

Lifestyle and Risk of Screening-Detected Abdominal Aortic Aneurysm in Men

Otto Stackelberg, MD, PhD; Alicja Wolk, DMSc; Ken Eliasson, MD; Anders Hellberg, MD, PhD; Adam Berszstel, MD, PhD; Susanna C. Larsson, PhD; Nicola Orsini, PhD; Anders Wanhainen, MD, PhD; Martin Björck, MD, PhD

Background—Modifiable lifestyle-related factors associated with risk of abdominal aortic aneurysm (AAA) are rarely investigated with a prospective design. We aimed to study possible associations among such factors and comorbidities with mean abdominal aortic diameter (AAD) and with risk of AAA among men screened for the disease.

Methods and Results—Self-reported lifestyle-related exposures were assessed at baseline (January 1, 1998) among 14 249 men from the population-based Cohort of Swedish Men, screened for AAA between 65 and 75 years of age (mean 13 years after baseline). Multivariable prediction of mean AAD was estimated with linear regression, and hazard ratios (HRs) of AAA (AAD ≥ 30 mm) with Cox proportional hazard regression. The AAA prevalence was 1.2% ($n=168$). Smoking, body mass index, and cardiovascular disease were associated with a larger mean AAD, whereas consumption of alcohol and diabetes mellitus were associated with a smaller mean AAD. The HR of AAA was increased among participants who were current smokers with ≥ 25 pack-years smoked compared with never smokers (HR 15.59, 95% CI 8.96–27.15), those with a body mass index ≥ 25 versus < 25 (HR 1.89, 95% CI, 1.22–2.93), and those with cardiovascular disease (HR 1.77, 95% CI, 1.13–2.77), and hypercholesterolemia (HR 1.59, 95% CI 1.08–2.34). Walking or bicycling for > 40 minutes/day (versus almost never) was associated with lower AAA hazard (HR 0.59, 95% CI 0.36–0.97) compared with almost never walking or bicycling.

Conclusions—This prospective study confirms that modifiable lifestyle-related factors are associated with AAD and with AAA disease. (*J Am Heart Assoc.* 2017;6:e004725. DOI: 10.1161/JAHA.116.004725.)

Key Words: abdominal aortic aneurysm • cohort study • epidemiology • lifestyle • risk factor

Abdominal aortic aneurysm (AAA) is a disease with high mortality rates and presents an important public health problem in most countries.¹ Although much of its pathophysiology has yet to be unveiled, the origin of the disease is likely to be explained by an interaction between hereditary and

environmental factors, of which male sex, advanced age, and smoking are considered to be of the most importance.^{2,3} Furthermore, the disease has been observed to be positively associated with other comorbidities, most commonly those shared with other cardiovascular diseases (CVDs) such as atherosclerosis, hypertension, and hyperlipidemia.^{4–8} In contrast, diabetes mellitus seems to have an inverse association with AAA.^{9,10}

Associations between modifiable lifestyle-related factors and AAA disease, however, are rarely investigated with a prospective design. Studies investigating associations with lifestyle-related factors have, in most cases, been cross-sectional screening studies⁶ or have relied on a register-based outcome.¹¹ Although the latter is relevant for prospectively investigating risk of clinically relevant AAA, inferences about early AAA development may be harder to draw, given the potential risk of differential outcome classification (eg, if not all participants have been radiologically examined).

Identification of modifiable factors associated with AAA disease could provide better understanding of AAA epidemiology and etiology and provide new hypotheses for studies of AAA growth rate to try to limit expansion of small

From the Unit of Nutritional Epidemiology, Institute of Environmental Medicine, Karolinska Institutet (O.S., A.W., S.C.L., N.O.) and Department of Surgery, Södersjukhuset (O.S.), Stockholm, Sweden; Section of Vascular Surgery, Department of Surgical Sciences, Uppsala University, Uppsala, Sweden (O.S., A.H., A.B., A.W., M.B.); Section of Vascular Surgery, Department of Cardiovascular Surgery, Örebro University Hospital, Örebro, Sweden (K.E.); Section of Vascular Surgery, Centre for Clinical Research, Västmanlands County Hospital, Västerås, Sweden (A.H., A.B.).

Accompanying Table S1 and Figure S1 are available at <http://jaha.ahajournals.org/content/6/5/e004725/DC1/embed/inline-supplementary-material-1.pdf>

Correspondence to: Otto Stackelberg, MD, PhD, Unit of Nutritional Epidemiology, Institute of Environmental Medicine, Karolinska Institutet, Box 210, Stockholm SE-171 77, Sweden. E-mail: otto.stackelberg@ki.se
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screening-detected AAAs. By identifying all men in a population-based prospective cohort from central Sweden from 1997 who were subjects of AAA screening between 65 and 75 years of age between 2007 and 2015, we aimed to examine possible associations among modifiable lifestyle-related factors and abdominal aortic diameter (AAD) and risk of AAA at screening. Lifestyle-related factors considered for analysis were cigarette smoking, obesity (body mass index [BMI] and waist circumference [WC]), physical activity, diet, alcohol consumption, and history of comorbidities (diabetes mellitus, hypercholesterolemia, hypertension, and CVD).

Methods

Study Population

The Cohort of Swedish Men was established in late autumn 1997 when all men residing in Västmanland and Örebro counties in central Sweden who were born between 1918 and 1952 were invited to complete a 350-item questionnaire regarding lifestyle-related factors (available for reading at <http://ki.se/en/imm/unit-of-nutritional-epidemiology>). Of the 100 303 men invited, 48 850 (49%) responded and constituted the population for this study. The cohort represents the Swedish male population in 1997 well in terms of age distribution, educational level, BMI, and proportion of current smokers (Table S1). The study was approved by the regional ethics review board at Karolinska Institutet, Stockholm, and a completed questionnaire was considered to imply informed consent.

Assessment of Lifestyle-Related Exposures

Smoking status was reported at baseline (never, past, or current), and daily cigarette consumption was reported at ages 15 to 20, at each decade thereafter, and at baseline. Although smoking status has not been validated specifically in this cohort, self-reported smoking habits tend to be underreported.¹²

Measures of obesity (BMI and WC) were based on self-reported weight and WC at baseline and height at age 20 years. The validity of self-reported BMI compared with clinical measures in this cohort has been reported as high ($r=0.9$).¹³ WC has not been validated in this cohort, but correlations between self-reported and technician-measured WC have been reported as high in other population-based studies ($r=0.9$).¹⁴

Physical activity, namely, time spent walking or bicycling, was reported for everyday transportation purposes during the previous year. The Spearman rank correlation coefficient between the questionnaire and activity records (two 7-day records performed 6 months apart in 111 men) was 0.4 for walking or bicycling.¹⁵

Information on diet and alcohol consumption was assessed by a 96-item food-frequency questionnaire. Alcohol

consumption was reported as baseline consumption status (never, former, or current drinker), and the average frequency of consumption of foods and alcohol during the previous year was reported by the use of 8 predefined categories ranging from never to ≥ 3 times per day. Commonly consumed foods, such as dairy products and bread, and amount of beer, wine, and liquor were reported using open-ended questions. A healthy diet was defined according to a healthy diet score based on guidelines and current knowledge¹⁶ and included foods beneficial for cardiovascular health.¹⁷ Adding up to a maximal score of 25, a score of 1 was assigned for ≥ 1 weekly serving of all individual fruits (apples and pears, bananas, citrus fruits, and berries), vegetables (spinach, lettuce and green salad, cabbage, cauliflower, broccoli and brussels sprouts, carrots, beets, tomatoes and tomato juice, sweet peppers, green peas, and mixed vegetables), legumes, nuts, low-fat dairy products (reduced-fat milk, reduced-fat cultured milk or yogurt), oatmeal, whole-grain bread, crisp or hard bread, and fish (herring or mackerel; salmon, whitefish, or char; and cod, pollack, or fish fingers).

Energy intake was calculated with the help of food composition data from the Swedish National Food Administration.¹⁸ The questionnaire was validated for nutrients, and the Spearman correlation coefficients between estimates from the dietary questionnaire and the mean of four 24-hour recall interviews of 248 men aged 40 to 74 years were 0.65 for macronutrients and 0.62 for micronutrients.¹⁹ Alcohol consumption was validated among 248 participants with 14 interviews (each month during 1 year on randomly chosen days) assessing 24-hour recall of intake, and the Spearman rank correlation coefficient was 0.81.¹⁹

Information on comorbidities (ie, diabetes mellitus, hypertension, hypercholesterolemia, and CVDs [angina pectoris, myocardial infarction, ischemic stroke, heart failure, and peripheral artery disease]) were obtained by linkage to the Swedish Inpatient Register and the Swedish National Diabetes Register and supplemented with self-reported data from the questionnaires. Educational level was self-reported in the questionnaire.

Ascertainment of AAA

Population based screening programs for AAA were introduced in Sweden in 2006.²⁰ In Västmanland County, screening of all men aged 65 and 75 years, except those under AAA surveillance or with a history of AAA repair, was initiated in 2007. In Örebro County, screening of 2 yearly birth cohorts of men between 65 and 70 years of age was initiated in 2009. Eligible participants were identified through the National Population Register, and examinations were performed either by an ultrasound technician or a registered nurse with specific ultrasound proficiency. Travel expenses were not reimbursed, and the fee for examination in Västmanland County was 200

Swedish krona (\$25) until 2011 and 300 Swedish krona (\$37.50) after 2011 and 80 Swedish krona (\$10) in Örebro County. There was no information on participants in the cohort who declined participation in the screening programs. However, by excluding those from the original cohort who did not live in the study area by the end of 2008, and those aged <65 or >75 years, or with AAA diagnosis or repair prior to when screening hypothetically would have taken place, the participation rate would have been 83.3%. This corresponded to the overall participation rate of 85% that has been reported for Central Sweden.² In Västmanland County, the maximal infrarenal AAD was measured according to the outer-to-outer principle. The same procedural principle was used in Örebro County until 2011, after which the leading edge-to-leading edge principle was adopted. In this study, differences in AAD depending on method used were accounted for by subtracting 2 mm from all diameters registered with the outer-to-outer principle prior to data analysis.²¹ AAA was defined as a maximum infrarenal AAD ≥ 30 mm. Prevalent AAA at baseline was identified in the Swedish Inpatient Register²² and the Swedish Registry for Vascular Surgery (Swedvasc).²³

Statistical Analysis

Of the 48 850 eligible men, 14 350 men were screened for AAA during follow-up between 65 and 75 years of age, of which those with prevalent AAA at baseline (n=1) and those with implausible energy intake (± 3 SD of the mean log-transformed energy, n=100) were excluded (Figure S1).

Possible predictors of mean AAD at time of screening were investigated in a multivariable linear regression model adjusted for age at screening as a continuous variable after excluding those for whom the AAD was registered only as “<25 mm” (n=5706).

Hazard ratios of AAA among all screened participants were investigated utilizing Cox proportional hazards regression models with attained age as time scale. Follow-up time could be accrued from January 1, 1998, until date of screening. Scaled Schoenfeld residuals were regressed against survival time to evaluate the assumption of proportional hazards; no violation of such assumption could be observed. We also considered a binomial logistic regression model additionally adjusted for age at screening for this analysis; however, results from such a model were similar with the Cox proportional hazards regression model.

Missing data were accounted for using chained iterations of multiple imputed data sets (n=40).²⁴ The proportion of missing data for each variable of interest is reported in the footnote of Table 1 (6.7% had missing values for >1 variables). Results, however, did not change in complete case analyses or when missing values were added as indicator variables. Variables included for multivariable analyses were education

Table 1. Baseline Characteristics

	Aortic Diameter	
	No AAA (<30 mm)	AAA (≥ 30 mm)
No. of participants	14 081	168
Age at baseline, y (SD)	55.3 (4.2)	56.7 (4.3)
High school/university, %	70.6	67.2
Current smokers, %	21.8	64.9
Pack-years of smoking	19.2	28.3
Body mass index, kg/m ²	25.9	26.9
Waist circumference, cm	95.5	97.3
Walking/bicycling >40 min/day, %	25.5	18.2
Healthy diet score	10.4	9.8
Energy intake, kcal/day	2779	2702
Alcohol consumption, g/day	16.2	14.9
Comorbidities, %		
Diabetes mellitus	4.6	6.3
Cardiovascular disease	4.7	17.0
Hypertension	17.8	26.4
Hypercholesterolemia	15.0	25.6

Values are means unless otherwise indicated. All values (except age) were age-standardized according to the distribution of age at baseline in five 5-year categories. The proportion of missing data for each variable was education, 0.2%; smoking status and pack-years smoked, 3.6%; body mass index, 3.3%; waist circumference 18.9%; physical activity, 9.5%; healthy diet score, 2.9%; and alcohol consumption, 1.0% (if not indicated, no data were missing). AAA indicates abdominal aortic aneurysm.

(primary school, high school/university), smoking (never, former with <15 or ≥ 15 pack-years smoked, current with <25 or ≥ 25 pack-years smoked), BMI (<25 or ≥ 25), WC (<94 or ≥ 94 cm), physical activity (walking or bicycling: almost never, <20, 20–40, or >40 minutes/day), healthy diet score (approximate tertiles: ≤ 8 , 9–12, ≥ 13), alcohol consumption (never/former drinker or current drinker consuming <1 or ≥ 1 standard glass per day [12 g of ethanol; ie, 15 cL (5 oz) of wine, 8 cL (2.7 oz) of strong wine, 66 cL (22 oz) of class I beer (<2.25%), 50 cL (17 oz) of class II beer (2.25–3.5%), 33 cL (11 oz) of class III beer ($\geq 3.5\%$), or 4 cL (1.35 oz) of liquor]), and total daily energy intake (continuous variable). Comorbidities (diabetes mellitus, hypertension, hypercholesterolemia, and CVDs) were modeled as binary variables. In analyses of quantitative covariates (eg, pack-years smoked), smoking status was added as a categorical covariate (never, former, or current smoker).

Nonlinearity was tested by modeling quantitative exposures using restricted cubic splines with 3 knots at fixed percentiles (10th, 50th, and 90th) of the distribution in the study population, and *P* values were obtained by investigating whether the coefficient of the second spline transformation was equal to zero.²⁵

The Wald test was applied to test statistical significance of a possible interaction between lifestyle-related exposures and diabetes mellitus, CVDs, and hypertension. Because diabetes mellitus and hypertension may serve as intermediary factors, sensitivity analyses were performed by not including diabetes mellitus or hypertension as covariates, by excluding participants with diabetes mellitus or hypertension at baseline, and by censoring follow-up at time of diagnosis for those who developed these diseases during the study. To account for a potential interobserver variability of AAD measurements, we performed additional analyses using an AAD ≥ 35 mm as a binary outcome. Data analysis was performed with Stata 13.1 (StataCorp). Two-sided $P < 0.05$ was considered statistically significant.

Results

Among the 14 249 men included in this study, the sample mean AAD was 17.2 mm (SD 4.3 mm), and 168 men had an AAA (1.18%, 95% CI 1.01–1.37%). Mean age at baseline (January 1, 1998) was 55.3 years, and mean follow-up to screening was 13.0 years.

Baseline characteristics according to AAD at time of screening are presented in Table 1. Compared with those without AAA, participants with the disease seemed to be more likely to be current smokers, to have higher BMI and larger WC, and to have comorbid diseases and less likely to be physically active and to have healthy dietary consumption and a higher educational level.

Associations Between Lifestyle and AAD

Possible associations between AAD and lifestyle-related predictors were investigated in a linear regression model (Table 2). Smoking, increased BMI, and CVD were associated with an increase in mean AAD. Consumption of ≥ 1 glass of alcohol per day (median 1.7), compared with < 1 glass per day (median 0.5), and diabetes mellitus were associated with 0.22 and 0.64-mm smaller mean AADs, respectively. In a continuous model, there was no formal evidence of nonlinearity in the associations between pack-years smoked ($P_{\text{nonlinearity}} = 0.061$) or BMI ($P_{\text{nonlinearity}} = 0.21$), and mean AAD. Every 5 pack-years smoked (Figure 1A) and every 1-value increment in BMI (Figure 1B) was associated with an increase in mean AAD of 0.21 mm (95% CI 0.16–0.26 mm) and 0.11 mm (95% CI 0.06–0.16 mm), respectively.

Associations Between Lifestyle and AAA

Associations between lifestyle-related factors and AAA hazard are presented in Table 3. The hazard was increased among

smokers, those with higher BMI, and those with CVDs or hypercholesterolemia. Walking or bicycling > 40 minutes/day was associated with a 41% lower AAA hazard compared with almost never walking or bicycling. There was evidence of a nonlinear association between AAA hazard and pack-years smoked ($P_{\text{nonlinearity}} = 0.003$), whereas no such evidence was observed for BMI ($P_{\text{nonlinearity}} = 0.92$). Every 5 pack-years smoked was associated with a 50% (95% CI 22–85%) increase in AAA hazard up to ≈ 20 pack-years smoked, after which no further increase in hazard was observed (Figure 2A). Each increment in BMI value was associated with a 9% (95% CI 2–17%) increase in AAA hazard (Figure 2B). There was no evidence of interaction between diabetes mellitus, CVD, or hypertension and mean AAD or AAA hazard. Exclusion of diabetes mellitus and/or hypertension at baseline or as covariates, and of participants with the diseases and censoring of follow-up time at date of diagnosis for those who developed those comorbidities during follow-up, did not change the observed associations. In addition, results did not change appreciably when an AAD ≥ 35 mm was used as an outcome.

Discussion

In this study, we observed that smoking, obesity, and CVD were associated with increased mean AAD and with increased risk of AAA disease. Moderate consumption of alcohol and diabetes mellitus were associated with smaller AAD, whereas increasing levels of physical activity were associated with a decreased risk of AAA disease. A healthy diet in general was not associated with AAD or with risk of AAA. This study is one of a few investigating prospective associations between lifestyle-related exposures and risk of AAA disease verified with ultrasound screening. It is likely that patients diagnosed with AAA will benefit from lifestyle advice, even though the current study did not assess associations with AAA growth rate. Smoking, obesity, and comorbidity, for example, have been associated with more peri- and postoperative complications of AAA repair.²⁶ A moderate consumption of alcohol,²⁷ a healthy diet,¹⁷ and physical activity²⁸ have been associated with a decreased risk of other CVDs that increase risk of the most common nontechnical complications after AAA repair.²⁹ Thus, even if a change in lifestyle does not decrease the aneurysm growth rate in small AAAs per se, patients with small AAAs are likely to do better when their AAA eventually needs to be repaired.

Comparison With Previous Studies

Results are consistent with previous prospective studies investigating AAA verified with ultrasound screening as an outcome.^{7,8} In the Tromsø study, it was observed that the

Table 2. Multivariable Linear Regression of AAD

	Mean Difference in AAD, mm	
	Age-Adjusted Estimate (95% CI)*	Multivariable Estimate (95% CI)†
Education		
Primary school	0 (Reference)	0 (Reference)
High school/university	−0.21 (−0.41 to 0.00)	−0.04 (−0.25 to 0.16)
Smoking status (pack-years smoked)		
Never	0 (Reference)	0 (Reference)
Former (<15)	0.07 (−0.18 to 0.32)	0.04 (−0.21 to 0.29)
Former (≥15)	0.63 (0.38–0.89)	0.47 (0.20–0.73)
Current (<25)	0.94 (0.63–1.25)	0.93 (0.61–1.24)
Current (≥25)	2.32 (2.01–2.63)	2.24 (1.93–2.56)
Body mass index, kg/m²		
≥25 vs <25	0.80 (0.61–0.99)	0.63 (0.39–0.86)
Waist circumference, cm		
≥94 vs <94	0.59 (0.38–0.79)	0.21 (−0.04 to 0.46)
Walking/bicycling		
Almost never	0 (Reference)	0 (Reference)
<20 min/day	−0.17 (−0.49 to 0.16)	−0.03 (−0.35 to 0.30)
20–40 min/day	−0.34 (−0.66 to −0.03)	−0.07 (−0.39 to 0.24)
≥40 min/day	−0.34 (−0.66 to −0.01)	−0.07 (−0.39 to 0.25)
Healthy diet score		
<9	0 (Reference)	0 (Reference)
9–12	−0.32 (−0.55 to −0.10)	−0.19 (−0.41 to 0.03)
>12	−0.24 (−0.48 to −0.00)	−0.08 (−0.32 to 0.17)
Alcohol consumption		
Never/former drinker‡
<1 glass/day	0 (Reference)	0 (Reference)
≥1 glass/day	−0.04 (−0.23 to 0.15)	−0.22 (−0.41 to −0.03)
Comorbidities, yes vs no		
Diabetes mellitus	−0.38 (−0.82 to 0.06)	−0.64 (−1.08 to −0.20)
Cardiovascular disease	1.05 (0.64–1.46)	0.83 (0.41–1.25)
Hypertension	0.42 (0.18–0.66)	0.23 (−0.02 to 0.49)
Hypercholesterolemia	0.36 (0.10–0.62)	0.12 (−0.15 to 0.38)

Modeling was based on multiply imputed data sets (n=40). AAD indicates abdominal aortic diameter.

*Adjusted for age at screening as a continuous variable.

†Additional adjustments for total energy intake (continuously) and with all variables in the table simultaneously included in the model.

‡Estimate of never/former drinkers not interpreted due to the low number of cases in this group (n=5).

odds of AAA were almost 14-fold increased among current smokers who smoked ≥20 cigarettes per day compared with never smokers.⁸ In the Atherosclerosis Risk in Community study, the odds of AAA were >3-fold increased among those in the highest tertile of total cholesterol levels compared with the lowest tertile.⁷ None of those studies prospectively

investigated associations with mean AAD or other exposures related to lifestyle. Furthermore, cross-sectional screening studies have previously reported an increased risk of AAA among those with coronary artery disease and hypercholesterolemia and a decreased risk among physically active participants.^{5,6}

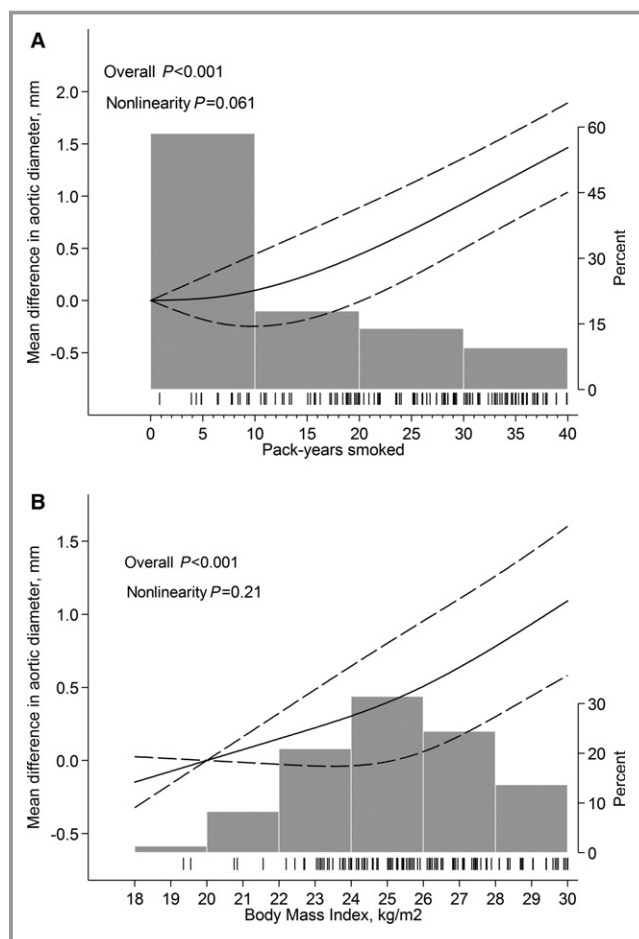


Figure 1. Predicted mean difference in abdominal aortic diameter by (A) pack-years smoked and (B) body mass index. Fitted with restricted cubic splines with 3 knots of the exposure distribution and modeled with multivariable linear regression according to Table 2. Dashed lines represent 95% confidence limits. Tick marks represent distribution of cases, and histograms represent distribution of exposure.

Whether obesity is associated with AAA is debated, and some studies have tried to differentiate whether a predominant disposition of abdominal fat, rather than general obesity, is of interest regarding risk of AAA development.^{5,30} In the current study, BMI, but not WC, was associated with a larger mean AAD and with risk of AAA. In contrast, the opposite was observed for risk of AAA diagnosis and/or repair in a previous study performed by the same investigators.³⁰ A possible explanation for this disparity is that different factors may have different effects depending on the average size of the AAAs studied. Because surgical repair is generally not indicated until the AAA reaches 55 mm,³¹ it is likely that cases identified in register-based studies have a larger mean AAD compared with cases identified in screening studies, in which the majority of AAAs are small (in the current study, 70% were < 40 mm and only 10% were ≥ 55 mm).^{2,5,32} In the Aneurysm Detection and Management study, Lederle et al observed that

WC was positively associated with large AAAs (≥ 40 mm),⁵ whereas BMI, but not WC, was associated with a larger mean AAD overall.³³ Unfortunately, insufficient statistical power limited the possibility of performing similar analyses with AAAs ≥ 40 mm as an outcome in the current study.

It is possible that a register-based outcome might actually support study of risk of AAA in its later stages, whereas AAAs verified with ultrasound might support study of the disease earlier in its progression. In the current study, the same theory might explain why physical activity and hypercholesterolemia were associated with risk of AAA but not with mean AAD and why a healthy diet was not associated with AAA risk, even though previous studies have observed a nonhealthy diet to be associated with AAA risk.⁶ An inverse association between fruit consumption and risk of AAA diagnosis and/or repair have also been reported previously, an association that seemed to be more pronounced for ruptured than intact AAAs.¹¹ It is also possible, however, that only certain foods are capable of decreasing AAA risk and that a healthy diet in general has little or no effect, as suggested previously by Jamrozik et al.³⁴

Strengths and Limitations

The strengths of this study involve the large population-based sample, the detailed information on prospectively collected lifestyle-related factors (with most of the exposures validated), and verification of AAD with ultrasound in all participants. There was no change of observed results when limiting analyses to participants free from diabetes mellitus or hypertension at baseline and during follow-up.

Nevertheless, some limitations deserve attention. Self-administered exposure data are likely to be associated with some degree of misclassification and may have changed during follow-up. Owing to the prospective design, however, such misclassification is most likely nondifferential with respect to AAA screening participation and AAD at time of screening.

The AAA prevalence of 1.2% in this cohort was lower than the 1.7%² and 2.4%³⁵ previously estimated among men aged 65 and 70 year, respectively, in nearby areas of Sweden, which could indicate that the cohort was healthier than the general population. The proportion of factors associated with an increased risk of AAA are likely to have been underestimated if healthy participants were more likely to attend screening. However, the proportions of educational level, BMI, and current smoking in the original and the analytical cohorts well represented the entire Swedish population in 1997 (Table S1). Furthermore, even if men in the current study had healthier lifestyles compared with nonparticipants, and thus would have been at lower risk of AAA, it is unlikely that the biological response to exposures investigated would depend

Table 3. Multivariable Hazard Ratios of AAA

	Hazard Ratios of AAA (≥30 mm)		
	Cases/ Person-Years*	Univariable Model (95% CI)	Multivariable Model (95% CI) [†]
Education			
Primary school	57/52 966	1.00 (Reference)	1.00 (Reference)
High school/university	111/132 232	1.11 (0.80–1.52)	1.20 (0.87–1.66)
Smoking status (pack-years smoked)			
Never	16/69 706	1.00 (Reference)	1.00 (Reference)
Former (<15)	15/37 306	1.98 (0.98–4.00)	1.87 (0.92–3.78)
Former (≥15)	39/31 798	4.76 (2.66–8.50)	3.88 (2.15–7.00)
Current (<25)	27/21 045	7.25 (3.91–13.44)	7.13 (3.83–13.26)
Current (≥25)	68/19 080	17.24 (10.00–29.71)	15.59 (8.96–27.15)
Body mass index, kg/m²			
≥25 vs <25	117/103 360	1.97 (1.38–2.81)	1.89 (1.22–2.93)
Waist circumference, cm			
≥94 vs <94	79/84 721	1.40 (0.98–2.00)	0.94 (0.61–1.44)
Walking/bicycling			
Almost never	31/21 681	1.00 (Reference)	1.00 (Reference)
<20 min/day	46/46 064	0.68 (0.43–1.07)	0.83 (0.53–1.32)
20–40 min/day	45/52 674	0.53 (0.34–0.84)	0.72 (0.45–1.16)
≥40 min/day	34/46 515	0.39 (0.24–0.63)	0.59 (0.36–0.97)
Healthy diet score			
<9	63/56 931	1.00 (Reference)	1.00 (Reference)
9–12	59/70 097	0.76 (0.53–1.08)	0.94 (0.65–1.35)
>12	43/53 202	0.68 (0.46–1.01)	0.94 (0.62–1.43)
Alcohol consumption			
Never/former drinker [‡]	5/9874
<1 glass/day	84/87 338	1.00 (Reference)	1.00 (Reference)
≥1 glass/day	77/86 532	1.11 (0.81–1.52)	0.91 (0.66–1.24)
Comorbidities, yes vs no			
Diabetes mellitus	8/8320	0.70 (0.34–1.43)	0.52 (0.25–1.09)
Cardiovascular disease	30/8591	2.46 (1.65–3.66)	1.77 (1.13–2.77)
Hypertension	45/32 614	1.33 (0.94–1.87)	1.15 (0.79–1.66)
Hypercholesterolemia	46/27 873	1.95 (1.39–2.73)	1.59 (1.08–2.34)

Modeling was based on multiply imputed data sets (n=40) with attained age as time scale. AAA indicates abdominal aortic aneurysm.

*Reported numbers was based on complete set data and do not add up due to missing data.

[†]Additional adjustments for total energy intake (continuously) and with all variables in the table simultaneously included in the model.

[‡]Estimate of never/former drinkers not interpreted due to the low number of cases in this group (n=5).

on participation in the current cohort and, consequently, should not limit the generalizability of the observed findings.

Moreover, there was no baseline assessment of AAD, and thus the assumption of exposure preceding the outcome may have been ambiguous in some cases. However, not excluding those with an aneurysmatic diameter at time of exposure assessment was unlikely to have any substantial impact on

the observed results, given that exposure misclassification was most likely nondifferential with respect to AAD at baseline and that the AAA prevalence at baseline was likely to be very low in this age group.^{5,8} In the current study, follow-up time was censored at age of screening, as the precise date of incident AAA was unknown. Although such misclassification most likely is nondifferential, estimates could still be driven in

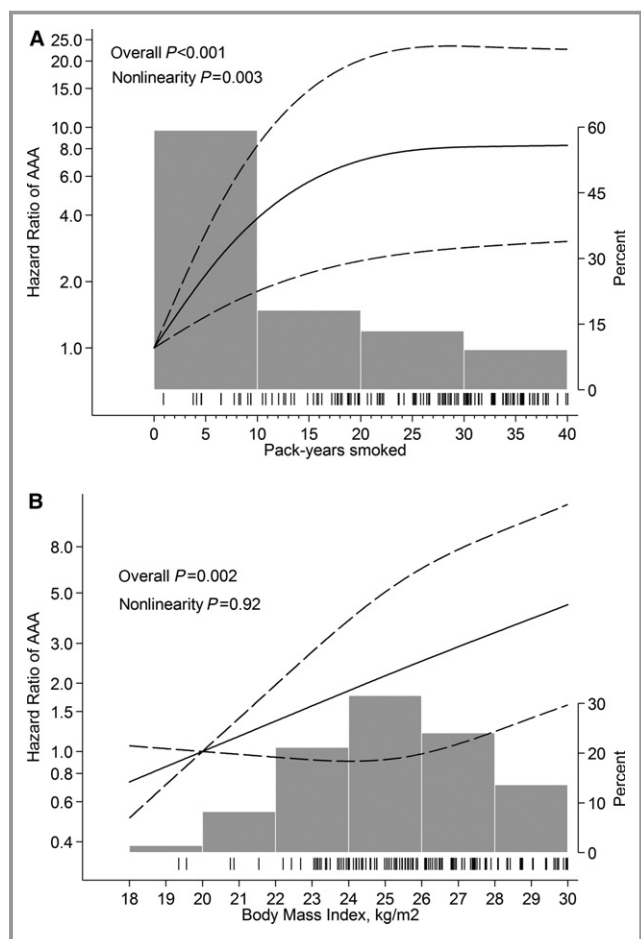


Figure 2. Hazard ratios of abdominal aortic aneurysm (AAA) by (A) pack-years smoked and (B) body mass index. Fitted with restricted cubic splines with 3 knots of the exposure distribution and modeled with multivariable Cox proportional hazards regression according to Table 3. Dashed lines represent 95% confidence limits. Tick marks represent distribution of cases, and histograms represent distribution of exposure.

any direction. Results from the utilized survival analyses, however, were consistent with those obtained from a binomial logistic regression model in which accurate timing of an event was less important. Last, given the potential interobserver variability of AAD measurements,²¹ we performed additional analyses using ≥ 35 mm as an outcome, and results did not change.

Conclusions

Results of the present study, which is one of few studying prospective associations between lifestyle-related factors and AAA detected through population-based screening, indicate that lifestyle is associated with development of the disease. It confirms that smokers and those with comorbidities are at increased risk of the disease and adds to the evidence

suggesting that obesity most likely increases and physical activity decreases risk of the disease. It remains unclear whether more general obesity or predominant abdominal adiposity is of most interest regarding AAA etiology. A healthy dietary consumption pattern was not associated with risk of having the disease at screening.

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Disclosures

None.

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SUPPLEMENTARY FILES

eTable 1. Comparison of the original Cohort of Swedish Men (COSM), and men in the COSM screened for abdominal aortic aneurysm between 65 and 75 years of age, with the Swedish population in 1997 for men aged 45-74 years, regarding age distribution, educational level, body mass index, and current smoking.

Characteristics	Original COSM 1997	Analytical COSM 1997*	Population 1997 †
Age groups, 45-79 years			
Total, n	45 906	14 249	1 594 952
45-49	15.9	7.6	19.5
50-54	18.8	45.1	20.8
55-59	15.9	33.3	15.6
60-64	13.1	11.4	12.5
65-69	14.1	2.6	11.6
70-74	12.4	-	10.8
75-79	9.9	-	9.2
Education, ages 45-74 years			
Total, n	41 382	14 249	1 448 585
≤12 years	82.3	80.4	77.1
>12 years	17.3	19.4	21.0
Body Mass Index (>25 kg/m²), by age groups ‡			
45-54	54.5	56.4	57.2
55-64	59.1	58.6	60.3
65-74	56.8	63.2	57.0
Current smokers, by age groups §			
45-54	27.7	24.2	23.2
55-64	23.7	20.2	22.8
65-74	22.4	16.1	17.2

COSM indicates the Cohort of Swedish Men. All values are percentages unless otherwise indicated and may not add up due to missing values.

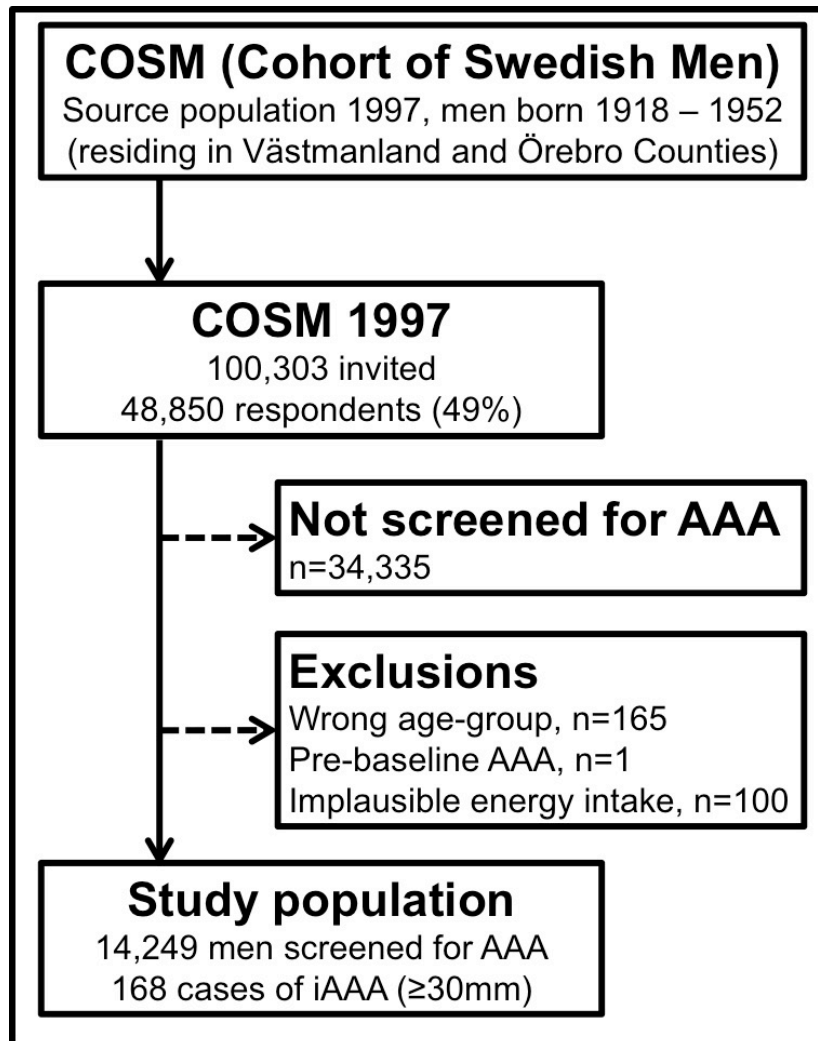
*) Analytical cohorts included participants of the COSM 1997 that were screened for AAA between 65 and 75 years of age, and excluded those with history of abdominal aortic aneurysm; or with implausible energy intake.

†) Data available from Official Statistics Sweden (OSS)

‡) Proportion of overweight (Body Mass Index >25 kg/m²) people within each age-group.

§) Proportion of current smokers within each age-group reported for the cohorts, while corresponding proportion of daily smokers are reported for the population.

eFigure 1.



Source population, exclusions, and study population