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Excess Body Weight, Cigarette Smoking, and Type 2 Diabetes Incidence in the National FINRISK Studies

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Abstract

Purpose: We identify the individual and joint contributions of excess weight and cigarette smoking to national-level T2D incidence and to educational and gender disparities therein filling an important gap in T2D epidemiology.

Methods: Based on the FINRISK surveys conducted in 1997, 2002 and 2007, and linked to the Finnish National Drug Reimbursement Register through 2011, we used a regression-counterfactual approach to estimate the percentage of diagnosed drug-treated incident T2D cases attributable to excess body weight and cigarette smoking. Body mass index (BMI) and waist circumference (WC) were evaluated.

Results: T2D incidence was 10.24 in men and 7.04 in women per 1,000 person-years. Excess baseline BMI ($> 25.0 \text{ kg/m}^2$) explained 69% and 63%, and smoking explained 9% and 14% of T2D incidence, in men and women, respectively. Most of the gender difference was explained by the risk factors. Approximately 90% in men and 98% in women of the higher T2D incidence among those in the lower versus upper third of the educational distribution was explained by excess BMI. Results were similar for WC and lifetime maximum BMI.

Conclusions: Excess body weight is the main risk factor contributing to national-level T2D incidence and disparities by educational attainment and gender in a high-income population.

Keywords

Diabetes; obesity; cigarette smoking; Finland; population attributable risk fractions

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Introduction

Type 2 diabetes [T2D] levels are rising internationally [1]. Contemporary populations are also characterized by high levels of obesity and a high percentage of current and former smokers, both risk factors for T2D and amenable to behavioral-based interventions [2–9]. While many studies evaluate the individual-level association between each risk factor and T2D, less attention is given to how these risk factors affect national-level T2D incidence. We often do not know, for example, the percentage of national-level T2D cases attributable to each risk factor. Moreover, the extent to which the risk factors account for differences in T2D incidence across gender and socioeconomic groups is also understudied. Filling these gaps provides valuable evidence on the benefits of behavioral-based interventions to improve national-level T2D incidence.

Excess body weight is an established T2D risk factor. An international meta-analysis of 18 observational studies found that the pooled relative risk (RR) of incident diabetes from obesity (body mass index, BMI ≥ 30) was 7.19 relative to a BMI <25 [2]. The pooled RR from being overweight (BMI 25 to <30) was 2.99. Randomized controlled trials of intensive lifestyle interventions, which included weight loss and dietary improvement, have recorded beneficial effects of lifestyle on diabetes risk [4,5,10].

The effect of cigarette smoking on T2D risk is less extensively studied compared to that of body weight. Large prospective cohort studies have, however, consistently documented a higher diabetes risk for current and former smokers relative to never smokers independent of weight status [6–9]. The European Prospective Investigation into Cancer and Nutrition study found that current and former smokers had elevated risks of incident diabetes relative to never smokers in the range of 13–40% [8]. A similar level of association was observed in the U.S Atherosclerosis Risk in Communities Study [9]. Quitting smoking has been associated with a higher T2D risk in the short-term than continued smoking, but a reduction in risk over the longer term [6,9]. The rise in short-term risk is mediated by weight gain related to smoking cessation [11].

We quantify the percentage of incident T2D cases attributable to excess body weight and cigarette smoking in the national Finnish population. We apply a population attributable risk approach and examine the individual and joint contributions of the two risk factors to T2D incidence for the overall population and to differences by gender and educational attainment. Finland, similar to other high-income countries, is characterized by a high prevalence of obesity and current and former smoking. Therefore, our findings have relevancy to other high-income countries [12].

We provide several contributions. First, we evaluated the roles of excess body weight and cigarette smoking individually and jointly. Second, we compared three weight status indicators—BMI measured at the time of survey (baseline BMI), waist circumference measured at the time of survey (baseline WC), and respondents' maximum lifetime BMI based on reported maximum lifetime bodyweight (maximum BMI). Compared to BMI, WC is believed to provide a more direct indicator of central adiposity, which is strongly associated with T2D [13]. Maximum BMI has been shown to be a robust predictor of

mortality [14,15], as it may capture well long-term trajectories of BMI [3] and be robust to reverse causal processes [16]. Third, we quantified the percentage of gender and educational attainment differences in T2D incidence attributable to the risk factors.

Methods

Data and Sample

We use the 1997, 2002, and 2007 FINRISK surveys [17]. FINRISK is a large population-based survey on risk factors of non-communicable diseases targeting adults aged 25–74. The survey was carried out every five years for 40 years since 1972 using independent national-level samples. The surveys cover six regions representing both urban and rural areas. Participation rates have been high [17]. Surveys consist of questionnaires, a health examination, and blood samples. FINRISK is linked to the National Drug Reimbursement Register (NDRR) via the unique identification code given to all Finnish citizens or non-citizen permanent residents. NDRR records reimbursement for medications for the entire population. Prospective NDRR follow-up through December 31, 2011 is used.

Our target population was adults aged 40–74 years at survey who reported no previous diabetes diagnosis, had not been prescribed a diabetes medication, and who survived the calendar year they were surveyed ($n=15,053$). We excluded those *who* had missing information on baseline BMI ($n=169$) and WC ($n=30$). Individuals with BMI values outside the 18.5–49.9 kg/m² range ($n=65$) and the 60–150 cm range for WC ($n=2$) were excluded. An additional 359 respondents who were missing information on educational attainment or smoking were excluded. The analytic population consisted of 14,428 respondents (7,066 men and 7,362 women) followed over 136,980 person-years (mean: 9.5 years). There were 1,177 incident T2D cases. $N=1,096$ individuals died during follow-up.

T2D Incidence

We evaluated diagnosed drug-treated T2D incidence. The timing of an incident case was identified by the first post-survey appearance in NDRR of a reimbursed diabetes medication based on the Anatomical Therapeutic Chemical (ATC) class A10. These include insulin (ATC A10A) and oral diabetes medications (ATC A10B). Since new cases were identified after age 40 years, we assumed that all incident cases were T2D and not type 1. Our estimates of incidence from FINRISK are consistent with previously published estimates for other high-income countries (Supplemental Figure 1).

Covariates

Educational attainment was measured using birth cohort-specific tertiles to account for improving educational attainment over time [18]. Baseline BMI was calculated from measured body weight with a precision to 0.1 kilograms and measured height with a precision to 0.1 centimeters. We used a threshold of BMI=25.0 and define BMI 25.0 as excess BMI. BMI was entered in regression models as a continuous variable whereby BMI values less than 25.0 were assigned a value of zero, and BMI values greater than 25.0 were assigned a value of the actual BMI minus 25.0 [19,20].

Baseline WC was measured in centimeters. We used sex-specific thresholds from the World Health Organization to define excess WC: >95 cm for men and >80 cm for women [21]. Those at or below the sex-specific threshold were given a value of zero and those above were assigned a value of their WC minus the appropriate sex-specific threshold.

Never smokers were defined as those who reported having smoked less than 100 cigarettes. Current smokers were defined as those who reported smoking at least 100 cigarettes and smoked within the month prior to survey. Former smokers were defined as individuals who reported smoking at least 100 cigarettes and who had not smoked in the prior month.

Additional robustness checks were performed. We used maximum lifetime BMI as the weight status indicator. And, we evaluated the confounding roles of current alcohol consumption and physical activity.

Regression Models

Discrete time logistic regression models were implemented on a person-year file. Models were sex stratified. The baseline BMI model was:

$$\log\left(\frac{p_{it}}{1 - p_{it}}\right) = \beta_1 * Age_{it} + \sum_{j=1}^3 \beta_{3j} * Education_{ij} + \beta_4 * BMI_i + \beta_5 * BMI_i^2 + \beta_6 * Current_i + \beta_7 * Former_i + \beta_2 * Year_{it}; \quad \text{eq. (1)}$$

where it denotes an individual i at t years since baseline. Age is age in single years. $Education_{ij}$ are the indicators for educational category and BMI_i is the continuous term for baseline BMI. $Current_i$ and $Former_i$ refer to baseline smoking status. $Year_{it}$ is calendar year. Analogous specifications for baseline WC were implemented.

Preliminary analyses informed the specification. Linear splines indicated no association between weight status and T2D incidence below the thresholds (e.g., 25.0 for baseline and maximum BMI; P values > .10). Statistical interactions between educational attainment and weight status and between education and smoking were insignificant (P values greater than .10 and in many instances greater than .50). Household income was not predictive of T2D in the multivariate models. Inclusion of this variable did not alter main findings.

Population Attributable Risk Fractions

We used a counterfactual approach to identify the percentage of T2D incidence attributable to the risk factors [22–24]. The regression equation (e.g., eq. [1]) was used to predict the annual risk of incident T2D. The mean of the individual-level predictions equals the population T2D incidence. We re-estimated mean incidence under three counterfactual scenarios: (1) everyone has a baseline BMI of 25.0 or below (i.e., eliminating excess baseline BMI), (2) everyone never smoked (i.e., eliminating current and former smoking), and (3) the elimination of both risk factors jointly. The difference between the counterfactual-based incidence and the original incidence provides the population attributable risk. The procedure was separately conducted for baseline WC and maximum BMI.

To identify the percentage of educational differences in T2D attributable to the risk factors, we calculated age-adjusted T2D incidence for each education and sex groups. Age-adjustment was achieved by incrementing each respondent's age by an amount equal to the difference between their own education-sex subgroup's mean age and the mean age of highly educated males. Then we applied the three counterfactual scenarios to estimate how much of the difference in T2D incidence across educational groups is attributable to the risk factors.

Results

Men experienced a higher T2D incidence compared to women (10.24 vs. 7.04 cases per 1,000 per years) (Table 1). Approximately 73% of men and 62% of women had a baseline BMI ≥ 25.0 . The mean baseline waist circumference was 97.3 cm for men and 86.0 cm for women; whereas the percentage above 94.0 cm for men is 61% and above 80.0 cm for women is 65%. Men, compared to women, were also more likely to be current (28% vs. 18%) or former (30% vs. 23%) smokers.

Educational group differences in T2D incidence were more pronounced among men than women (Table 1). In contrast, baseline BMI and baseline waist circumference tended to vary more across educational groups among women than men. Low educated men and women were also more likely to smoke compared to their middle and high educated counterparts.

Model 1 of Table 2, which excluded a weight status variable, indicated that the high education group had an approximate 20% (women) to 25% (men) lower odds of incident diabetes compared to the low education group. Model 2, which included baseline BMI and BMI-squared, shows a strong association, but one that diminishes, with increasing BMI (as evidenced by an $OR < 1.00$ on the BMI squared term). The interpretation is as follows. For men, at baseline BMI=25.0, the odds of incident diabetes increases by 44% per unit increase in BMI. The percentage increases for a one unit change in BMI at a BMI=30.0 is 29%. For women, the one unit increase is 36% at a baseline BMI=25.0 and 24% at a BMI=30.0.

Under the counterfactual of eliminating excess baseline BMI, T2D incidence for men falls to 3.20 cases per 1,000 person-years or by 69% from the observed 10.24 cases per 1,000 person-years (Table 3). Eliminating current and former smoking results in a fall by 9% to 9.28 cases per 1,000 person-years. Simultaneous elimination of both risk factors accounts for 72% or 7.35 cases per 1,000 person-years of T2D incidence. Results for women are comparable, although a slightly lower attribution is given to excess baseline BMI (63%) and a slightly higher attribution to smoking (14%). Jointly, the two risk factors accounted for 69% of the T2D incidence among women.

The observed sex difference in incidence was 3.20 cases per 1,000 PYs (Table 3). Under the scenario of jointly eliminating excess BMI and smoking, the predicted sex difference was 0.72 cases per 1,000 person-years (obtained by subtracting 2.18 from 2.90). Thus, eliminating excess BMI and smoking jointly accounts for 78% of the sex difference.

We found that baseline WC was positively associated with the odds of T2D incidence, but the magnitude of this association declines with increasing WC (Model 3 of Table 2). At the

thresholds of 94 cm for men and 80 cm for women, there was a 15% (men) and 13% (women) increase in the odds of diabetes for each cm increase in WC. Table 4 provides counterfactual results for baseline WC. Eliminating excess WC, explained 60% (men) and 64% (women) of T2D incidence.

Results for maximum BMI are shown in Supplemental Tables S1–S3 and Supplemental Figure 2. Similar to baseline BMI, maximum BMI was positively associated with T2D incidence (Table S2). Eliminating excess maximum BMI explained 72% (men) and 64% (women) of T2D incidence (Table S3). Tables S4 and S5 indicate that findings were robust to alcohol consumption and physical activity.

T2D Incidence by Educational Attainment

Most of the differences in T2D incidence across the educational groups was explained by excess baseline BMI (Figure 1). Among men, the age-adjusted T2D difference between the high and low education groups is 2.57 cases per 1,000 person-years, which declines to 0.27 cases per 1,000 person-years or by 90% with the elimination of excess baseline BMI. Among women, the difference between the high and low educational groups was eliminated. Smoking explained 14% (men) and 21% (women) of the high-low difference. Similar patterns were observed for baseline WC and maximum BMI (results not shown).

Discussion

Understanding the population-level drivers of T2D is critical for public health policy. We measured the contribution of two major behavioral factors—excess body weight and cigarette smoking—to identify the importance of behavioral interventions in reducing T2D levels nationally. Approximately 70% of incident T2D cases among Finnish adults during 1997–2011 were jointly attributable to the two behavioral factors. Excess body weight had a substantially larger role than cigarette smoking. The two risk factors accounted for nearly 80% of excess male T2D incidence relative to that of females and nearly the entire gap between those in the top and bottom one-third of the educational attainment distribution. The findings are robust to the measure of weight status used, i.e., baseline BMI, baseline WC, and maximum BMI, and adjustments for alcohol consumption and physical activity.

Few studies have estimated the percentage of incident T2D cases attributable to excess weight using a population attributable risk framework, the approach we use in this study [25]. These studies were either derived from convenience samples, had a small number of T2D cases, or pertained to an earlier period. Laaksonen et al.[26] used a pooled sample from two national surveys of the Finnish population, one conducted in 1978–1980 (Mini-Finland Health Survey) and one conducted in 2000 (Health 2000). The authors reported that excess BMI (> 25.0) accounted for 77% (men) and 79% (women) and smoking accounted for 12% (men) and 4% (women) of T2D incidence. These prior estimates are consistent with our findings, although our study pertains to a more recent period.

Diabetes prevalence in Finland at ages 18+ was 9.6% in 2017, which is similar to a prevalence of 9.1% for Europe as a whole [27]. Levels have increased faster among men, compared to women, and among those with low, compared to high, education between the

1970s and 1990s [18]. Our results suggest that the differing pace of the obesity epidemic by educational attainment and gender can explain the diverging trends in T2D prevalence. Abouzeid et al. [18], also using FINRISK data, report that incident T2D among men and women were similar in the 1970s, but by the 1990s men had higher levels than women. Mehta et al. [19], show that between 1978–1980 and 2000–2001, obesity levels rose faster among men, compared to women, in Finland.

We evaluated three indicators of weight status: two based on BMI and WC. Both measures of BMI, baseline and maximum, have been used to quantify health risks associated with obesity in prospectively followed samples [16,28]. Compared to baseline BMI, respondent's lifetime maximum BMI is less likely to be affected by reverse causality [14,16,29,30]. WC in turn provides a more direct indicator of central adiposity, which is thought to be strongly associated with diabetes risk [13]. Despite the comparative strengths and weaknesses of the three indicators, we report a remarkable similarity in results in terms of their population attributable risk fractions of T2D incidence.

Our estimates of incidence pertain to diagnosed and drug-treated T2D. The total incidence of T2D in the Finnish population will be higher. The 2000–2010 Finnish DEHKO D2 project, which covered a similar period as our study, indicated that that approximately 20% of those whose blood glucose met the threshold for diabetes were not diagnosed [31]. Moreover, a subset of individuals with diagnosed T2D are not treated with medications, which in Finland has been estimated to be about 25% in 2011 [32] and 10% in 2017 [33].

The gradient in T2D incidence by educational attainment that we report will likely be an under-estimate of the actual educational-based disparities in T2D incidence. Using the FIN-D2D surveys conducted in 2004–2005 and 2007, Wikström et al. [34] found that adults with low education are more likely to have undiagnosed diabetes compared with those who have high education. Thus, Wikström et al. [34] specifically found that among 45–74 year olds, those with low education (0–9 years of schooling) had a 3–4 percentage point higher likelihood of being undiagnosed compared to those with high education (≥13 years of schooling).

Detailed historical information on alcohol consumption and physical activity were unavailable and activity levels around time of survey may be subject to reverse causal bias and therefore was not included [35]. Detailed dietary data was also unavailable. Our main weight status indicators—baseline BMI and baseline WC—were clinically measured. Maximum BMI is based on a self-report of historical body weight and is subject to self-reporting bias as is reports of status. Maximum body weight has been partially validated in a U.S. sample [36]. The validity of self-reported smoking status in the Finnish population has been shown to be high, nonetheless, underreporting may have contributed to a downward bias in our estimates [37]. We were unable to investigate the effect of quitting-related weight gain among former smokers.

Conclusion

Evaluations of the population attributable risks associated with T2D risk factors sheds light on the most important factors contributing to T2D incidence at a national level. Our findings

indicate that excess body weight is the main factor contributing to national-level T2D incidence in a European population. Cigarette smoking plays an important, but more minor role, compared to excess body weight. To reverse adverse trends in T2D incidence, behavioral interventions should be targeted throughout the life course with special attention given to those with lower educational attainment.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

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Figure 1.

Type 2 diabetes (T2D) incidence by educational attainment and sex under counterfactual scenarios of eliminating excess baseline BMI, cigarette smoking, and both risk factors jointly.

Legend: Counterfactuals calculated from logistic regression models shown in Table 2. Ages 40–74 years at time of survey. Excess BMI is a BMI ≥ 30.0 . Smoking status ascertained at baseline. Data are from FINRISK 1997, 2002, 2007 with follow-up through 2011.

Figure 2.

Type 2 diabetes (T2D) incidence by educational attainment and sex under counterfactual scenarios of eliminating excess baseline waist circumference, cigarette smoking, and both risk factors jointly.

Legend: Counterfactuals calculated from logistic regression models shown in Table 2. Ages 40–74 years at time of survey. Excess waist circumference defined using sex-specific cut-points from the World Health Organization: >95 cm for men and >80 cm for women.

Smoking status ascertained at baseline. Data are from FINRISK 1997, 2002, 2007 with follow-up through 2011.

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Table 1.

Descriptive characteristics by sex and educational attainment

Characteristic	Men					Women				
	Educational Attainment					Educational Attainment				
	All (N=7,066)	Low (N=2,219)	Medium (N=2,391)	High (N=2,456)	All (N=7,362)	Low (N=2,448)	Medium (N=2,442)	High (N=2,472)		
Diabetes cases (N)	681	232	244	205	496	185	164	147		
Diabetes incidence (per 1000 person-years)	10.24	11.18	10.89	8.79	7.04	7.98	6.94	6.21		
Age at survey (mean, years)	(9.48, 11.01)	(9.75, 12.61)	(9.53, 12.25)	(7.60, 9.99)	(6.42, 7.65)	(6.83, 9.12)	(5.88, 8.00)	(5.21, 7.21)		
	55.41	55.26	55.34	55.63	54.51	54.4	54.39	54.73		
	(55.19, 55.63)	(54.87, 55.65)	(54.96, 55.72)	(55.25, 56.00)	(54.30, 54.71)	(54.03, 54.76)	(54.03, 54.75)	(54.37, 55.09)		
Baseline BMI, kg/m ²										
Mean	27.45	27.69	27.64	27.04	27.16	27.88	27.17	26.44		
	(27.36, 27.54)	(27.53, 27.86)	(27.49, 27.80)	(26.89, 27.18)	(27.05, 27.27)	(27.67, 28.08)	(26.98, 27.36)	(26.26, 26.62)		
Mean of those with a BMI ≥ 25.0	28.99	29.20	29.12	28.65	29.86	30.32	29.83	29.35		
	(28.90, 29.08)	(29.04, 29.37)	(28.97, 29.27)	(28.51, 28.80)	(29.74, 29.98)	(30.11, 30.53)	(29.62, 30.03)	(29.15, 29.55)		
BMI ≥ 25.0, (%)	73.11	74.81	74.82	69.91	62.27	67.65	62.24	56.96		
	(72.08, 74.14)	(73.00, 76.62)	(73.08, 76.56)	(68.10, 71.73)	(61.16, 63.37)	(65.79, 69.50)	(60.32, 64.17)	(55.01, 58.91)		
BMI ≥ 30.0, (%)	21.65	24.16	23.96	17.14	24.07	29.82	23.87	18.57		
	(20.69, 22.61)	(22.37, 25.94)	(22.25, 25.68)	(15.65, 18.63)	(23.09, 25.05)	(28.01, 31.63)	(22.18, 25.57)	(17.03, 20.10)		
Baseline Waist Circumference (WC)										
Mean, (cm)	97.32	97.68	97.74	96.59	85.98	87.65	85.71	84.6		
	(97.07, 97.58)	(97.21, 98.15)	(97.30, 98.18)	(96.18, 97.00)	(85.70, 86.26)	(87.13, 88.16)	(85.23, 86.18)	(84.13, 85.07)		
WC ≥ 94.0 cm (men) or ≥ 80.0 (women), (%)	61.19	61.06	62.9	59.65	65.08	69.32	64.91	61.04		
	(60.06, 62.33)	(59.03, 63.09)	(60.97, 64.84)	(57.71, 61.59)	(63.99, 66.17)	(67.49, 71.15)	(63.01, 66.80)	(59.12, 62.97)		
Baseline Cigarette Smoking, (%)										
Current	28.22	32.85	28.36	23.90	17.96	22.14	17.77	14.00		
	(27.17, 29.27)	(30.90, 34.81)	(26.55, 30.16)	(22.21, 25.59)	(17.08, 18.83)	(20.50, 23.79)	(16.26, 19.29)	(12.63, 15.36)		
Former	39.68	38.98	41.61	38.44	22.56	21.32	21.83	24.51		
	(38.54, 40.82)	(36.95, 41.01)	(39.64, 43.59)	(36.51, 40.36)	(21.61, 23.52)	(19.70, 22.95)	(20.19, 23.47)	(22.82, 26.21)		

Characteristic	Men						Women					
	Educational Attainment						Educational Attainment					
	All (N=7,066)	Low (N=2,219)	Medium (N=2,391)	High (N=2,456)	All (N=7,362)	Low (N=2,448)	Medium (N=2,442)	High (N=2,472)	All (N=7,362)	Low (N=2,448)	Medium (N=2,442)	High (N=2,472)
Never	32.10 (31.01,33.19)	28.17 (26.29,30.04)	30.03 (28.19,31.87)	37.66 (35.75,39.58)	59.48 (58.36,60.60)	56.54 (54.57,58.50)	60.40 (58.46,62.34)	61.49 (59.57,63.41)				
Diabetes cases (N)	681	232	244	205	496	185	164	147				
Person-years	66,477	20,758	22,407	23,312	70,503	23,194	23,641	23,668				

Note: 95% confidence interval shown in parentheses. Data are from FINRISK 1997, 2002, 2007 with follow-up through 2011. Ages 40–74 years at time of survey. Educational attainment based on cohort-specific tertiles.

Table 2.

Odds ratios (95% confidence intervals) from logistic regression models predicting type 2 diabetes (T2D) incidence.

Characteristic	Men			Women		
	Model 1	Model 2: Baseline BMI	Model 3: Baseline Waist Circumference	Model 1	Model 2: Baseline BMI	Model 3: Baseline Waist Circumference
Age	1.03 (1.02, 1.04)	1.03 (1.02, 1.04)	1.03 (1.02, 1.03)	1.04 (1.03, 1.05)	1.04 (1.03, 1.05)	1.04 (1.03, 1.05)
Educational Level (Low)						
Medium	0.96 (0.80, 1.15)	0.96 (0.80, 1.15)	0.96 (0.80, 1.15)	0.89 (0.71, 1.10)	0.98 (0.80, 1.22)	0.99 (0.80, 1.23)
High	0.76 (0.63, 0.92)	0.92 (0.76, 1.12)	0.87 (0.72, 1.05)	0.81 (0.64, 1.01)	1.02 (0.82, 1.27)	0.98 (0.79, 1.22)
Calendar Year	1.11 (1.08, 1.13)	1.12 (1.09, 1.14)	1.11 (1.09, 1.14)	1.10 (1.07, 1.13)	1.11 (1.08, 1.14)	1.09 (1.07, 1.12)
Baseline BMI (kg/m ²)		1.44 (1.37, 1.51)			1.36 (1.29, 1.42)	
Baseline BMI-squared		0.989 (0.986, 0.992)			0.991 (0.988, 0.994)	
Baseline Waist Circumference (cm)			1.15 (1.13, 1.17)			1.13 (1.10, 1.15)
Baseline Waist Circumference-squared			0.998 (0.998, 0.999)			0.999 (0.998, 0.999)
Smoking Status (Never) Current		1.24 (1.00, 1.53)			1.92 (1.52, 2.43)	1.77 (1.40, 2.24)
Former		1.11 (0.92, 1.33)	1.06 (0.88, 1.28)		1.21 (0.96, 1.52)	1.12 (0.89, 1.41)

Note: Ages 40–74 years at time of the survey. Educational attainment based on birth cohort specific tertiles. Omitted categories shown in parentheses. Model 1 excludes any measure of weight status. Model 2 includes baseline BMI and Model 3 includes baseline waist circumference. Models stratified by sex. Data are from FINRISK 1997, 2002, 2007 with follow-up through 2011. Three decimal places shown for BMI-squared and waist circumference-squared to highlight the direction of the effect size (odds ratios < 1.00).

Table 3.

Type 2 diabetes (T2D) incidence (95% confidence intervals) by sex under counterfactual scenarios eliminating excess baseline BMI and current and former cigarette smoking

Scenarios	T2D Incidence (per 1,000 person years)	Amount Explained (per 1,000 person years)	Percentage Explained
Men			
Observed	10.24 (9.48, 11.00)	-	-
Eliminating Excess Baseline BMI	3.20 (2.66, 3.75)	7.04 (6.33, 7.75)	68.72 (63.98, 73.46)
Eliminating Smoking	9.28 (7.95, 10.61)	0.97 (-0.17, 2.11)	9.45 (-1.67, 20.56)
Eliminating Excess Baseline BMI and Smoking	2.90 (2.30, 3.49)	7.35 (6.57, 8.12)	71.71 (66.30, 77.12)
Women			
Observed	7.04 (6.42, 7.65)	-	-
Eliminating Excess Baseline BMI	2.58 (2.12, 3.04)	4.46 (3.90, 5.01)	63.34 (57.63, 69.04)
Eliminating Smoking	6.05 (5.34, 6.76)	0.98 (0.50, 1.46)	13.97 (7.24, 20.70)
Eliminating excess Baseline BMI and Smoking	2.18 (1.74, 2.61)	4.86 (4.28, 5.43)	69.03 (63.50, 74.57)

Note: Counterfactuals calculated from logistic regression models shown in Table 2. Ages 40–74 years at time of survey. Excess BMI is a BMI BMI 25.0. Smoking status ascertained at baseline. Data are from FINRISK 1997, 2002, 2007 with follow-up through 2011.

Table 4.

Type 2 diabetes (T2D) incidence (95% confidence intervals) by sex under counterfactual scenarios eliminating excess baseline waist circumference and current and former cigarette smoking

Scenarios	Diabetes Incidence (per 1,000 person years)	Amount Explained (per 1,000 person years)	Percentage Explained
Men			
Observed	10.24 (9.48, 11.00)		
Eliminating Baseline Excess Baseline Waist Circumference	4.08 (3.49, 4.67)	6.16 (5.49, 6.84)	60.17 (55.28, 65.05)
Eliminating Smoking	9.69 (8.30, 11.08)	0.55 (-0.64, 1.75)	5.41 (-6.23, 17.05)
Eliminating Excess Baseline Waist Circumference and Smoking	3.86 (3.15, 4.57)	6.38 (5.58, 7.18)	62.3 (55.99, 68.60)
Women			
Observed	7.04 (6.42, 7.65)		
Eliminating Excess Baseline Waist Circumference	2.53 (2.06, 2.99)	4.51 (3.94, 5.07)	64.05 (58.25, 69.86)
Eliminating Smoking	6.21 (5.48, 6.94)	0.82 (0.33, 1.31)	11.68 (4.78, 18.59)
Eliminating Excess Baseline Waist Circumference and Smoking	2.21 (1.77, 2.66)	4.82 (4.24, 5.40)	68.53 (62.83, 74.23)

Note: Counterfactuals calculated from logistic regression models shown in Table 2. Ages 40–74 years at time of survey. Excess waist circumference defined using sex-specific cut-points from the World Health Organization: 95 cm for men and 80 cm for women. Smoking status is ascertained at time of survey. Data are from FINRISK 1997, 2002, 2007 with follow-up through 2011.