e*) Describe any sensitivity analyses

Continued on next page

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Results		
Participants	13*	(a) Report numbers of individuals at each stage of study—eg numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analysed
		(b) Give reasons for non-participation at each stage
		(c) Consider use of a flow diagram
Descriptive data	14*	(a) Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders- done
		(b) Indicate number of participants with missing data for each variable of interest- done
		(c) *Cohort study*—Summarise follow-up time (eg, average and total amount)
Outcome data	15*	*Cohort study*—Report numbers of outcome events or summary measures over time
		Case-control study—Report numbers in each exposure category, or summary measures of exposure
		Cross-sectional study—Report numbers of outcome events or summary measures- done
Main results	16	(*a*) Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (eg, 95% confidence interval). Make clear which confounders were adjusted for and why they were included- done
		(*b*) Report category boundaries when continuous variables were categorized- done
		(*c*) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period
Other analyses	17	Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses
Discussion		
Key results	18	Summarise key results with reference to study objectives- done
Limitations	19	Discuss limitations of the study, taking into account sources of potential bias or imprecision. Discuss both direction and magnitude of any potential bias- done
Interpretation	20	Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence- done
Generalisability	21	Discuss the generalisability (external validity) of the study results
Other information		
Funding	22	Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based

*Give information separately for cases and controls in case-control studies and, if applicable, for exposed and unexposed groups in cohort and cross-sectional studies.

Note: An Explanation and Elaboration article discusses each checklist item and gives methodological background and published examples of transparent reporting. The STROBE checklist is best used in conjunction with this article (freely available on the Web sites of PLoS Medicine at http://www.plosmedicine.org/, Annals of Internal Medicine at http://www.annals.org/, and Epidemiology at http://www.epidem.com/). Information on the STROBE Initiative is available at www.strobe-statement.org.

In performing and reporting our cross-sectional study we have observed these guidelines (where applicable)

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