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TEN-YEAR INCIDENCE OF HYPERTENSION IN A SWISS POPULATION-BASED SAMPLE

Incidence of hypertension in Switzerland

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Abstract

Few studies assessed incidence and determinants of hypertension. We assessed the incidence and determinants of hypertension in a cohort of healthy adults aged 35 to 75 years living in Lausanne, Switzerland. Baseline data was collected from 2003 to 2006. Follow-ups were conducted in 2009-2012 and 2014-2017. Incident hypertension, defined as a systolic BP ≥140 mm Hg or a diastolic BP ≥90 mm Hg or anti-hypertensive medication, was assessed at 1) second follow-up only; 2) first and/or second follow-up. After 10.9 years, incident hypertension was 26.8% (analysis 1, N=3299) and 30.3% (analysis 2, N=3728). After multivariate adjustment, the variables associated with increased hypertension incidence were male gender [incident-rate ratio (IRR) and (95% confidence interval)]: 1.20 (1.07-1.35) and 1.24 (1.13-1.37) for analyses 1 and 2, respectively; increasing age (p for trend <0.001) and body mass index (p for trend <0.001) and history of cardiovascular disease (CVD). Being physically active was negatively associated with incident hypertension: 0.88 (0.78-0.98) and 0.92 (0.83-1.01) for analyses 1 and 2, respectively. Except for male gender, these associations remained after adjusting for baseline BP levels, with incident rate ratios for physical activity of 0.86 (0.77-0.96) and 0.91 (0.83-0.99) for analyses 1 and 2, respectively. No association was found for education, alcohol consumption or smoking status. We conclude that over 10.9 years, between 1/4 and 1/3 of the Swiss population aged 35 to 75 developed hypertension. Male gender, history of CVD, increasing age and higher BMI increase the risk of hypertension, while being physically active reduces the risk.

Abstract word count: 250

Keywords: prospective study; hypertension; incidence; Switzerland.

Introduction

Hypertension is a major public health challenge given its involvement in cardiovascular diseases (CVD). Hypertension is one of the main causes of disability-adjusted life years (DALY) worldwide [1] and ranks second in Switzerland [2]. Over 1 billion people have hypertension worldwide, and the prevalence is increasing [3]. Hypertension is a major risk factor for cardiovascular diseases, renal failure, and retinal disorders. Several different guidelines have been published regarding the prevention and management of hypertension [4, 5].

The strongest determinants of hypertension incidence are aging and obesity. Nevertheless, the importance of individual factors such as smoking [6], alcohol [7], physical activity [8] and socioeconomic status such as education [9] is less well characterized. Such information is important both from a public health and individual perspective. Furthermore, although many studies have assessed the incidence of hypertension in several countries, none has been performed in Switzerland.

The aim of this study was thus to assess the incidence of hypertension and to identify the socio-demographic and clinically-actionable risk factors of hypertension, in a sample of healthy adults aged 35 to 75 years living in Lausanne (Switzerland).

Participants and methods

Recruitment

The CoLaus Study (www.colaus-psycolaus.ch) is a prospective study aimed to assess the prevalence and determinants of cardiovascular risk factors in participants aged 35 to 75 years living in the city of Lausanne (Switzerland). The sampling procedure of the CoLaus study can be found elsewhere [10]. Participants were included if they provided (a) written informed consent; (b) willingness to take part in the examination and to provide blood samples.

Recruitment began in June 2003 and ended in May 2006, enrolling 6733 participants who underwent an interview, a physical exam, and a blood analysis. The first and second follow-ups were performed between April 2009 and September 2012 and between May 2014 and April 2017,

respectively, corresponding to an average of 5.6 and 10.9 years after the collection of baseline data, respectively. Data collected in the follow-ups was similar to the baseline examination.

Blood pressure measurement

At baseline and follow-ups, blood pressure (BP) and heart rate were measured thrice on the left arm after a 10 minutes rest in the seated position. A clinically validated automated oscillometric device (Omron® HEM-907, Matsusaka, Japan) was used with a standard cuff. In the case of an arm circumference ≥33 cm, a larger cuff was used. The average of the last two BP readings was used. Hypertension was defined as a systolic BP (SBP) ≥140 mm Hg or a diastolic BP (DBP) ≥90 mm Hg or presence of anti-hypertensive medication. Incident hypertension was defined as presence of hypertension at first or second follow-up among participants devoid of hypertension at baseline.

Other variables

All participants were examined in the morning after a fast of at least 8 hours. Personal and family history of CVD, CVRFs, and cardiovascular treatment were assessed by questionnaire. Smoking was categorized into never, former (irrespective of the time since quitting) and current. Education was categorized according to the highest educational level completed into low (primary), middle (apprenticeship), upper middle (high school), and high (university) . Self-reported alcohol consumption during the previous week was based on the number of units (i.e. a glass of wine, a can of beer or a shot of liquor) and categorized as none, 1-13, 14-34 and 35+/week. Physical activity was defined if the participant exercised at least twice per week for at least 20 minutes per session. Participants also indicated all medicines they were taking, prescribed or obtained over the counter.

Body weight and height were measured using Seca® equipment (Hamburg, Germany) to the nearest 100 g and 5 mm, respectively, while participants stood shoeless in light indoor attire.

Inclusion and exclusion criteria

Participants were excluded if they: 1) presented with hypertension at baseline; 2) did not participate in the follow-up; and 3) had missing covariates.

Ethical considerations

The institutional Ethics Committee of the University of Lausanne, which afterwards became the Ethics Commission of Canton Vaud (www.cer-vd.ch) approved the baseline CoLaus study and subsequent follow-ups. The study was performed in agreement with the Helsinki declaration and its former amendments. Informed consent was obtained from all participants.

Statistical analysis

Statistical analyses were conducted using Stata version 14.2 (Stata Corp, College Station, Texas, USA).

Two analyses were performed focusing on incident hypertension between baseline and 1) second follow-up only, or 2) first and/or second follow-up. In each analysis, the following clinical and lifestyle determinants of incident hypertension were analyzed: gender, age, BMI, smoking, alcohol consumption, education, and physical activity.

Participants characteristics were expressed as number (percentage) for categorical variables or as average ± standard deviation for continuous variables. Between-group comparisons were performed using chi-square or Fisher's exact test for categorical variables and student's t-test for continuous variables. As the incidence of hypertension was high (>20%), Poisson regression with robust confidence intervals was preferred to logistic regression for multivariable analysis, as the results from logistic regression might be overestimated [11]. Results of the multivariable analysis were expressed as incidence rate ratio and (95% confidence interval). As some studies did [9, 12] and others did not [13, 14] adjust for baseline blood pressure, two multivariable models were used: with and without adjusting for baseline blood pressure.

A sensitivity analysis was performed to take into account the fact that excluded and included participants differed significantly regarding several clinical and demographic characteristics. First, and for each analysis as defined previously, the probability of nonparticipation was computed using a lostic model with gender, age, BMI, smoking, alcohol consumption, education, physical activity, personal and

family history of CVD as the independent variables. The inverse of the probability of nonparticipation was used for weighting [15]. Statistical significance was considered for $p<0.05$ (two-sided test).

Results

Characteristics of the sample

The selection procedures for the two analyses are presented in **Figure 1**. Respectively 3299 (49.0%) and 3728 (55.4%) participants were included in the first and in the second analysis. The characteristics of the included and excluded participants are provided in **supplemental tables 1 and 2** for the first and second analysis, respectively. Overall, excluded participants were older, more frequently men, with lower education, higher alcohol consumption, higher BMI and no physical activity. Excluded participants also had a higher prevalence of personal and family history of CVD.

Incidence and determinants of incident hypertension

After an average follow-up of 10.9 years, 883 (26.8%) and 1128 (30.3%) participants developed hypertension in the first and second analysis, respectively. The analysis of factors associated with incident hypertension is summarized in **tables 1** (bivariate), **2** (multivariable, not adjusted for baseline blood pressure) and **3** (multivariable, adjusted for baseline blood pressure).

As alcohol consumption was not associated with incident hypertension in the bivariate analysis, it was not introduced in the multivariable model. Overall, male gender, increasing age, higher BMI and personal or family history of CVD were positively associated, while being physically active was inversely associated with incident hypertension (**table 2**), and most of the associations remained after adjusting for baseline blood pressure (**table 3**).

The results of the sensitivity analyses taking into account non-participation in the follow-up are summarized in **supplemental tables 3 and 4**. Again, male gender, increasing age, higher BMI and personal or family history of CVD were positively associated, while being physically active was inversely associated with incident hypertension (**supplemental table 3**). The associations for age, BMI, personal

history of CVD and physical activity remained after adjusting for baseline blood pressure (**supplemental table 4**).

Discussion

To our knowledge, this is the first study to assess incidence of hypertension in a Swiss population. Our results indicate that, over a period of 10.9 years, between one fourth and one third of the population aged 35 to 75 develops hypertension. Our results also indicate that male gender, increasing age, higher BMI and history of CVD (personal or familial) increase the risk of developing hypertension, while being physically active reduces the risk.

Prevalence of hypertension

One-third (35.4%) of participants was excluded at baseline due to hypertension. This prevalence is almost identical to the one found in the Bus Santé study of Geneva (34.4%) [16] and in another multi-cantonal cohort study (34.9%) [17]. Overall, the prevalence of hypertension in our sample agrees with other existing data for Switzerland.

Incidence of hypertension

Between one fourth (26.8%) and one third (30.3%) of the sample developed hypertension after 10.9 years of follow-up. Those values are comparable or lower to those reported in studies conducted for a shorter period in France (19.6% after 3 years) [14], Portugal (23.2% after 3.8 years) [9], and China (38.9% after 3.5 years) [18]. Possible explanations are the rather low prevalence of obesity in the Swiss population [19] and a differing dietary intake [20] relative to other European countries, which might reduce the incidence of hypertension. Another explanation is the different economic status of the country, as it has been shown that developing countries are more affected by emerging risk factors than developed ones due to societal changes in diet and physical activity [21]. Overall, our results indicate that the incidence of hypertension in the Swiss population appears to be lower than in other countries.

Determinants of incident hypertension

Male gender was positively associated with incident hypertension, a finding also reported elsewhere [5, 13]. Possible explanations include the protective effect of hormonal status among premenopausal women [22], a less healthy dietary intake and a lower health consciousness among men [23].

Increasing age was positively associated with incidence of hypertension, a finding in agreement with the literature [5]. Possible explanations are lower physical activity levels and increasing BMI, although in this study the association between age and hypertension remained after adjusting for BMI categories and physical activity status. Other explanations include differences in dietary intake, or an age-dependent hardening of the vascular system [24] or worsening of kidney function [25]. Overall, our results stress the need for adequate prevention of hypertension among elderly subjects.

Increasing BMI was associated with increased incidence of hypertension. Indeed, several studies have shown that weight loss, either via diet or bariatric surgery, leads to a decrease in BP levels [5]. Hence, our results indicate that overweight or obese subjects should be motivated to lose weight, as it will reduce the risk of developing hypertension.

Personal and familial history of CVD were positively associated with incident hypertension, independently of other cardiovascular risk factors such as smoking, obesity or physical activity. These findings are partly in agreement with the literature, where subjects with a family history of hypertension also had a higher risk of developing hypertension [26, 27]. Possible explanations include other cardiovascular risk factors not accounted for such as dyslipidemia and diabetes [6]. Alternatively, genetic markers associated with both conditions (i.e. CVD and hypertension) might also play a role [28]. Our results thus suggest that subjects with personal or family history of CVD are at a higher risk of developing hypertension.

Being physically active was inversely associated with incident hypertension, a finding in agreement with the literature [8]. Several mechanisms have been put forward to explain this effect, such

as a decrease in heart rate and in systemic vascular resistance. Our results thus stress the need of regular physical exercise to prevent incidence of hypertension.

Former smoking was associated with increased incidence of hypertension on bivariate analysis, but this association disappeared after multivariate adjustment, namely by the inclusion of BMI. This suggests that the effect of quitting smoking on incidence of hypertension is due to the frequent increase in weight after quitting smoking. Hence, subjects who quit smoking without increasing BMI have a triple benefit: no increase of body weight, no increase of BP, and no deleterious effects of smoking.

Contrary to other studies [7], no association was found between alcohol consumption and incidence of hypertension. A likely explanation is the small proportion of excessive alcohol consumers in the sample, making the analyses underpowered to detect such associations. Also contrary to other studies [9], no association was found between educational level and incidence of hypertension, suggesting that, at least in this setting, the impact of education is modest.

Implications for clinical practice and public health

From a clinical perspective, prevention of hypertension should focus on men, the elderly and overweight/obese subjects. Subjects with personal of family history of CVD should also be recommended to regularly monitor their blood pressure levels. Measures aimed at losing weight, quitting smoking and increasing physical exercise, together with an improvement in dietary intake by reducing alcohol consumption [5] should be performed. From a public health perspective, general measures to promote healthy eating, a physically active friendly environment, and health education should be strengthened. Still, as our findings are based on observational and not on interventional data, our conclusions should be interpreted with caution.

Strengths and limitations

To our knowledge, this is the first ever study assessing the incidence and socio-demographic determinants of hypertension in Switzerland. It is also based on a relatively long follow-up time (10.9 years on average) while most studies relied on a 5-year follow-up [9, 14].

This study has several limitations: firstly, it was based on an urban, French-speaking sample of Switzerland. Hence, it might not reflect the status of the other linguistic parts of the country. Still, both the prevalence rates and the determinants identified were in agreement with the literature, and similar findings might be expected in the other parts of Switzerland. Still, it would be interesting that such a study be conducted in the German or Italian speaking parts of Switzerland. Secondly, as the original sampling database was no longer available, we cannot compare the characteristics of responders and non-responders. Even though, only gender and age were available in the population register, so comparisons regarding socio-demographic determinants would have been limited. Thirdly, participation rate was low (6733 participants out of 19,830 invited, 34%) but in line with other European surveys (participation rates ranging between 16% and 57% for men and 31% and 74% in women) [29]. Participation rate was lower than for a comparable study conducted in the canton of Geneva (55% to 65%) [16] but higher than or comparable to other Swiss national surveys that also included physical examinations: 9.7% for the Swiss Survey on Salt Intake [30] and 38% for the Swiss National nutrition survey [31]. Fourthly, sample size was rather small, which might have reduced statistical power and precluded the identification of some associations such as with alcohol consumption. Still, most of the existing associations were identified. Fifthly, more women than men accepted to participate in the study, a finding in agreement with the literature [29]. This might have reduced the incidence of hypertension, as women have a lower risk of developing hypertension than men [6, 9]. Still, most associations remained after inverse probability weighting, suggesting that the higher prevalence of women in our sample did not distort the findings.

Conclusion

After a follow-up of 10.9 years, between one fourth and one third of the Swiss population aged 35 to 75 developed hypertension. Male gender, increasing age and higher BMI increase the risk of developing hypertension, while being physically active reduces the risk.

Conflict of interest

The authors report no conflict of interest.

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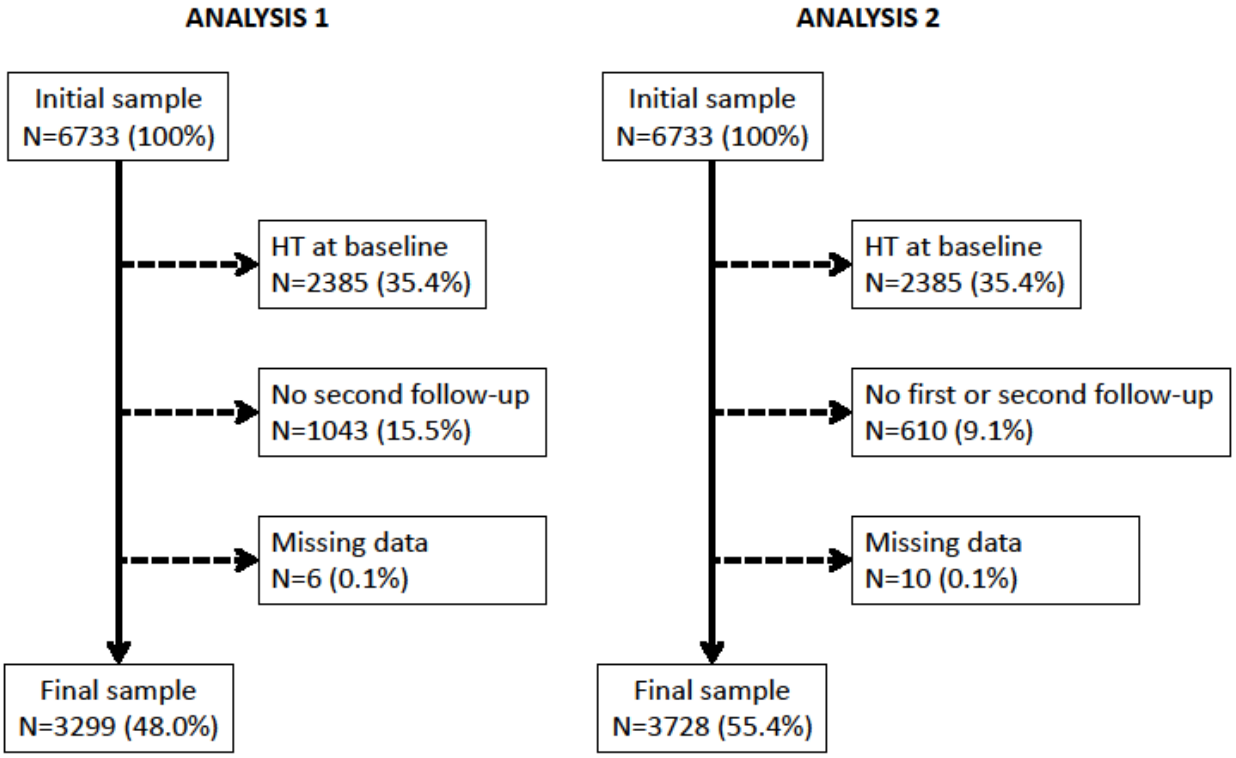
Figure legends

Figure 1: selection procedure for the two analyses.



Tables

Table 1: comparison between participants who developed/did not develop hypertension between the baseline and 1) the second follow-up only or 2) the first or the second follow-up and participants who remained free of the condition, CoLaus study, Lausanne, Switzerland

	Between baseline and second FU only			**Between baseline and first or second FU**		
	Normotensive	**Hypertensive**	**P-value**	**Normotensive**	**Hypertensive**	**P-value**
Sample size	2416	883		2600	1128	
Women	1474 (61.0)	480 (54.4)	<0.001	1575 (60.6)	590 (52.3)	<0.001
Age (years)	48.1 ± 9.1	52.6 ± 10.1	<0.001	47.9 ± 9.0	52.7 ± 10.3	<0.001
Age groups			<0.001			<0.001
[35-44[	1058 (43.8)	233 (26.4)		1162 (44.7)	300 (26.6)	
[45-54[	796 (33.0)	295 (33.4)		851 (32.7)	368 (32.6)	
[55-64[	445 (18.4)	246 (27.9)		471 (18.1)	308 (27.3)	
[65+	117 (4.8)	109 (12.3)		116 (4.5)	152 (13.5)	
BMI (kg/m^2)	24.1 ± 3.7	25.6 ± 3.8	<0.001	24.1 ± 3.7	25.8 ± 4.0	<0.001
BMI categories			<0.001			<0.001
Normal	1585 (65.6)	403 (45.6)		1708 (65.7)	506 (44.9)	
Overweight	674 (27.9)	384 (43.5)		729 (28.0)	488 (43.3)	
Obese	157 (6.5)	96 (10.9)		163 (6.3)	134 (11.9)	
Smoking categories			<0.001			<0.001
Never	1028 (42.6)	331 (37.5)		1089 (41.9)	433 (38.4)	
Former	704 (29.1)	331 (37.5)		744 (28.6)	406 (36.0)	

Current	684 (28.3)	215 (24.4)		767 (29.5)	289 (25.6)	
Alcohol consumption			0.051			0.055
None	648 (26.8)	252 (28.5)		712 (27.4)	321 (28.5)	
1-13/week	1483 (61.4)	504 (57.1)		1563 (60.1)	639 (56.7)	
14-34/week	262 (10.8)	121 (13.7)		298 (11.5)	160 (14.2)	
35+/week	23 (1.0)	6 (0.7)		27 (1.0)	8 (0.7)	
Education categories			<0.001			<0.001
Basic	360 (14.9)	166 (18.8)		412 (15.9)	219 (19.4)	
Apprenticeship	764 (31.6)	322 (36.5)		821 (31.6)	399 (35.4)	
High School	673 (27.9)	216 (24.5)		709 (27.3)	278 (24.7)	
University	619 (25.6)	179 (20.3)		658 (25.3)	232 (20.6)	
Physical activity			<0.001			0.016
No	1016 (42.1)	421 (47.7)		1120 (43.1)	534 (47.3)	
Yes	1400 (58.0)	462 (52.3)		1480 (56.9)	594 (52.7)	
Personal history of CVD			<0.001			<0.001
No	2374 (98.3)	840 (95.1)		2557 (98.4)	1070 (94.9)	
Yes	42 (1.7)	43 (4.9)		43 (1.7)	58 (5.1)	
Family history of CVD			0.002			<0.001
No	1833 (75.9)	622 (70.4)		1993 (76.7)	796 (70.6)	
Yes	583 (24.1)	261 (29.6)		607 (23.4)	332 (29.4)	

BMI, body mass index; CVD, cardiovascular disease; FU, follow-up. Results are expressed as number (percentage) for categorical variables or as average ± standard deviation for continuous variables. Between-group comparisons performed using chi-square for categorical variables and student's t-test for continuous variables.

Table 2: Multivariable analysis without adjusting for baseline blood pressure of the factors associated with incident hypertension at 1) the second follow-up only or 2) at the first or the second follow-up, CoLaus study, Lausanne, Switzerland.

	Between baseline and second FU only	**Between baseline and first or second FU**
Sample size	3299	3728
Gender		
Woman	1 (ref.)	1 (ref.)
Man	1.22 (1.08 - 1.36)	1.25 (1.13 - 1.38)
Age groups		
[35-44[	1 (ref.)	1 (ref.)
[45-54[	1.43 (1.23 - 1.66)	1.40 (1.23 - 1.60)
[55-64[	1.83 (1.57 - 2.14)	1.80 (1.58 - 2.06)
[65+	2.45 (2.04 - 2.96)	2.53 (2.17 - 2.95)
p-value for trend	<0.001	<0.001
BMI categories		
Normal	1 (ref.)	1 (ref.)
Overweight	1.57 (1.39 - 1.77)	1.55 (1.39 - 1.72)
Obese	1.58 (1.32 - 1.89)	1.70 (1.47 - 1.98)
p-value for trend	<0.001	<0.001
Smoking categories		
Never	1 (ref.)	1 (ref.)
Former	1.17 (1.03 - 1.33)	1.11 (0.99 - 1.23)
Current	0.95 (0.82 - 1.10)	0.95 (0.84 - 1.07)
p-value for trend	0.521	0.418
Education categories		
University	1 (ref.)	1 (ref.)
High school	1.04 (0.88 - 1.23)	1.04 (0.90 - 1.20)
Apprenticeship	1.15 (0.99 - 1.35)	1.11 (0.97 - 1.26)
Basic	1.18 (0.99 - 1.42)	1.12 (0.96 - 1.31)
p-value for trend	0.035	0.102
Physically active		
No	1 (ref.)	1 (ref.)
Yes	0.87 (0.78 - 0.98)	0.92 (0.83 - 1.01)
Personal hist. of CVD		
No	1 (ref.)	1 (ref.)
Yes	1.51 (1.21 - 1.90)	1.45 (1.21 - 1.74)
Family history of CVD		
No	1 (ref.)	1 (ref.)
Yes	1.17 (1.04 - 1.32)	1.19 (1.08 - 1.32)

BMI, body mass index; CVD, cardiovascular disease; FU, follow-up. Results expressed as multivariable adjusted incident rate ratio and (95% confidence interval). Statistical analysis conducted using Poisson regression adjusting for all the variables in the table.

Table 3: Multivariable analysis with further adjustment for baseline systolic and diastolic blood pressure of the factors associated with incident hypertension at 1) the second follow-up only or 2) at the first or the second follow-up, CoLaus study, Lausanne, Switzerland.

	Between baseline and second FU only	**Between baseline and first or second FU**
Sample size	3299	3728
Gender		
Woman	1 (ref.)	1 (ref.)
Man	0.94 (0.84 - 1.05)	0.98 (0.89 - 1.08)
Age groups		
[35-44[	1 (ref.)	1 (ref.)
[45-54[	1.28 (1.11 - 1.47)	1.24 (1.10 - 1.40)
[55-64[	1.41 (1.21 - 1.65)	1.38 (1.21 - 1.58)
[65+	1.74 (1.44 - 2.11)	1.81 (1.55 - 2.11)
p-value for trend	<0.001	<0.001
BMI categories		
Normal	1 (ref.)	1 (ref.)
Overweight	1.33 (1.19 - 1.50)	1.32 (1.19 - 1.45)
Obese	1.19 (1.00 - 1.42)	1.30 (1.13 - 1.50)
p-value for trend	0.049	<0.001
Smoking categories		
Never	1 (ref.)	1 (ref.)
Former	1.18 (1.05 - 1.33)	1.13 (1.02 - 1.25)
Current	1.09 (0.95 - 1.25)	1.06 (0.95 - 1.19)
p-value for trend	0.239	0.302
Education categories		
University	1 (ref.)	1 (ref.)
High school	1.04 (0.89 - 1.22)	1.04 (0.91 - 1.19)
Apprenticeship	1.10 (0.95 - 1.27)	1.07 (0.95 - 1.21)
Basic	1.12 (0.94 - 1.33)	1.08 (0.93 - 1.25)
p-value for trend	0.167	0.270
Physically active		
No	1 (ref.)	1 (ref.)
Yes	0.86 (0.77 - 0.95)	0.9 (0.82 - 0.99)
Personal hist. of CVD		
No	1 (ref.)	1 (ref.)
Yes	1.62 (1.31 - 1.99)	1.60 (1.35 - 1.90)
Family history of CVD		
No	1 (ref.)	1 (ref.)
Yes	1.12 (1.00 - 1.25)	1.14 (1.03 - 1.25)

BMI, body mass index; CVD, cardiovascular disease; FU, follow-up. Results expressed as multivariable adjusted incident rate ratio and (95% confidence interval). Statistical analysis conducted using Poisson regression adjusting for all the variables in the table.