

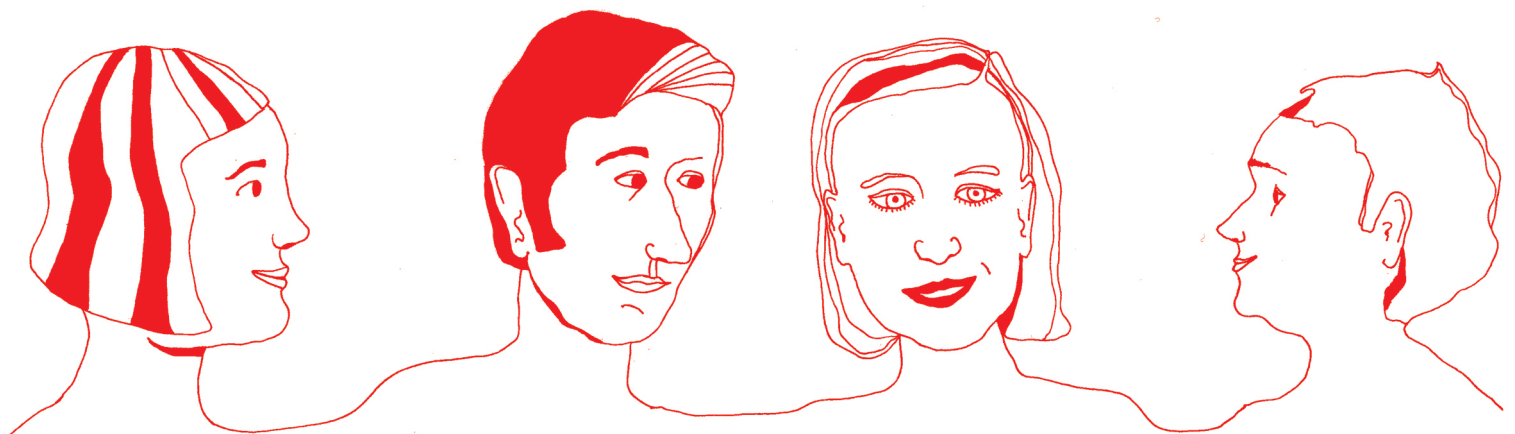
Relationship between smoking and erectile dysfunction

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Abstract

The aims of this study were to determine the effects of smoking on the incidence and prognosis of erectile dysfunction (ED) and that of ED on smoking behavior, and to find out whether smoking either directly or through vascular diseases causes ED.

The target population comprised of all men born in 1924, 1934 or 1944 and residing in the city of Tampere or 11 adjacent municipalities in Finland. Questionnaires were mailed to 3,143 men in 1994, to 2,864 in 1999 and to 2,510 men in 2004. The response rates were 70%, 75% and 75% respectively. ED was assessed using two questions on subjects' erectile capacity. Logistic and Poisson regression models were used in the multivariable analyses.

Current smoking was associated with ED (Adjusted prevalence odds ratio (POR) = 1.7, 95% CI 1.2-2.4), but not with ex smoking. The incidence of ED non-significantly increased (incidence density ratio (IDR)=1.4) and that of ED recovery reduced (IDR=0.7) with current smoking. A dose-response relationship was found between smoking and ED. Although the relative risks estimates were not statistically significant, probably due to small numbers. Only heavy smokers were significantly at higher risk of ED. Compared with non-smokers, confounder-adjusted IDR was 1.6 (95% CI 1.0-2.6) for men who smoked 21 cigarettes or more daily. Both quitting (IDR=1.7) and starting smoking (IDR=1.9) were rare and higher in men with ED. However, the IDRs estimates were not statistically significant. Current smokers at baseline (1994) who developed vascular disease during 1994-1999 were three times (Confounder-adjusted IDR=3.1, 95% CI 1.3-7.5) at higher risk of ED during 1999-2004 compared with never or ex smokers who did not develop vascular diseases. On the other hand, current smokers who did not develop vascular diseases were not at higher risk of ED (IDR=1.0).

There were two bi-directional relations between smoking and ED. Smoking caused ED though vascular diseases and ED caused smoking. The recovery from ED was less in smokers than in non-smokers, and current smokers with ED were more likely to stop smoking compared with men free from ED.

Key words

Cigarette, erectile dysfunction, impotence, smoking, vascular disease

Relationship between Smoking and Erectile Dysfunction

Rahman Shiri

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LIST OF ORIGINAL PUBLICATIONS

This work is based on the following articles, which are referred to in Roman numerals.

- I. Shiri R, Hakama M, Hakkinen J, Tammela TL, Auvinen A, Koskimaki J. Relationship between smoking and erectile dysfunction. *Int J Impot Res* 2005; 17:164-9.
- II. Shiri R, Koskimaki J, Hakkinen J, Tammela TL, Auvinen A, Hakama M. Smoking causes ED through vascular diseases.

ABBREVIATIONS

BMI	body mass index
CI	confidence interval
ED	erectile dysfunction
IDR	incidence density ratio
MMAS	Massachusetts Male Aging Study
N	number
POR	prevalence odds ratio
TAMUS	Tampere Aging Male Urological Study

1 BACKGROUND

Erectile dysfunction (ED) is defined as the inability to achieve or maintain an erection sufficient for satisfactory sexual function (1). It is a common public health problem affecting the quality of life of millions of men worldwide (2). ED has a strong negative effect on interpersonal relationship, well-being, quality of life (3-9) and is associated with sexual life dissatisfaction, depression, anger, anxiety, loss of self-esteem and increased drug and alcohol abuse (2, 4, 10-12). Improved erectile function has been accompanied by improved quality of life and decrease in general psychiatric symptoms (13-14).

The prevalence of ED varied between 13% and 81% among different populations (10, 15-25). Reported prevalence has ranged 46-52% in the United States, 13-74% in Europe, 24-80% in Asia and 40-49% in the other countries.

ED has recently been the focus of public and scientific attention as a result of effective therapies. Phosphodiesterase-5 antagonists offer the first safe and orally effective symptomatic treatment of ED. Sildenafil, Vardenafil and Tadalafil have been shown to be highly effective and generally well-tolerated treatment for men with ED (26-28).

There are substantial gaps in our knowledge of the occurrence and etiology of ED (29-30). Epidemiological studies on ED are needed for identifying etiology and subsequently for developing appropriate service delivery and prevention strategies when modifiable risk factors are established.

Cigarette smoking is a major public health problem worldwide, and because the warnings of cancer and cardiovascular disease have lost their ability to alarm, anti-tobacco advertisements now feature the risk of impotence as a reason to avoid or cease tobacco use. Only two population-based prospective studies have been published on the association between smoking and erectile dysfunction so far (29-31). The association has been assessed mainly in prevalence studies, which have considerable weaknesses for elucidating the etiology of ED. The previous follow up studies have shown that smoking is not associated with ED (29-30). However, the Massachusetts Male Aging Study found that the incidence of ED doubled in a sub-group of men free from vascular diseases (31).

Little is known about the effect of smoking on the recovery from ED and that of ED on starting or stopping smoking.

2 AIMS OF THE STUDY

The overall aim of the current study was to find out the interrelationship between smoking and erectile dysfunction.

The specific objectives of the study were as follows:

To assess the association between smoking and ED

To determine the effect of smoking on the incidence of ED

To investigate the effect of smoking on the prognosis of ED

To assess the effect of ED on smoking behaviour (starting or quitting smoking)

To find out whether smoking either independently or through vascular diseases causes ED

3 REVIEW OF THE LITERATURE

3.1 Erectile dysfunction

3.1.1 Prevalence

Worldwide the prevalence of ED has been reported 13% to 81% among men ages 18 years or over. The prevalence of ED markedly increases with age. The prevalence of severe ED has been reported 3% to 26% among men ages 50-60 years, 12% to 49% between 60 and 70 years and in 37% to 54% of those above 70 years (10, 15-25, 32-34).

3.1.2 Incidence

The incidence rate of ED has been reported 26 to 99 cases per 1,000 person-years among men ages 40 years or over and has ranged from 12 to 33 cases per 1,000 person-years in men ages 40-49 years, 22 to 77 among men ages 50-59 and 46 to 205 in those ages 60 or over (29-30, 35-36).

3.1.3 Risk factors

Penile erection is a neurovascular phenomenon that requires dilation of penile vasculature, relaxation of smooth muscle, increased intracavernosal blood flow and normal veno-occlusive function (37).

As the population has become older, the prevalence of sexual dysfunction has steadily increased (38). Prevalence, incidence and severity of ED increase with age. Age is a major risk factor of ED and an increase in ED prevalence is markedly due to secular and demographic transition. The elderly population, over 65 years, is the fastest growing age group and a large proportion of them suffer from ED. However, younger men consider their ED as a big problem than older ages (35, 39). Pathophysiology of ED due to aging includes chronic ischemia, which causes corporeal fibrosis and the deterioration of cavernosal smooth muscle (40). Although, ED is not solely a consequence of aging and multiple age-related factors are responsible for ED in elderly men. Vascular diseases account for a large proportion of ED in the elderly (41).

Several chronic diseases are associated with the risk of ED (Table 1). ED is more common among men with chronic diseases including vascular, neurological, psychological, urinary and genetic. Several medications, operation and injury are also related to ED (10, 15-19, 21-25, 32, 42-52).

Vascular diseases are the most common cause of ED and the risk of ED increases with the number of vascular comorbidities (53). ED may be an earliest signal of endothelial damage in men. Vasculogenic ED occurs in two third of cases and is caused by the impairment of the relaxation of the smooth muscle in the penile corpora cavernosal (54). It is caused by the relative loss of smooth muscle cells and replacement by collagen fibers. Improving vascular diseases risk factors decrease the risk of ED (55). In contrast the less common neurogenic ED is caused by an insufficient synthesis of nitric oxide or the loss of the cells themselves.

Among lifestyle factors, smoking, physical inactivity, obesity and bicycling are associated with a higher risk and physical activity with a lower risk of ED (48, 56-59). Controversial results have been reported on the relation between alcohol consumption and ED (15, 18, 56, 60).

Table 1. Risk factors of ED

Aging

Chronic condition

Diabetes
Hypertension
Cardiac disease
Hypercholesterolemia
Renal failure
Depression and other psychogenic factors
Stroke
Obstructive sleep apnea syndrome
Lower urinary tract symptoms
Behcet's disease
Disc herniation

Medication

Anti hypertensive
Cardiac drugs
Antidepressants
Antipsychotics
Analgesics
Substance abuse

Injury

Spinal
Pelvic
Urethral

Radiation

Surgery

Prostate surgery
Open abdominal aortic aneurysm repair

Lifestyle factor

Smoking
Obesity
Sedentary lifestyle
Cycling

Controversial risk factors

Chronic condition

Arthritis
Peptic ulcer
Allergy
Pulmonary disease
Chronic hepatitis

Medication

Ulcer medications
Steroids
Hypoglycemic agents
Antihypercholesterolemic agents

Lifestyle factor

Alcohol consumption
Coffee consumption
Diet (fat)

3.2 Smoking

Tobacco represents the single most preventable cause of disease and death in the world today (61-62). Smoking rate has varied from 31% to 65% among men ages 18 years or older in the different countries (62-67). Prevalence has varied widely, being highest in some European countries and lowest in developing countries. The prevalence of smoking is slowly decreasing in the industrialized world and rising in developing countries, especially in Asia and Africa (68-69). The majority of smokers initiate smoking at age 18 (67, 70). In Finland smoking prevalence among men decreased continuously from 58% to 28% in the period from 1960 to 2000 (71).

Smoking causes a wide range of diseases, including many types of cancer, chronic obstructive pulmonary disease (COPD), coronary heart disease, hypertension, stroke, peripheral vascular disease, and peptic ulcer (72-74). Cardiovascular morbidity and mortality are increased four times in smokers compared with non-smokers (75). The World Health Organization has estimated that tobacco causes approximately five million deaths annually worldwide, a number expected to double by 2025, with 70% of these deaths occurring in developing countries (76).

3.3 Smoking and erectile dysfunction

Studies show that smoking is having a far more serious effect on erectile function than previously thought and is responsible for many thousands of cases of ED. Literature reviews have shown that smokers are 1.5 times more likely to suffer ED than non-smokers (77-80). Meta-analysis has shown that 40% of impotent men are current smokers compared with 28% of men in the general population (80).

However, there have been controversial reports on association between smoking and ED. Some previous studies have shown that smoking is associated with ED (21, 31, 33, 46, 56, 81-82), but not all (15, 30, 32, 60). Smoking may amplify the effect of other diseases (18, 82-85). It has also been shown that smoking is related to ED in current smokers without comorbidities (84).

Effect of cigarette smoking on the incidence of ED is still controversial. Only few longitudinal studies have published so far (29-31). The Massachusetts Male Aging Study and a Brazilian study have shown that smoking was not related to an increased incidence of ED (29-30). Although, the Massachusetts Male Aging Study reported that the incidence of ED doubled in a sub-sample of men free from vascular diseases (31).

3.3.1 Past smoking

Previous cross sectional studies have found that past smoking is also associated with ED (83-86). The review of literature (79) has shown that the excess risk of ED in past smokers decreases substantially in the initial 2 to 3 years; thereafter the risk reduction slows down, so that up to 10 years is required for former smokers to achieve the risk level of never smokers. However, a prospective study (57) found no change in ED among smokers who stopped smoking for an eight-year period. The higher rate of ED in former smokers may be related to smoking induced vascular diseases.

Reversibility of the risk of ED by smoking cessation is a key component in smoking-ED causality. Most smokers start cigarette smoking at younger age (67, 70), so if smokers stop to smoke anymore, they more often quit after many years of smoking. As a result of that, a longer exposure to tobacco causes damage to vascular system. Smoking causes arteriosclerosis in the pelvic and penile arteries (77, 79, 87). The effect of smoking is not clearly associated with time from stopping, suggesting a lasting effect of smoking on ED (84). However, stopping cigarette smoking is a factor that rapidly improves penile tumescence and rigidity (88).

3.3.2 Passive smoking

Regular exposure to passive smoking at home and work increases the risk of ED among nonsmokers (31). Passive smoking substantially reduces coronary flow velocity reserve in healthy nonsmokers. It may cause endothelial dysfunction of the coronary circulation in nonsmokers (89). Regular exposure to passive smoking at home or work increases the risk of coronary heart disease among non-smokers (90). Therefore, passive smoking may cause ED through causing vascular diseases.

Exposure to environmental tobacco smoke has declined in Finland. The decline has been accelerated by the 1994 Tobacco Act reform (91-92). Many large workplaces completely banned smoking indoors. The most recent revision of the Tobacco Act in 2000, environmental tobacco smoke is classified as a carcinogen and restricted smoking in the restaurants. Nearly 14% of nonsmokers' ages 15 to 64 years in Finland are exposed to environmental tobacco smoke, either at home or in the workplace (92).

3.3.3 Intensity of smoking

The dose response effect of cigarette smoking on ED is also controversial. Some studies have shown a higher risk of ED in heavy smokers (32, 81, 84, 93-95). They have reported a strong association between the intensity of cigarette smoking and severity of ED. It has been shown that severe ED is 2.5 times higher in heavy smokers compared with light

smokers (43% vs. 17% respectively) (93). Some studies have found that only heavy smokers are at higher risk of ED (24, 59).

On the other hand, other studies have found that the number of years smoked or number of cigarette smoked daily were not associated with an increased risk of ED (18, 83).

3.3.4 Stopping smoking

There is little evidence regarding recovery from ED after stopping smoking. Stopping smoking may improve ED in a considerable proportion of smokers (95). Age and the severity of ED before quitting smoking are inversely related to the chance of recovery from dysfunction.

It has been shown that stopping smoking decreases substantially the risk of ED (79). Although a prospective study has found that quitting smoking at middle age is too late to improve erectile function (57). Smoking may damage endothelium that stopping smoking after a long period of smoking does not repair the vascular damage and does not improve smoking related vascular diseases.

Cessation of cigarette smoking might prevent or delay the onset of erectile dysfunction (44). Multi-dimensional actions are needed in reducing cigarette smoking (68). Antismoking and smoke free policy is effective and acceptable in society.

4 MATERIALS AND METHODS

4.1 Population

In this population-based follow-up study, the target population comprised of 3,143 men born in 1924, 1934 or 1944 residing in the city of Tampere or 11 adjacent municipalities in 1994, identified from the population register.

The questionnaire was mailed to 3,143 men in the target population during the first quarter of 1994 (Figure 1). An identical questionnaire was re-sent three months later to the 1,433 men who did not respond to the first inquiry. A total of 2,198 completed questionnaires (70%) were returned. Of them, 257 were excluded from the study, 244 due to missing data regarding erectile function and 13 as the respondents were institutionalised or unable to respond independently and 8 cases because of missing information on smoking. Therefore, 1,933 men (61.5%) were included in the study at baseline.

Similar questionnaires were sent five years later in May 1999 to 2,837 men, with a reminder to the 1,162 who did not respond to the first within three months. Between 1994 and 1999, 262 men had died, six had emigrated and 38 no longer had a permanent address in the population register. Altogether 2,133 men (75%) returned the questionnaires, of whom 287 were excluded for the reason of missing data on erection and 24 due to lack of data on smoking and finally 1,822 were included in the 1999 material.

A similar questionnaire was mailed to 2,510 men in the last quarter of 2004, with a reminder to the 844 who did not respond to the first inquiry within three months. Between 1999 and 2004, 318 men died, three emigrated and six did not have an address in the population registry. Overall, 1,883 (75%) questionnaires were returned and 1,636 (65%) men without missing data on erectile function were included in 2004 material.

Overall 1,683 men (59% of those alive and eligible) responded to both the baseline and 5-year follow-up inquiries. Of them, 241 were excluded because of missing data on erectile function in either of the study round and four cases as a result of unknown information on smoking, and finally the 1,438 men were included in the 5-year follow up material.

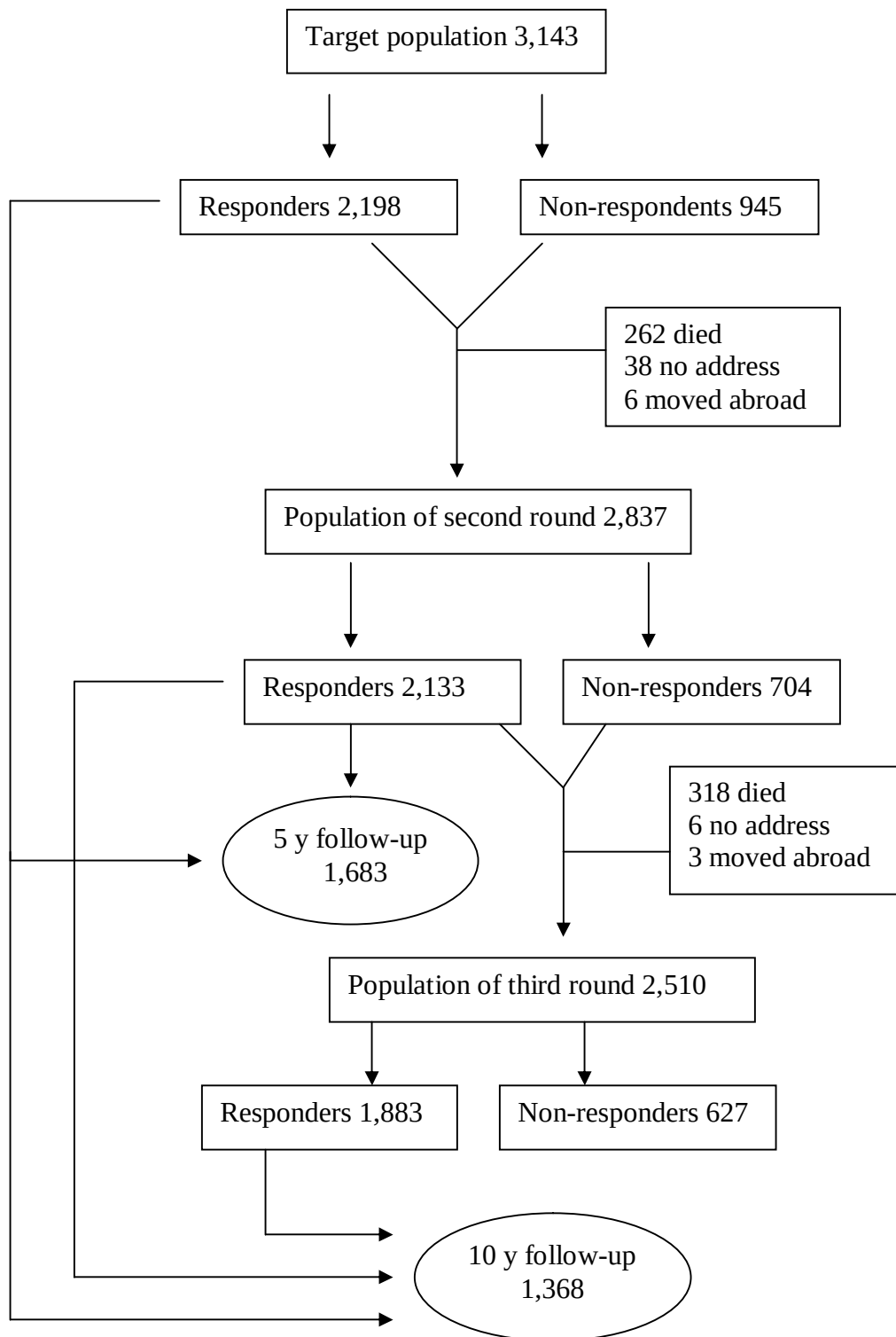


Figure 1. Flow chart of responders to 5- and 10-year follow up, Tampere Aging Male Urological Study (TAMUS)

Altogether, 1,368 men (55% of alive and eligible) responded to all three surveys. Of whom, 250 men were excluded as a result of missing data on erectile function in one of the three surveys and four because of missing information on smoking. Therefore, a total of 1,114 men were included in the 10-year follow-up study.

To find out whether smoking either directly or through vascular disease causes ED, men with ED at baseline (1994) and in 1999 and those with vascular diseases (hypertension, heart disease and cerebrovascular disease) at baseline were excluded from the 10-year follow up data and 529 men free from ED and vascular diseases at baseline were included in the analysis.

4.2 Study instruments

Information was collected by a mailed self-administered questionnaire comprising items on sociodemographic status, life-style factors, medical conditions and medications, lower urinary tract symptoms, erectile capacity and concern about erection problems (see questionnaire in the appendix).

Depression was assessed by the five-item version of the Mental Health Inventory (MHI-5), which was derived from the 38-item Mental Health Inventory (96-97). Score ranged from 5 to 30, higher score indicated increasing severity of depressive symptoms. Men were dichotomized into those with and without depression. A score greater or equal to 16 was used to classify men as having depression.

Smoking history was obtained from the self-administered questionnaire. Men were defined as current smokers, if their history of smoking had lasted for at least one year, and ex-smokers if they had smoked at least one year in their life and were not current smokers, and never smokers if they had never smoked or smoked less than one year.

ED was assessed by two questions on subjects' erectile capacity. The two questions were: "Have you had problems getting an erection before intercourse begins?" and "Have you had problems maintaining an erection once intercourse has begun?" These questions were adopted from the questionnaire used in the Massachusetts Male Aging Study (18), while the alternative answers were different in these two studies. For both questions four response options were: never, sometimes, quite often and always (intercourse does not succeed). The two questions were combined to classify the severity of ED. No difficulty in achieving and maintaining erection was defined as normal erectile function. Some difficulties in achieving and/or maintaining an erection was classified as minimal ED and fairly frequent difficulties as moderate ED. Complete ED was defined when intercourse did not succeed at all. Erectile dysfunction was dichotomised as absence (no or minimal dysfunction) or presence of ED (moderate or complete dysfunction) for the analysis.

4.3 Statistical analyses

Prevalence of erectile dysfunction or smoking was estimated as the ratio of men with a characteristic to all men with data on that characteristic. The incidence of ED was calculated by dividing the number of new cases of moderate or complete ED occurring between baseline and follow up surveys by the number of person-years of follow up. Person-years were estimated by multiplying the number of men who did not develop ED by 5 years and the number of those who developed ED by 2.5 years (midpoint of follow up period).

The statistical significance (two-tailed P -value ≤ 0.05) was assessed by a chi-square test. Logistic and Poisson regression models were used in the multivariable analyses. Age, marital status, education, chronic medical conditions, medications, body mass index and alcohol intake were included in the multivariable model as covariates. The final models were limited to age and the variables associated with outcome at a P value less than 0.1 in the age-adjusted analyses.

4.4 Ethical considerations

Confidentiality is distinguished as one of the most important strategies, when the topic is associated to questions related to sexuality. Confidentiality has been taken into consideration in this study. The study protocol was approved by the Tampere University Hospital and Tampere City ethical review committees.

5 RESULTS

5.1 Background characteristics

The 5- and 10-year follow up populations were on average one and two years respectively younger than baseline men (mean age 57.6, 56.7, 58.6 respectively) (Table 2). The followed up men reported less frequently comorbidities and medications use compared with baseline population. The prevalence of smoking was slightly lower in the men who were followed up compared with baseline population.

Table 2. Background characteristics of the study populations

Characteristic	Baseline		5 y follow up		10 y follow up	
	N	%	N	%	N	%
<i>Demographic status</i>						
Age cohort (year)						
1944	766	39.6	627	43.6	543	48.8
1934	669	34.6	535	37.2	418	37.5
1924	498	25.8	276	19.2	153	13.7
Marital status						
Married or living as married	1555	80.4	1199	83.4	945	84.8
Single, divorced or widower	377	19.5	238	16.6	168	15.1
Unknown	1	0.1	1	0.1	1	0.1
<i>Medical conditions</i>						
Hypertension	558	28.9	415	28.9	314	28.2
Erectile dysfunction	502	26.0	311	21.6	201	18.0
Arthritis	509	26.3	371	25.8	268	24.1
Heart disease	345	17.8	221	15.4	151	13.6
Pulmonary disease	198	10.2 *	138	9.6	94	8.4
Depressive symptoms	207	10.7 *	137	10.0 *	89	8.3 *
Diabetes	143	7.4	92	6.4	60	5.4
Cerebrovascular disease	123	6.4	78	5.4	49	4.4
Cancer	60	3.1	37	2.6	23	2.1
<i>Lifestyle factors</i>						
Body Mass Index (kg/m ²)						
Normal (< 25.0)	661	34.2	489	34.0	374	33.6
Overweight (25.0-29.9)	933	48.3	693	48.2	560	50.3
Obese (30.0 +)	321	16.6	244	17.0	175	15.7
Missing	18	0.9	12	0.8	5	0.4
Smoking status						
Never smoker	635	32.9	502	34.9	416	37.3
Ex or current smoker	1298	67.1	936	65.1	698	62.7
Total	1933	100.0	1438	100.0	1114	100.0

* Among men without missing information

5.2 Association between smoking and erectile dysfunction

The prevalence of moderate or complete ED was 20% among never smokers and 29% in ever smokers aged 50 to 70 years in 1994 (Table 3). The corresponding figures were 26.5% and 34.0% among men aged 55 to 75 in 1999 (Table 4). Smoking was significantly associated with ED ($P \leq 0.001$). Confounder-adjusted prevalence odds ratio (POR) of ED by smoking was similar in both cross sectional studies (1.4, 95% CI 1.1-1.8). Only current smoking was associated with ED (POR=1.7, 95% CI 1.2-2.4), but not ex smoking (POR=1.2, 95% CI 0.9-1.7).

Table 3. Association of smoking with erectile dysfunction, baseline material (1994)

Smoking status	Sample	Prevalent cases	%	Age-adjusted		Multivariable	
				POR	95% CI	POR	95% CI
Smoking							
Never smoker	635	127	20.0	1		1	
Ever smoker	1298	375	28.9	1.5	1.2-1.9	1.4	1.1-1.8
Past smoker	853	260	30.5	1.4	1.1-1.8	1.2	0.9-1.7
Current smoker	445	115	25.8	1.8	1.3-2.5	1.7	1.2-2.4

The duration of cigarette smoking was strongly associated with ED ($P \leq 0.001$). Men who smoked 21 years or more were two-fold (adjusted POR=1.9, 95% CI 1.4-2.5) at higher risk of ED compared with those who never smoked. There was a dose response relationship between the numbers of cigarettes smoked daily and ED. The risk of ED increased by increasing in the number of cigarette smoked daily. Confounder-adjusted prevalence odds ratio of ED was 1.3 (95% CI 0.9-1.9), 1.4 (95% CI 1.1-1.8) and 1.7 (95% CI 1.2-2.5) for men who smoked ≤ 10 , 11-20 and ≥ 21 cigarettes daily respectively.

Table 4. Association between the duration of smoking or number of cigarette smoked daily and erectile dysfunction, 1999 material

Smoking	Sample	Prevalent cases	%	Age-adjusted		Multivariable	
				POR	95% CI	POR	95% CI
Smoking status							
Never smoker	818	217	26.5	1		1	
Ex or current smoker	1004	339	33.8	1.7	1.3-2.2	1.4	1.2-1.8
Duration of smoking (years)							
None	814	216	26.5	1		1	
≤ 10	89	23	25.8	1.0	0.6-1.7	1.0	0.6-1.7
11-20	167	52	31.1	1.3	0.9-1.9	1.2	0.8-1.8
≥ 21	314	145	46.2	2.0	1.5-2.7	1.9	1.4-2.5
Numbers smoked daily							
None	813	214	26.3	1		1	
≤ 10	199	65	32.7	1.3	0.9-1.8	1.3	0.9-1.9
11-20	505	167	33.1	1.5	1.2-1.9	1.4	1.1-1.8
≥ 21	187	67	35.8	1.9	1.3-2.8	1.7	1.2-2.5

5.3 Prevalence of medical treatment for erectile dysfunction

A total of 83 men (4.9%) used treatment for ED in 1999. Thirty-five men used oral medicines and 77 used other types of treatment. In 2004, a total of 216 (11.9%) used treatment for their erectile dysfunction. Of them, 172 (80%) used oral tablets. Among tablet users the 122 men (71%) used Viagra (Sildenafil).

5.4 Effect of smoking on the incidence of erectile dysfunction

Among the 1,123 men free from moderate or complete ED at baseline, 201 men developed ED during the follow-up (1994-1999). The overall incidence of ED was 39 (95% CI 34- 45) cases per 1,000 person-years. It was 33 (95% CI 26-42) cases per 1,000 person-years in never smokers and 43 (95% CI 37-51) among ever smokers (Table 5). It was 45 (95% CI 37-55) cases per 1,000 person-years among past smokers and 39 (95% CI 29-53) in current smokers. The incidence of ED was non-significantly higher among current smokers (confounder-adjusted incidence density ratio=IDR=1.4, 95% CI 0.9-2.1) than in non-smokers. IDR for former smokers was 1.2 (95% CI 0.8-1.6) relative to never smoked men.

Table 5: Effect of smoking on the incidence of erectile dysfunction, 1994-1999 follow-up

Exposure	Baseline sample	Incident cases	Incidence/ 1,000	Age-adjusted		Multivariable	
				IDR	95% CI	IDR	95% CI
Smoking status							
Never smoker	420	64	33 (26-42)	1		1	
Ex or current smoker	703	137	43 (37-51)	1.3	0.9-1.7	1.2	0.9-1.7
Ex smoker	472	96	45 (37-55)	1.3	0.9-1.7	1.2	0.8-1.6
Current smoker	231	41	39 (29-53)	1.4	0.9-2.0	1.4	0.9-2.1

A non-significant dose-response effect of smoking on the incidence of ED was found (Table 6). Among 930 men with data on the number of cigarettes smoked daily, the incidence of ED was 46 (95% CI 38-56) cases per 1,000 person-years in non-smokers, 52 (95% CI 40-68) cases in men smoked 11-20 cigarettes daily and 66 (95% CI 45-97) in those smoked 21 cigarettes or more daily. Only heavy smokers were significantly at higher risk of ED compared with non-smokers. Confounder-adjusted IDR was 1.6 (1.0-2.6) for men who smoked 21 cigarettes or more relative to never smoked men.

Among 720 men with information on the duration of smoking, a total of 177 men developed ED during the follow up. The overall incidence of ED was 54 (95% CI 46-62) and was higher in men who smoked for longer time. However, the relative risks were not statistically significant. ED non-significantly increased by the number of years spent smoking from 42 (95% CI 27-65) cases per 1,000 person-years in men who smoked for 15 years or less to 83 (95% CI 57-121) among those who smoked for 26 years or more.

Table 6: Dose-response effect of smoking on erectile dysfunction, 1999-2004 follow-up

Smoking	Sample	Incidence cases	Incidence/1,000 (95% CI)	Age-adjusted		Multivariable	
				IDR	95% CI	IDR	95% CI
Numbers of cigarettes smoked daily							
None	493	102	46 (38-56)	1		1	
≤ 10	103	21	45 (30-70)	0.9	0.6-1.5	1.0	0.6-1.6
11-20	242	56	52 (40-68)	1.2	0.9-1.7	1.2	0.8-1.7
≥ 21	92	26	66 (45-97)	1.7	1.1-2.6	1.6	1.0-2.6
Numbers of years smoked cigarettes							
None	456	105	50 (41-60)	1		1	
≤ 15	97	19	42 (27-65)	0.9	0.6-1.5	0.9	0.6-1.5
16-25	90	26	63 (43-93)	1.2	0.7-1.8	1.1	0.7-1.8
≥ 26	77	27	83 (57-121)	1.4	0.9-2.1	1.3	0.8-2.1

5.5 Effect of smoking on the prognosis of erectile dysfunction

Between 1994 and 1999, among 311 men with ED, 60 improved from ED (Table 7). Recovery from ED was almost 4% annually. Improvement from ED was not related to ED treatment ($P=0.17$). It was non-significantly lower in smokers compared with never smokers ($IDR=0.8$, 95% CI 0.4-1.5). IDR of recovery from dysfunction was 0.7 among current smokers relative to never smokers, but it was not statistically significant.

5.6 Effect of erectile dysfunction on smoking behaviour

Forty-three men among 292 current smokers stopped smoking (Table 7). The incidence of quitting smoking was 52 cases per 1,000 person-years among men with ED and 27 in those free from ED. Quitting smoking was 1.7 times (95% CI 0.8-3.9) higher in men with ED compared with those free from ED.

Table 7: Effect of smoking on the prognosis of erectile dysfunction and that of erectile dysfunction on smoking behaviour, 1994-1999 follow-up

Exposure	Baseline sample	Incident cases	Incidence/ 1,000	Age-adjusted	
				IDR	95% CI
Effect of smoking on the recovery from ED					
Smoking status					
Never smoker	82	17	46	1	
Ever smoker	229	43	41	0.8	0.4-1.5
Ex smoker	168	30	39	0.8	0.4-1.7
Current smoker	61	13	48	0.7	0.3-1.7
Effect of ED on quitting smoking					
ED					
No	231	29	27	1	
Yes	61	14	52	1.9	0.9-4.0
Effect of ED on starting smoking					
ED					
No	420	11	5	1	
Yes	82	4	10	1.9 *	0.6-6.1

* Crude incidence density ratio (IDR)

Only 15 men (3%) among 502 non-smokers at baseline started to smoke during the follow up. Starting smoking was higher in men with ED than in those without ED. The incidence of starting smoking was 10 and 5 cases per 1,000 person-years respectively in men with and without ED.

5.7 Smoking caused erectile dysfunction via vascular disease

Between 1994 and 1999 follow up, 99 men (19%) developed vascular disease (Table 8). Smoking at baseline (1994) was not associated with vascular diseases at 5-year follow up in 1999 ($P=0.23$). However, there was an association between smoking and the incidence of vascular disease before excluding the men with ED at baseline and in 1999 ($P \leq 0.001$).

A total of 93 men developed moderate or complete ED over a 5-year period, from 1999 to 2004. The overall incidence of ED was 39 (95% CI 31-47) cases per 1,000 person-years. It was 92 (95% CI 42-206) cases per 1,000 person-years among current smokers who developed vascular disease during 1994-1999 follow up period, while the incidence of ED was 32 (20-54) cases in those who did not develop vascular diseases. The incidence of ED was 43 and 37 cases respectively in never or ex smokers with and without vascular diseases.

After adjustment for age, education, marital status, diabetes, alcohol consumption and body mass index, current smokers in 1994 who developed vascular disease during 1994-1999 were at three times (adjusted IDR=3.1, 95% CI 1.3-7.5) higher risk of ED during 1999-2004 compared with never or past smokers who did not develop vascular diseases. On the other hand, current smokers who did not develop vascular diseases were not at higher risk of ED (adjusted IDR=1.0, 95% CI 0.5-1.8). In addition, ex-smokers were not at higher risk of ED compared with never smokers.

Table 8: Incidence density ratio (IDR) of erectile dysfunction by smoking at baseline and vascular disease at midpoint of the follow up

Baseline smoking	Vascular disease at 5 y	Sample	ED at 10 y	Incidence/ 1,000	95% CI	Age-adjusted		Multivariable	
						IDR	95% CI	IDR	95% CI
Effect of current smoking									
Never or ex smoker	No	330	56	37	29-48	1		1	
Never or ex smoker	Yes	83	16	43	26-70	1.1	0.6-2.0	1.1	0.6-2.0
Current smoker	No	100	15	32	20-54	1.0	0.5-1.7	1.0	0.5-1.8
Current smoker	Yes	16	6	92	42-206	3.2	1.4-7.4	3.1	1.3-7.5
Effect of ex smoking									
Never smoker	No	183	28	33	23-48	1		1	
Never smoker	Yes	40	8	44	22-89	1.4	0.6-3.0	1.2	0.7-2.0
Ex smoker	No	147	28	42	29-61	1.3	0.8-2.2	1.0	0.4-2.2
Ex smoker	Yes	43	8	41	21-82	1.2	0.5-2.6	1.0	0.8-1.4

6 DISCUSSION

Our findings in a population-based 10-year follow up study with a representative sample of the male general population aged 50 to 75 years demonstrate that erectile dysfunction is a common health problem. There were two bi-directional relations between smoking and ED. Smoking caused ED through vascular diseases and ED made men to smoke. The recovery from ED was less in smokers than in non-smokers, and current smokers with ED were more likely to stop smoking than men free from ED.

6.1 Medical help for erectile dysfunction

It has been estimated that between 6% and 21% of men suffering from ED seek medical help for their problem (42, 60, 98-100). In the current study only 5% used treatment for their ED in 1999 and 12% in 2004. Willingness to discuss sexual matters depends upon age and actual erectile function. It has been reported that only 9% of men have been asked about their sexual health by a doctor in a routine visit (99). ED is still highly undiagnosed and under-treated even after worldwide approval and release of effective treatment. It is still perceived as a condition mainly due to distress or advancing age and therefore not deserving medical care.

6.2 Association between smoking and erectile dysfunction

Our cross sectional studies consistent with the previous studies demonstrate that smoking associated with ED (21, 31, 33, 46, 56, 81-82). Present study showed that current smoking is associated with ED, but not ex smoking. Men who smoked more than two decades or more than 20 cigarettes daily were almost two times at higher risk of ED than those who never smoked.

However, cross sectional studies are not the appropriate study designs to investigate causal relationship between smoking and ED, because they are based on prevalent rather than incident cases. Cross-sectional studies can only reveal the presence or absence of relationship between smoking and erectile dysfunction. Another main disadvantage of cross sectional studies for investigating the etiology of ED is that, it is not possible to know either ED followed smoking in time or smoking resulted from ED. Information on both smoking and ED is collected at the same single point in time and smoking can change through time.

6.3 Effect of smoking on erectile dysfunction

Prospective follow up studies do not have cross-sectional studies limitations and are proper study design to determine the etiology of ED. Smoking is antedated the onset of ED and there is also temporal relationship between smoking and ED.

Our findings showed that smoking increased the incidence of ED and there was a dose response effect between the numbers of cigarettes smoked daily and ED. However, the estimates were not statistically significant. The incidence of ED increased significantly only among heavy smokers. Only two population-based longitudinal studies have been published on the effect of smoking on ED so far (29-31). They have found that smoking does not increase the risk of ED (29-30). Although the Massachusetts Male Aging Study reported that smoking doubled the incidence of ED in a sub-group of men free from vascular diseases (31).

Mechanisms by which smoking causes ED are not known. One of the possible targets of chronic smoking in the penis is the synthesis of nitric oxide. Nitric oxide is responsible for erection by involving in the nonadrenergic and noncholinergic neurotransmission that leads to the smooth-muscle relaxation in the corpus cavernosum (101-103). Nitric oxide is synthesized via conversion of L-arginine into citrulline by nitric oxide synthase (104). Defects in this pathway may cause ED. Animal model in rat showed that chronic smoking leads to moderate hypertension and considerable decreases in penile nitric oxide synthase activity and neuronal nitric oxide synthase content (105).

Cigarette smoking decreases penile vascular flow and is a potential accelerator of atherogenesis (106-107). It may involve impairment of endothelium mediated smooth muscle relaxation (79) and causes ED through vascular injury. Our findings demonstrate that smoking causes ED through vascular diseases. Vascular diseases are on a causal pathway between smoking and ED. Cigarette smoking does not independently cause ED. Smoking causes vascular diseases and vascular diseases cause ED.

A vasculogenic etiology is the most common cause of ED in men over 30 years (108). A rise in blood nicotine after smoking may increase the sympathetic tone in the penis due to the vasoconstrictor effects of nicotine on the smooth muscle (109-110). Long-term smoking causes damage to the corporal tissue in impotent men (87) and predisposes young impotent men to early atherosclerotic lesions in the cavernous artery (111).

It has been found that smokers have abnormal nocturnal penile tumescence and rigidity compared with nonsmokers (112-113), which indicate that ED in smokers is mainly of organic etiology. Cigarette smoking increases the risk of vascular diseases that are linked to erectile dysfunction. Dysfunction of penile veno-occlusive mechanisms may also play a role in the development of ED in smokers (113). An association between higher degrees of ischemic heart disease and the increased severity of ED has been reported (114).

Developing arterial atherosclerosis in the penis and subsequent impotence is 30% for each 10-pack year smoked (111). It has been reported that almost 86% of smokers have an abnormality in the penile vascular assessment (87) and long-term smoking causes ultrastructural damage to the corporal tissue in impotent men (115).

It has been reported that smoking is associated with ED in patients without a history of vascular diseases (31, 84). These men are more likely to have undiagnosed and untreated medical conditions or once a vascular injury has occurred, smoking is not an additive risk. ED in asymptomatic patients may be a marker of silent vascular diseases or increased vascular risk factors (116).

6.4 Effect of smoking on the prognosis of erectile dysfunction

Our findings showed that recovery from ED was lower in smokers compared with never smokers. Cigarette smoking has been shown to have a detrimental effect on response to sildenafil citrate (117). Current smoking is an independent prognostic factor for a poor response to ED treatment and it is associated with the failure of ED treatment (118). A lower success rate for penile revascularization has also been reported in smokers compared with nonsmokers (29% vs. 57% respectively) (119). Thus smoking status enables physicians to predict the success of ED treatment.

Stopping cigarette smoking can improve ED in a considerable proportion of smokers. Erectile dysfunction improves in a quarter of ex-smokers after one year quitting smoking (95). Age and the severity of ED before stopping are inversely related to the chance of improvement. Stopping cigarette smoking improves penile tumescence and rigidity (88). In the current study the risk of ED in former smoker was similar to never smoker after at least 10 years of quitting smoking.

6.5 Effect of erectile dysfunction on smoking behaviour

Smoking has a central role among health behaviours and is associated positively with alcohol use and negatively with physical activity (120). Smoking behaviour is a constant behaviour and is clearly related from adolescence to adulthood. Non-smokers choose not to smoke because of health and they are more aware of the adverse effects of smoking than smokers (65). The reasons smokers give for starting smoking are pleasure, stress and curiosity. ED is a distressing condition for the man and his partner and has a negative effect on interpersonal relationship and causes stress. Men with ED are more likely to start smoking because of stress due to dysfunction. ED is also likely to cause marital discord, which perpetuates the vicious cycling.

Our findings showed that men with ED are more likely to stop smoking than those free from ED. Known association between smoking and ED increases stopping smoking in men with ED in the hope of recovery from erectile dysfunction.

6.6 Prevention

Erectile dysfunction is a worldwide health problem and the number of ED patients will certainly be increased due to population ages. It may be possible to identify patients at risk of ED by the identification of risk factors. The results of this study contribute to practical knowledge on erectile dysfunction, an area where new public health problem is emerging. The results are applicable to lifestyle modification and ED prevention.

There is compelling evidence for a strong need to develop a policy for the effective control of tobacco consumption. Smoking places a substantial economic burden on the societies. Estimated direct and indirect costs attributable to the treatments of specific smoking-induced chronic diseases ranged from 5 to 6 million US dollars per 100,000 populations in 1998. In addition, all causes treatments yielded a cost of 7 to 10 million dollars (121). Tobacco-control measures are needed to prevent the use of tobacco especially in the developing countries. Improving vascular diseases risk factors in mid-life may decrease the risk of ED. Our findings revealed that former smokers who stopped smoking for at least 10 years are not anymore at higher risk of ED.

A clear decline in the prevalence of ever smokers from 1978 to 2001 concurrent with the 1976 Tobacco Control Act has been reported in Finland (122). Legislation is more efficient than voluntary workplace smoking restrictions in reducing cigarette consumption and passive smoking (91). More needs to be done to protect people from the harmful effects of passive smoking and also to discourage them from smoking. As developing countries can ill afford the added economic burden of smoking-related diseases, there is an urgent need for multi-dimensional actions in reducing cigarette smoking (68). Antismoking and smoke free policy is effective and acceptable in society.

6.7 Strengths and shortcomings

This study was a population-based prospective study and a representative of the entire study base. The response proportion was relatively high, 70% in the 1994 and 75% in the 1999 and 2004 surveys. Data collection was carried out solely through a mailed, self-administered questionnaire. This approach compared with face-to-face interviews, have been shown to provide more accurate information on sexual issues (123). In addition bias from interviewer and from different interview techniques has also been avoided.

Two questions were used for the assessment of erectile function. It has been shown that a single global question is a reliable means of assessing erectile dysfunction for population-based studies (57). ED is a subjective term and is therefore best described by the individual's personal assessment of his unique situation (124).

The sample size of our population-based follow-up study was sufficient at baseline. However, vascular diseases and ED are common problems in middle age and elderly men and restriction of analyses to men free from ED and vascular diseases reduced our sample. These selected men were younger and had less often comorbidities than whole study population. Men who were lost to the follow-up were more likely to suffer from vascular diseases and ED than those who were followed up. Therefore, we may have underestimated the incidence of vascular diseases and ED in smokers. The incidence rate ratios of interrelationship among smoking, vascular disease and ED may have diluted.

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9 APPENDIX

Study questionnaire

Sociodemographic status

Surname

Forename

Personal identity number

Date of birth

Occupation

1. Self-employed
2. White-collar worker
3. Blue-collar worker
4. Farmer
5. Retired
6. Unemployed

Education

1. Basic compulsory
2. Vocational school
3. High school
4. College
5. University

Marital status

1. Married
2. Living as married
3. Unmarried
4. Divorced
5. Widower

Number of children

Place of residence

Type of residence

1. Block of flats
2. Terraced house
3. One-family house
4. Old-age home

Height (centimeters)

Weight (kilograms)

Do any of your closest relatives (grandfathers, father, brothers) have or have had urinary problems?

1. No
2. Don't know
3. Yes, who?

Diet and habits

Have you ever smoked for at least one year in your life?

1. Never
2. Yes, but I have stopped
3. Yes and I smoke now

When you started to smoke (year)

When you stopped smoking (year)

Do you use alcohol?

1. Not at all or occasionally
2. Yes

How much per week?

Beer (in bottles) (1/3 l)

Wine (in bottles) (3/4 l)
(in glasses) (12 cl)

Spirits (in bottles) (3/4 l)
(in glasses) (12 cl)

Do you drink coffee?

1. No
2. Yes

How many cups per day?

Do you drink tea?

1. No
2. Yes

How many cups per day?

How often do you eat fresh vegetables?

1. Daily
2. Weekly
3. Sometimes

How often do you eat meals of meat or sausages?

1. Daily
2. Weekly
3. Sometimes

Do you use in food (e.g., on bread)?

1. Butter

2. Margarine
3. Vegetable oil
4. None of these

Medical conditions

Have you ever had any of the following diseases?

Diabetes	1. No	2. Yes, how many years?	
Hypertension	1. No	2. Yes, how many years?	
Heart disease	1. No	2. Yes, how many years?	
Arthritis	1. No	2. Yes, how many years?	
Constipation	1. No	2. Yes, how many years?	
Fecal incontinence	1. No	2. Yes, how many years?	
Pulmonary disease	1. No	2. Yes, how many years?	What?
Neurological disease	1. No	2. Yes, how many years?	What?
Cerebrovascular disease	1. No	2. Yes, when?	
Stroke	1. No	2. Yes, when?	
Back disease or ischias	1. No	2. Yes, when?	
Spinal cord injury	1. No	2. Yes, when?	
Urinary tract injury	1. No	2. Yes, when?	
Urinary stone	1. No	2. Yes, when?	
Urinary retention	1. No	2. Yes, when?	
Urinary tract infection	1. No	2. Yes, when?	
Urethral stricture	1. No	2. Yes, when?	
Cancer	1. No	2. Yes, when?	What?
Inguinal hernia (at the moment)	1. No	2. Yes	
Other disease	1. No	2. Yes	

Operation

Have you ever been operated on or examined?

Rectal cancer	1. No	2. Yes, when?
Fecal incontinence	1. No	2. Yes, when?
Back	1. No	2. Yes, when?
Transurethral resection of prostate	1. No	2. Yes, when?
Prostatectomy	1. No	2. Yes, when?
Urinary bladder	1. No	2. Yes, when?
Urethral stricture	1. No	2. Yes, when?
Cystoscopy	1. No	2. Yes, when?
Urography	1. No	2. Yes, when?
Laser vaporization of prostate	1. No	2. Yes, when?

Medication use

Are you on permanent medication? 1. No 2. Yes

Do you use regularly the following medications?

Antihypertensive	1. No	2. Yes
Heart drugs	1. No	2. Yes
Medication for mental disease	1. No	2. Yes
Medication for urinary disease	1. No	2. Yes
Analgesics	1. No	2. Yes
Diuretics	1. No	2. Yes
Hormonal medication	1. No	2. Yes

List the names and doses of your drugs.

General Health

Answer the questions according to the situation during the past month

Are you bothered by any illness, aches or pains?

1. All the time
2. Almost always
3. Most of the time
4. Rather seldom
5. Seldom
6. Never

Do you feel healthy enough to carry out things you like to do or have to do?

1. All the time
2. Almost always
3. Most of the time
4. Rather seldom
5. Seldom
6. Never

Are you worried or do you have any fears about your health?

1. All the time
2. Almost always
3. Most of the time
4. Rather seldom
5. Seldom
6. Never

Depression

Mental Health Inventory-5 (MHI-5)

During the past month, how much of the time were you in low spirits?

0. None of the time
1. A little of the time
2. Some of the time
3. A good bit of the time
4. Most of the time
5. All the time

How much of the time, during the past month, have you felt nervous?

1. None of the time
2. A little of the time
3. Some of the time
4. A good bit of the time
5. Most of the time
6. All the time

How much of the time, during the past month, have you been happy and satisfied?

0. All the time
1. Most of the time
2. A good bit of the time
3. Some of the time
4. A little of the time
5. None of the time

How much of the time, during the past month, have you felt balanced and peaceful?

0. All the time
1. Most of the time
2. A good bit of the time
3. Some of the time
4. A little of the time
5. None of the time

How much of the time, during the past month, have you felt downhearted and blue?

0. None of the time
1. A little of the time
2. Some of the time
3. A good bit of the time
4. Most of the time
5. All the time

Activity

Answer the questions according to the situation during the past month

Are you well enough to do the work you have to do and want to do in your home?

1. Not at all

2. Now and then
3. Fairly often
4. Usually
5. Always

Are you well enough to walk where you want?

1. Not at all
2. Now and then
3. Fairly often
4. Usually
5. Always

Are you well enough to do the things you want?

1. Not at all
2. Now and then
3. Fairly often
4. Usually
5. Always

How often do you have a sauna bath per week?

How does sauna influence your urination?

1. Causes some trouble
2. Causes trouble moderately
3. Causes a lot of trouble
4. No influence
5. Reduces trouble a bit
6. Reduces trouble moderately
7. Reduces trouble a lot

Erectile function

When was your last intercourse? (Days)

How many times on average you have had intercourse during a week?

How many times on average you have had full erection during a week?

During last month have you had trouble getting an erection before intercourse begins?

1. Never
2. Sometimes
3. Quite often
4. Intercourse does not succeed

During last month have you had trouble maintaining erection once intercourse has begun?

1. Never
2. Sometimes
3. Quite often
4. Intercourse does not succeed

How often you have had full erection once you have woken?

1. Every day
2. Two to three times during a week
3. Once a week
4. Two to three times in a month
5. Once a month
6. Less than once a month

How satisfied are you in your sex life?

1. Very satisfied
2. Rather satisfied
3. Not satisfied, but not unsatisfied
4. Little unsatisfied
5. Very unsatisfied

Have you been treated for your impotency?

1. No
2. Yes

Do you worry about your potency?

1. Never
2. Seldom
3. Rather seldom
4. Most of the time
5. Almost always
6. All the time

