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Social inequality in prevalence of NCD risk factors: a cross-sectional analysis from the population-based Tromsø Study 2015–2016

Rebecca A Hetland ,[1] Tom Wilsgaard ,[1] Laila Arnesdatter Hopstock ,[2] Inger Ariansen ,[3] Jonas Johansson ,[1] Bjarne K Jacobsen ,[1,4] Sameline Grimsgaard[1]

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[1]Department of Community Medicine, UiT The Arctic University of Norway, Tromsø, Norway
[2]Department of Health Care Sciences, UiT The Arctic University of Norway, Tromsø, Norway
[3]Department of Chronic Diseases, Norwegian Institute of Public Health, Oslo, Norway
[4]Centre for Sami Health Research, Department of Community Medicine, UiT The Arctic University of Norway, Tromsø, Norway

Correspondence to
Dr Rebecca A Hetland; rebecca.hetland@uit.no

ABSTRACT

Objective We aimed to examine associations between educational level, serving as an indicator of socioeconomic position, and prevalence of WHO-established leading behavioural and biological risk factors for non-communicable diseases (NCDs), in middle-aged to older women and men.

Design Population-based cross-sectional study.

Setting All inhabitants of the municipality of Tromsø, Norway, aged ≥40 years, were invited to the seventh survey (2015–2016) of the Tromsø Study; an ongoing population-based cohort study.

Participants Of the 32 591 invited; 65% attended, and a total of 21 069 women (53%) and men aged 40–99 years were included in our study.

Outcome measures We assessed associations between educational level and NCD behavioural and biological risk factors: daily smoking, physical inactivity (sedentary in leisure time), insufficient fruit/vegetable intake (<5 units/day), harmful alcohol use (>10 g/day in women, >20 g/day in men), hypertension, obesity, intermediate hyperglycaemia and hypercholesterolaemia. These were expressed as odds ratios (OR) per unit decrease in educational level, with 95% CIs, in women and men.

Results In women (results were not significantly different in men), we observed statistically significant associations between lower educational levels and higher odds of daily smoking (OR 1.69; 95% CI 1.60 to 1.78), physical inactivity (OR 1.38; 95% CI 1.31 to 1.46), insufficient fruit/vegetable intake (OR 1.54, 95% CI 1.43 to 1.66), hypertension (OR 1.25; 95% CI 1.20 to 1.30), obesity (OR 1.23; 95% CI 1.18 to 1.29), intermediate hyperglycaemia (OR 1.12; 95% CI 1.06 to 1.19), and hypercholesterolaemia (OR 1.07; 95% CI 1.03 to 1.12), and lower odds of harmful alcohol use (OR 0.75; 95% CI 0.72 to 0.78).

Conclusion We found statistically significant educational gradients in women and men for all WHO-established leading NCD risk factors within a Nordic middle-aged to older general population. The prevalence of all risk factors increased at lower educational levels, except for harmful alcohol use, which increased at higher educational levels.

STRENGTHS AND LIMITATIONS OF THIS STUDY

⇒ Large population-based study (n=21 069) encompassing all leading non-communicable disease (NCD) risk factors through comprehensive data collection.
⇒ The utilisation of all available data by multiple imputation.
⇒ The robustness of educational level as an indicator of socioeconomic position was assessed by using alternative indicators in sensitivity analyses.
⇒ Potential for misclassification due to the use of indicators to represent complex constructs.
⇒ Simplification of NCD risk factors' continuous nature through dichotomisation of outcomes.

INTRODUCTION

Non-communicable diseases (NCDs) are the primary cause of morbidity and premature death globally.[1 2] Several behavioural and biological risk factors have been established as leading shared risk factors for NCDs.[3 4] The behavioural risk factors include tobacco use, physical inactivity, unhealthy diet and harmful alcohol use and are associated with the biological risk factors of hypertension, overweight/obesity, and elevated blood glucose and cholesterol.[5]

In recent decades, global health initiatives concerning NCD risk factors and NCDs have gained priority. The United Nations aim to reduce premature NCD mortality by 33% from 2015 to 2030,[6] and the WHO's NCD Global Monitoring Framework expresses global targets that comprise the leading risk factors for NCDs.[7] Moreover, the WHO underscores the crucial role of addressing social determinants of health and promoting health equity in order to reach these goals.[8 9] The majority of premature deaths caused by NCDs occur in low-income and middle-income countries,[2] but social inequality in NCD morbidity also exists within high-income countries.[10–12] To better understand this inequity, it is essential to examine the distribution of preceding behavioural risk factors, as well as associated biological risk factors.[9 13 14] However, few studies have addressed how the full array of WHO-established leading NCD risk factors is socially distributed within a high-income country population.

These patterns of distribution are influenced by a complex interplay of social, economic, environmental and structural determinants that shape the socioeconomic position of individuals.[8] Multiple indicators have been applied in health research in an attempt to capture different dimensions of inequality; most commonly education, income and occupation.[15] However, the relative importance of these indicators varies both by cultural context and specific health outcome under study.[16] Educational level has come forward as an important structural driver of NCD morbidity and mortality[10 17] and serves as a significant indicator of circumstances that influence health behaviours throughout the life course.[18–20] Lower educational attainment may be associated with childhood circumstances such as limited access to resources, exposure to stressful environments and risk transmitted across generations.[21–24] These circumstances can increase the risk of adopting unhealthy behaviours later in life.[19 21] In adulthood, those with lower education may face relative poverty, structural barriers, limited job prospects and less control over working conditions—all factors associated with unhealthy behaviours and their biological imprint.[9 19 25]

The aim of this study was to examine the associations between education as an indicator of socioeconomic position and the prevalence of WHO-established leading behavioural and biological NCD risk factors in Norwegian middle-aged to older women and men. Additionally, we aimed to investigate how the prevalence of having more than one NCD risk factor varied across educational groups.

METHODS

Study design, setting and participants

This cross-sectional analysis is based on data from the seventh survey (Tromsø7; 2015–2016) of the Tromsø Study,[26] which is an ongoing population-based cohort study (Tromsø1–Tromsø7; 1974–2016) in Tromsø, Norway.[27] Tromsø is the largest municipality in Northern Norway with ~78 000 inhabitants (~73 000 in 2015). Tromsø consists of both urban (80%) and rural living areas, and the residents are mainly employed in tertiary industries such as trade, health service, education and public administration.[26] Around 85% of the population is of Norwegian origin.[26] Data collection in Tromsø7 included questionnaires, biological sampling and clinical examinations, described in detail elsewhere.[26] All 32 591 women and men living in the municipality of Tromsø in 2015 aged 40 years or older were invited, of which 21 083 (65%) attended. Subsequently, 14 participants were excluded because they withdrew their consent to medical research, leaving n=21 069 women and men in our total sample (figure 1). All participants signed consent forms at attendance.[26] We followed the checklist for cross-sectional studies as outlined by the Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) guidelines when writing our report.[28]

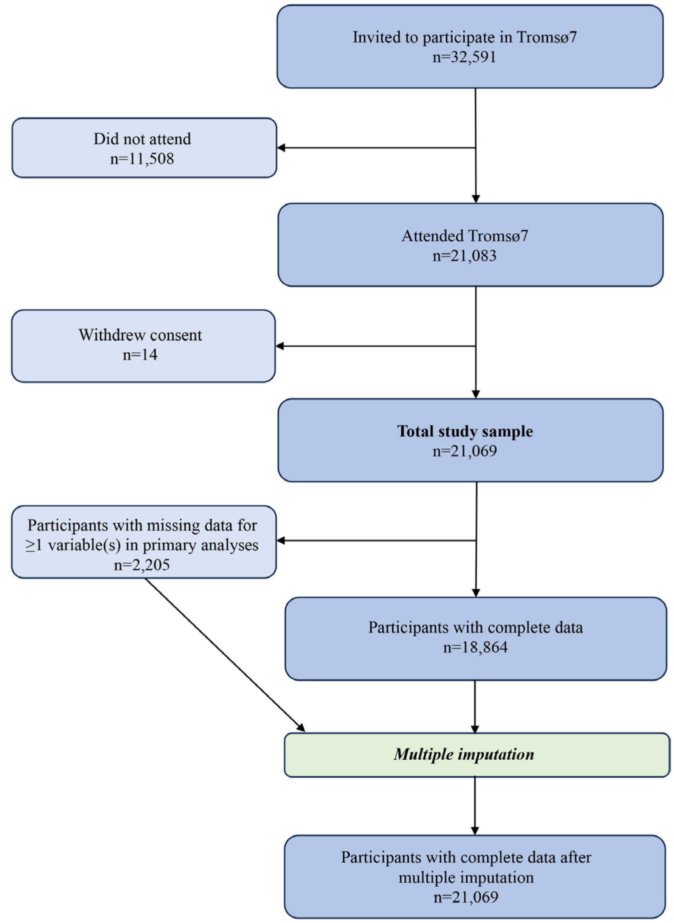

Figure 1 Participant flow chart: complete case and multiple imputation.

Patient and public involvement

Users of the Tromsø Study include the municipality, county, health authorities, healthcare providers, participants and the general public. Users of Tromsø7 were involved on a strategic level (Tromsø7 steering group), in the detailed planning of subprojects, piloting of questionnaires and dissemination of results.[26]

Exposure and outcomes

In our study, we assessed the associations between educational level and four behavioural, as well as four biological, risk factors for NCDs. We included the behavioural risk factors of daily smoking, physical inactivity, insufficient fruit/vegetable intake and harmful alcohol use; and the biological risk factors of hypertension, obesity, intermediate hyperglycaemia and hypercholesterolaemia. To assess the robustness of our findings, we conducted sensitivity analyses by examining the associations with two alternative indicators for socioeconomic position: income level and subjective occupational status. All risk factor indicators selected for this study align with WHO's monitoring framework for leading NCD risk factors,[7] with adaptions to relevant guidelines (online supplemental figure 1).

Variable definitions and measurements

Education

Attained educational level was categorised as primary (up to 10 years of primary level education), upper secondary (minimum of 3 years of education at lower than university level), short tertiary (university/college degree of <4 years) and long tertiary (university/college degree of ≥4 years). These categories correspond to the International Standard Classification of Education 2011 categories 1–2, 3–4, 5–6 and 7–8.[29] Educational level was measured by the question 'What is the highest level of education you have completed?' Self-reported educational level in Tromsø7 has been found to be adequately complete and correct when compared with national records.[30]

Daily smoking

Daily smoking was defined as current daily smoking by answering 'yes, now' to the question 'Do you smoke, or have you smoked, daily?'

Physical inactivity

Physical inactivity was defined as being physically inactive in leisure time, corresponding to the lowest level ('reading, television watching or other sedentary behaviour') on the four-level Saltin-Grimby Physical Activity Level Scale.[31] This was measured by the question 'Estimate your physical activity level in your leisure time over the past year.'

Insufficient fruit/vegetable intake

Insufficient fruit/vegetable intake was defined as a fruit/vegetable intake of <5 units/day. This was measured by the question 'How many units of fruit and vegetables do you eat a day? A unit is for example an apple or a bowl of salad.' The unit examples are approximately equivalent to 100 g, and align with Nordic Nutrition Recommendations.[32]

Harmful alcohol use

Harmful alcohol use was defined as having an average alcohol intake of >10 g/day in women and >20 g/day in men.[33 34] Alcohol intake was measured by detailed questions about frequency and amount of intake of different alcoholic beverages. Calculation of alcohol intake in g/day was conducted using a food database (KBS AE14, with KBS software system vV.7.3, at the University of Oslo, Norway) derived from the Norwegian food composition tables spanning 2014–2015, as well as supplementing data from calculated recipes and other databases.[35]

Hypertension

Hypertension was defined as systolic blood pressure ≥140 mm Hg, or diastolic blood pressure ≥90 mm Hg, or the use of blood pressure-lowering medication. Blood pressure measurements were obtained using an oscillometric digital automatic device (Dinamap ProCare 300 monitor, GE Healthcare, Norway). Three measurements were taken at 1 minute intervals on the participant's right upper arm after 2 minutes of seated rest. The mean of the last two recordings was used for analysis. The use of blood pressure-lowering medication was assessed through participants' responses to two questions: whether they currently use such medication and by listing all medication used in the past 4 weeks. Reported medications were categorised according to the Anatomical Therapeutic Chemical (ATC) classification system. Medications in the ATC groups C02, C03, C07, C08 and C09 were considered blood pressure-lowering medications.

Obesity

Obesity was defined as body mass index ≥30 kg/m^2. Height and weight were measured wearing light clothing and without shoes with a Jenix DS-102 scale (DongSahn Jenix, Seoul, Korea).

Intermediate hyperglycaemia

Intermediate hyperglycaemia was defined as a glycated haemoglobin (HbA1c) level of 6.0%–6.4% (42–47 mmol/mol), and no self-reported diabetes or use of antidiabetic medication. Non-fasting blood samples were collected from an antecubital vein after a brief stasis with the participant seated. Laboratory analyses of HbA1c were performed within 24 hours by high-performance liquid chromatography with Tosoh G8 (Tosoh Bioscience, San Francisco, USA) at the University Hospital of Northern Norway. Prevalent diabetes was assessed by the question 'Have you had, or do you have diabetes?' and defined by the response category 'yes, now'. The use of antidiabetic medication was assessed through participants' responses to two questions: whether they currently use such medication and by listing all medication used during the last 4 weeks. Reported medications in the ATC groups A10A and A10B were considered antidiabetic medications.

Hypercholesterolaemia

Hypercholesterolaemia was defined as total cholesterol ≥5.0 mmol/L, or the use of lipid-lowering medication. Non-fasting blood samples were collected from an antecubital vein after a brief stasis with the participant seated. Analyses of total cholesterol were performed within 24 hours by enzymatic colourimetric methods with Cobas 8000 c702 (Roche Diagnostics, Mannheim, Germany). The use of lipid-lowering medication was assessed through participants' responses to two questions: whether they currently use such medication and by listing all medication used during the last 4 weeks. Reported medications in the ATC group C10 were considered lipid-lowering medications.

Alternative indicators of socioeconomic position

Income level

Income level, in Norwegian Kroner (NOK), was categorised into four groups of total household income: low: ≤NOK 450 000; lower middle: NOK 451 000–NOK 750 000; upper middle: NOK 751 000–NOK 999 000; and high: ≥NOK 1 million. Income was measured by the question 'What was the households total taxable income last year? Include income from work, social benefits and similar', with alternative answers in eight income brackets. These brackets were subsequently collapsed into approximate income quartiles.[36]

Subjective occupational status

Subjective occupational status was categorised into four levels as very low/low, middle, fairly high and high. Participants were asked to respond to the statement 'I consider my occupation to have the following social status in the society (if you are not currently employed, think about your latest occupation)' with five response alternatives. As there were few respondents in the lowest category (<1%), we collapsed the two lowest categories into one (very low/low).[36]

Confounding variables

Age and sex were considered confounding variables, as these variables are likely to be related both to the attained educational level and to the indicators of NCD risk factors.

Auxiliary variables

Auxiliary variables were included in a multiple imputation model to enhance the imputation process. These variables provided additional information to better estimate missing values, but were not part of our study analyses. Included auxiliary variables were parental educational level (primary, upper secondary, short tertiary, long tertiary), self-perceived financial situation during childhood (four levels) and estimated variables for amount of fruit (g/day), vegetables (g/day), salt (g/day) and saturated fat (% of total energy intake). Calculations of dietary variables were based on self-reported dietary habits in a food frequency questionnaire and are described in detail elsewhere.[35]

Missing data

Proportions of missing data varied between 0% and 4% for all study variables; including no missing data for confounding variables (online supplemental table 1). However, 10% (n=2205) of the total sample had one or more missing among the variables included in the primary analyses; leaving 18 864 participants in a complete case sample (figure 1). We considered all missing values to be missing at random.

Statistical analyses

Multiple imputation

Comparisons of variables with no missing (age and sex) in the complete case sample (n=18 864) and the sample of participants who had one or more missing variables (n=2205), indicated that there were differences between these groups (online supplemental table 2). We performed multiple imputation by chained equations to obtain complete data for a total study sample of 21 069 participants (figure 1). All study and auxiliary variables were included in the imputation model, and imputations were made for all variables with missing data (online supplemental table 1). Imputed datasets were created separately for women and men, and subsequently combined. To adequately reduce sampling variability and increase precision of estimates for all analyses, 82 imputed datasets were created.[37]

Analyses

Characteristics of the study population are presented as percentages (%) and numbers (n), or by means and SD. Educational level was modelled as a nominal categorical independent variable, and age as a continuous independent variable. All outcome variables (behavioural and biological risk factors, as well as having ≥2 behavioural or ≥2 biological risk factors) were dichotomised, and the associations between educational level and each individual risk factor were assessed using age-adjusted logistic regression models. The probability of having the risk factor was calculated with age set as average and was reported as age-adjusted proportions in percentages. ORs with 95% CIs of each risk factor were estimated for each level of education using the highest level (long tertiary) as the reference level. In separate age-adjusted models, we included education as a continuous variable to estimate p value for trend and to estimate OR of each risk factor per unit decrease in educational level. We also investigated if the regression coefficients for educational trend differed between women and men by using a z-test.

Sensitivity analyses were conducted using income level and subjective occupational status as alternative exposure variables. The same statistical models employed for educational level were applied in these analyses.

All analyses were stratified by sex. Two-sided p values <0.05 were considered statistically significant. Multiple imputation and all analyses were performed in Stata (StataCorp. 2021. Stata Statistical Software: Release V.17, StataCorp).

RESULTS

ORs for each risk factor are presented as per unit decrease in educational level in the following text, while the results of more detailed analyses for each educational level, treated as a nominal categorical variable, are provided in the cited tables.

Participants

Of the total study sample (n=21 069), 53% were women and mean age was 57 years (SD 11.4) in both sexes (table 1). More women than men reported having a primary education (women: 24%, men: 22%), as well as

Table 1 Characteristics of study population (The Tromsø Study 2015–2016)

	Women	Men
Characteristics*	n=11 063	n=10 006
Age, years	57 (11.4)	57 (11.4)
Educational level†, % (n)		
Primary	24 (2616)	22 (2179)
Upper secondary	25 (2753)	30 (2995)
Short tertiary	18 (1915)	21 (2090)
Long tertiary	33 (3579)	26 (2564)
Income level‡, % (n)		
Low	25 (2796)	17 (1745)
Lower middle	28 (3084)	28 (2795)
Upper middle	21 (2268)	25 (2468)
High	20 (2257)	28 (2758)
Subjective occupational status§, % (n)		
Very low/low	7 (800)	6 (592)
Middle	53 (5854)	46 (4588)
Fairly high	31 (3375)	38 (3784)
Very high	6 (646)	8 (789)
Current daily smoking, % (n)	14 (1583)	13 (1318)
Physical activity level¶, % (n)		
Physically inactive	14 (1464)	15 (1506)
Light physical activity	65 (6892)	50 (4915)
Moderate physical activity	19 (1998)	30 (2951)
Vigorous physical activity	2 (250)	4 (382)
Alcohol intake, g/day	8.4 (10.5)	14.4 (16.6)
Fruit/vegetable intake, units/day	2.4 (1.6)	1.8 (1.6)
BMI, kg/m^2	26.9 (4.9)	27.8 (4.0)
Systolic blood pressure, mm Hg	127 (21)	133 (18)
Diastolic blood pressure, mm Hg	73 (10)	78.3 (10)
HbA1c %	5.7 (0.6)	5.7 (0.7)
Total cholesterol, mmol/l	5.6 (1.1)	5.4 (1.1)

*Reported as mean (SD) or, if otherwise noted; as % (n).
†Highest level of completed education: primary (≤10 years), upper secondary (≥3 years at lower than university level), short tertiary (university/college degree of <4 years), long tertiary (university/college degree of ≥4 years).
‡Household income level (NOK): low: ≤NOK 450 000; lower middle: NOK 451 000–NOK 750 000; upper middle: NOK 751 000–NOK 999 000; high: ≥NOK 1 million.
§Subjective occupational status rated on a 5-level scale (very high; fairly high; middle; fairly low; very low) and subsequently collapsed into four groups by combining the two lowest levels.
¶Physical activity level in leisure time by Saltin-Grimby Physical Activity Level Scale. Physically inactive: reading, television watching or other sedentary behaviour. Light physical activity: walking, cycling or performing other forms of recreational movement ≥ 4 hours/week. Moderate physical activity: regular participation in exercise activities and sports, performing heavy gardening, etc ≥ 4 hours/week. Vigorous physical activity: regular participation in hard training or sports competitions, several times/week.
BMI, Body Mass Index; HbA1c, glycated haemoglobin.

having a low household income level (women: 25%, men: 17%).

Women were also more frequently represented among those with a long tertiary education (women: 33%, men 26%), while more men than women reported having a high household income level (men: 28%, women: 20%). Approximately half of both women and men considered their subjective occupational status to be on the middle level (women: 53%, men: 46%).

Behavioural risk factors

There were statistically significant associations between educational level and each behavioural risk factor (shown as OR per unit decrease in educational level), with no significant differences between women and men (table 2). In women, lower educational levels were associated with higher odds of daily smoking (OR 1.69; 95% CI 1.60 to 1.78), physical inactivity (OR 1.38; 95% CI 1.31 to 1.46) and fruit/vegetable intake <5 units/day (OR 1.54; 95% CI 1.43 to 1.66). For harmful alcohol use, the association was in the opposite direction; with decreasing odds by lower educational level (women: OR 0.75; 95% CI 0.72 to 0.78). Age-adjusted proportions with a fruit/vegetable intake of < 5 units/day varied between 89%–97% in women and 93%–98% in men. Among the other behavioural risk factors, the highest observed value for age-adjusted proportions was found for harmful alcohol use among the most highly educated women (38%).

Biological risk factors

In both women and men, lower educational levels were significantly associated with higher odds of each of the four biological risk factors of hypertension, obesity, intermediate hyperglycaemia and hypercholesterolaemia (table 3). In women, the strength of the associations ranged between OR 1.25 (95% CI 1.20 to 1.30) for hypertension and OR 1.07 (95% CI 1.03 to 1.12) for hypercholesterolaemia per unit decrease in educational level. Associations with educational level were significantly different in men and women only for hypertension (men: OR 1.15; 95% CI 1.10 to 1.19). Age-adjusted proportions with hypercholesterolaemia were high for all educational groups, with values ranging between 80%–83% for women and 77%–80% for men. Among the other biological risk factors the largest observed age-adjusted proportion was found for hypertension among men with the lowest level of education (52%).

NCD risk factor burden

In both women and men, lower educational levels were associated with higher odds of having ≥2 of the four behavioural risk factors (women: OR 1.08; 95% CI 1.05 to 1.12) as well as with having ≥2 of the four biological risk factors (women: 1.25; 95% CI 1.20 to 1.30) (table 4). When excluding harmful alcohol use from the analyses of the association between educational level and having ≥2 behavioural risk factors, the inverse educational gradient appeared steeper (women: OR 1.57; 95% CI 1.50 to 1.64).

Table 2 Age-adjusted proportions and ORs for the associations between educational level and behavioural risk factors, by sex (the Tromsø Study 2015–2016)

	Daily smoking†		Physical inactivity‡		Insufficient fruit/vegetable intake§		Harmful alcohol use¶	
Educational level*	**%****	**OR (95% CI)††**	**%****	**OR (95% CI)††**	**%****	**OR (95% CI)††**	**%****	**OR (95% CI)††**
Women (n=11 063)								
Primary	24	4.71 (3.97 to 5.60)	21	2.62 (2.23 to 3.08)	97	3.92 (3.03 to 5.07)	19	0.38 (0.34 to 0.43)
Upper secondary	19	3.43 (2.92 to 4.03)	15	1.69 (1.44 to 1.97)	95	2.20 (1.80 to 2.68)	29	0.68 (0.61 to 0.76)
Short tertiary	11	1.86 (1.54 to 2.25)	11	1.19 (0.99 to 1.43)	93	1.68 (1.37 to 2.07)	32	0.78 (0.70 to 0.88)
Long tertiary	6	1 (reference)	9	1 (reference)	89	1 (reference)	38	1 (reference)
OR per unit decrease‡‡		1.69 (1.60 to 1.78)		1.38 (1.31 to 1.46)		1.54 (1.43 to 1.66)		0.75 (0.72 to 0.78)
P value for trend§§		p<*0.001*		p<*0.001*		p<*0.001*		p<*0.001*
Men (n=10 006)								
Primary	22	4.69 (3.86 to 5.71)	22	2.31 (1.96 to 2.73)	98	4.02 (2.80 to 5.79)	17	0.47 (0.41 to 0.55)
Upper secondary	15	2.96 (2.45 to 3.58)	17	1.62 (1.39 to 1.90)	97	2.16 (1.67 to 2.79)	22	0.64 (0.56 to 0.72)
Short tertiary	10	1.82 (1.47 to 2.25)	13	1.21 (1.01 to 1.44)	96	1.76 (1.34 to 2.31)	26	0.78 (0.69 to 0.89)
Long tertiary	6	1 (reference)	11	1 (reference)	93	1 (reference)	31	1 (reference)
OR per unit decrease‡‡		1.66 (1.56 to 1.76)		1.33 (1.26 to 1.40)		1.54 (1.39 to 1.70)		0.79 (0.75 to 0.82)
P value for trend§§		p<*0.001*		p<*0.001*		p<*0.001*		p<*0.001*
P value for sex equality¶¶		p=*0.694*		p=*0.309*		p=*0.938*		p=*0.153*

*Primary (≤10 years), upper secondary (≥3 years at lower than university level), short tertiary (university/college degree of <4 years), long tertiary (university/college degree of ≥4 years).
†Current daily smoking.
‡Physically inactive in leisure time, as reported in Saltin-Grimby Physical Activity Level Scale.
§Intake of <5 units of fruit and/or vegetables per day.
¶Alcohol intake >10 g/day in women or >20 g/day in men.
**Age-adjusted proportion (%).
††Reported as OR with 95% CI, unless specified (in italics) as p value.
‡‡OR per unit decrease in educational level.
§§P value for log-linear trend of education.
¶¶P value for equality between men and women in educational trend.

Table 3 Age-adjusted proportions and ORs for the associations between educational level and biological risk factors, by sex (the Tromsø Study 2015–2016)

	Hypertension†		Obesity‡		Intermediate hyperglycaemia§		Hypercholesterolaemia¶	
Educational level*	**%****	**OR (95% CI)††**	**%****	**OR (95% CI)††**	**%****	**OR (95% CI)††**	**%****	**OR (95% CI)††**
Women (n=11 063)								
Primary	43	1.93 (1.70 to 2.19)	28	1.84 (1.61 to 2.10)	10	1.44 (1.19 to 1.74)	82	1.15 (0.99 to 1.34)
Upper secondary	38	1.57 (1.40 to 1.77)	26	1.64 (1.45 to 1.85)	9	1.42 (1.17 to 1.71)	83	1.24 (1.10 to 1.41)
Short tertiary	33	1.22 (1.06 to 1.40)	21	1.27 (1.11 to 1.47)	9	1.27 (1.02 to 1.58)	80	96 (0.84 to 1.09)
Long tertiary	28	1 (reference)	17	1 (reference)	7	1 (reference)	80	1 (reference)
OR per unit decrease‡‡		1.25 (1.20 to 1.30)		1.23 (1.18 to 1.29)		1.12 (1.06 to 1.19)		1.07 (1.03 to 1.12)
P value for trend §§		p<*0.001*		p<*0.001*		p<*0.001*		p=*0.002*
Men (n=10 006)								
Primary	52	1.51 (1.33 to 1.71)	30	2.15 (1.86 to 2.47)	11	1.64 (1.34 to 2.00)	80	1.24 (1.08 to 1.44)
Upper secondary	50	1.38 (1.23 to 1.55)	28	1.93 (1.70 to 2.20)	9	1.40 (1.15 to 1.71)	79	1.12 (0.99 to 1.27)
Short tertiary	47	1.24 (1.09 to 1.40)	26	1.71 (1.48 to 1.97)	10	1.41 (1.14 to 1.74)	78	1.06 (0.92 to 1.21)
Long tertiary	42	1 (reference)	17	1 (reference)	7	1 (reference)	77	1 (reference)
OR per unit decrease‡‡		1.15 (1.10 to 1.19)		1.27 (1.22 to 1.33)		1.15 (1.08 to 1.23)		1.07 (1.02 to 1.12)
P value for trend§§		p<*0.001*		p<*0.001*		p<*0.001*		p=*0.002*
P value for sex equality¶¶		p=*0.003*		p=*0.333*		p=*0.567*		p=*0.944*

*Primary (≤10 years), upper secondary (≥3 years at lower than university level), short tertiary (university/college degree of <4 years), long tertiary (university/college degree of ≥4 years).
†Systolic blood pressure ≥140 mm Hg, or diastolic blood pressure ≥90 mm Hg, or use of blood pressure-lowering medication (including ATC groups C02, C03, C07, C08 and C09).
‡Body mass index ≥30 kg/m^2.
§HbA1c 6.0–6.4% (42–47 mmol/mol) and no self-reported current diabetes or use of antidiabetic medication (including ATC groups A10A and A10B).
¶Total cholesterol ≥5.0 mmol/L or use of lipid-lowering medication (including ATC group C10).
**Age-adjusted proportion (%).
††Reported as OR with 95% CI, unless specified (in italics) as p value.
‡‡OR per unit decrease in educational level.
§§P value for log linear trend of education.
¶¶P value for equality between men and women in educational trend.
ATC, Anatomical Therapeutic Chemical; HbA1c, glycated haemoglobin.

Table 4 Age-adjusted proportions and ORs for the associations between educational level and having ≥2 behavioural or ≥2 biological NCD risk factors, by sex (the Tromsø Study 2015–2016)

	Behavioural risk factors (≥2 of 4), including harmful alcohol use†		Behavioural risk factors (≥2 of 3), excluding harmful alcohol use‡		Biological risk factors (≥2 of 4)§	
Educational level*	%¶	OR (95% CI)**	%¶	OR (95% CI)**	%¶	OR (95% CI)**
Women (n=11 063)						
Primary	47	1.21 (1.09 to 1.36)	37	3.75 (3.27 to 4.30)	53	1.91 (1.69 to 2.16)
Upper secondary	48	1.26 (1.14 to 1.40)	29	2.58 (2.27 to 2.93)	49	1.61 (1.44 to 1.80)
Short tertiary	43	1.02 (0.92 to 1.15)	19	1.52 (1.31 to 1.76	43	1.26 (1.11 to 1.42)
Long tertiary	43	1 (reference)	14	1 (reference)	37	1 (reference)
OR per unit decrease††		1.08 (1.05 to 1.12)		1.57 (1.50 to 1.64)		1.25 (1.20 to 1.30)
P value for trend‡‡		p<*0.001*		p<*0.001*		p<*0.001*
Men (n=10 006)						
Primary	47	1.41 (1.26 to 1.59)	37	3.35 (2.90 to 3.87)	59	1.81 (1.60 to 2.04)
Upper secondary	43	1.20 (1.08 to 1.34)	27	2.19 (1.91 to 2.51)	56	1.62 (1.45 to 1.81)
Short tertiary	40	1.06 (0.94 to 1.19)	20	1.45 (1.25 to 1.69)	52	1.40 (1.24 to 1.58)
Long tertiary	38	1 (reference)	15	1 (reference)	44	1 (reference)
OR per unit decrease††		1.12 (1.08 to 1.16)		1.50 (1.43 to 1.57)		1.22 (1.17 to 1.27)
P value for trend‡‡		p<*0.001*		p<*0.001*		p<*0.001*
P value for sex equality§§		p=*0.190*		p=*0.162*		p=*0.395*

*Primary (≤10 years), upper secondary (≥3 years at lower than university level), short tertiary (university/college degree of <4 years), long tertiary (university/college degree of ≥4 years).
†Having ≥2 of the 4 behavioural risk factors: current daily smoking, physical inactivity in leisure time, fruit/vegetable intake <5 units/day, alcohol intake >10 g/day in women or >20 g/day in men.
‡Having ≥2 of the 3 behavioural risk factors: current daily smoking, physical inactivity in leisure time, fruit/vegetable intake <5 units/day.
§Having ≥2 of the 4 biological risk factors: obesity (BMI≥30 kg/m^2), hypertension (systolic blood pressure >140 mm Hg or diastolic blood pressure >90 mm Hg or use of blood pressure-lowering medication; including ATC groups C02, C03, C07, C08 and C09), intermediate hyperglycaemia (HbA1c 6.0%–6.4% (42–47 mmol/mol) and no self-reported current diabetes or self-reported use of antidiabetic medication; including ATC groups A10A and A10B), hypercholesterolaemia (serum cholesterol ≥5.0 mmol/L or use of lipid-lowering medication; including ATC group C10).
¶Age-adjusted proportion (%).
**Reported as OR with 95% CI, unless specified (in italics) as p value.
††OR per unit decrease in educational level.
‡‡P value for log-linear trend of education.
§§P value for equality between men and women in educational trend.
ATC, Anatomical Therapeutic Chemical; BMI, body mass index; HbA1c, glycated haemoglobin.

There were no significant differences between women and men in the strength of the relationships.

Sensitivity analyses

Using income level and subjective occupational status as alternative indicators for socioeconomic position (online supplemental tables 3–8) did not substantially alter the associations with the behavioural and biological NCD risk factors displayed in tables 2–4. However, we note that the association with hypercholesterolemia seemed to be less consistent.

DISCUSSION

In this large population-based study of Norwegian women and men aged 40–99, we found inverse associations between educational level and each of the risk factors of daily smoking, physical inactivity, insufficient fruit/vegetable intake, obesity, hypertension, intermediate hyperglycaemia and hypercholesterolaemia; as well as for the burden of having ≥2 behavioural or ≥2 biological risk factors. Only harmful alcohol use was positively associated with educational level.

The sensitivity analyses, with alternative indicators of socioeconomic position, confirmed the stability of the associations between educational level and NCD risk factors, underscoring the significance of socioeconomic influences on health outcomes. Our study findings align with previous research that has consistently shown a clear association between lower socioeconomic position and a higher prevalence of NCD risk factors.[9 11 13 38–42]

The steepest educational gradient among the risk factors in our study was seen for daily smoking. This is in line with previous research which has repeatedly demonstrated a higher prevalence of tobacco use in groups of lower socioeconomic position.[43–45] This association is observed in both high-income, middle-income and low-income countries.[46 47]

Physical inactivity in leisure time was associated with lower socioeconomic position, and these findings are also in accordance with previous research.[39 48–50] However, the association is complex. In our study, we assessed physical activity in leisure time, which is associated with reduced cardiovascular mortality.[51 52] Occupational physical activity, which is more prevalent in groups of lower socioeconomic position,[53] has not shown the same cardiovascular benefits.[54 55] Nevertheless, this view has been challenged in a recent study by Dalene *et al* who found that occupational activity was also associated with higher longevity in men after controlling for socioeconomic and behavioural risk factors.[56] Solely focusing on leisure time physical inactivity may introduce bias to our study, by not capturing the full spectrum of physical activity across socioeconomic groups. The complexity of the associations between the different domains of physical activity and socioeconomic position requires further exploration.

We observed an inverse association between educational level and the unhealthy diet indicator of fruit/vegetable intake <5 units/day, consistent with previous research.[57 58] This pattern has been previously demonstrated in the Tromsø7 population,[59] along with educational gradients in other unhealthy diet indicators, such as intake of saturated fat, salt and sugar.[60] Although our finding was statistically significant, we observed that the age-adjusted proportions who had an insufficient fruit/vegetable intake were high across all educational groups, indicating that few meet the recommendations regardless of educational level.

Harmful alcohol use stands out among the NCD risk factors in our study due to its increasing prevalence by higher levels of education. This is consistent with findings in recent large cross-sectional and Mendelian randomisation studies.[38 61–63] Our chosen thresholds for defining harmful alcohol use—10 g/day in women and 20 g/day in men—were based on recommendations from Norwegian health authorities[34] and supported by an overview of systematic reviews performed by the Norwegian Knowledge Centre for the Health Services.[33] These thresholds take into account sex-specific variations in alcohol metabolism and associated health risks.[64] Nevertheless, there is no consensus on what amount of alcohol intake increases disease risk.[65–67] Several recent studies suggest that no level of alcohol consumption contributes to improved health,[68 69] and the new Nordic Nutrition Recommendations 2023 advise avoiding alcohol altogether.[70] Irrespective of threshold for harmful alcohol use, our data suggest a higher alcohol intake among individuals with higher educational levels. However, this does not necessarily imply that those with lower educational levels experience less alcohol-related harm. Research has consistently shown that groups of lower socioeconomic position experience greater harm from the same amount of alcohol compared with groups of higher socioeconomic position, known as the 'Alcohol Harm Paradox'.[71–73] This discrepancy may be attributed to differences in drinking patterns, such as heavy episodic drinking being more common in groups of lower socioeconomic position, while groups of higher socioeconomic position tend to consume smaller amounts more frequently.[63 71 74] Nevertheless, all-cause mortality associated with light-to-moderate alcohol drinking has also been shown to be modified by educational level, favouring those with higher levels of education.[75] Further research and a comprehensive approach are essential for better understanding the complexities surrounding alcohol consumption and health implications.

The biological risk factors showed weaker associations with educational level than the behavioural risk factors in this study. The weakest association was found for hypercholesterolemia, which mirrors the diverging findings of other studies.[76–78] The educational gradient was weak also for intermediate hyperglycaemia.[79] Obesity and hypertension in women displayed the strongest associations with educational level among the biological risk factors, which is consistent with evidence from other high-income countries.[80 81] Our threshold values for biological risk factors could contribute to these weaker educational associations. By defining thresholds adjacent to values considered healthy, the prevalence may increase across all educational levels, reducing the observed educational gradient. This is especially true for our definitions of hypercholesterolaemia and intermediate hyperglycaemia. Also, the biological risk factors are influenced by a complex interplay of genetic, physiological and environmental factors which may attenuate the association with education.[82]

The burden of having two or more behavioural or biological risk factors was also inversely associated with educational level. The association was weaker for the behavioural risk factors when all risk factors were accounted for, but appeared considerably stronger when the discrepant contribution of harmful alcohol use was omitted from the analysis.

Strengths and limitations

Several strengths can be attributed to this large (n=21 069) population-based health study. The data collection was extensive, including validated questionnaires, biological sampling and clinical measurements; thus enabling us to measure indicators of all WHO-defined leading NCD behavioural and biological risk factors.[7] By multiple imputation, we fully made use of the available data and performed analyses on all participants.

The study attendance of 65% is noteworthy, considering the significant commitment that was required from participants due to the comprehensive nature of the data collection. However, as demonstrated by Vo *et al*; demographic factors, such as lower educational level, male gender, and age ranges of 40–49 and 80–89 years, increased the probability of not attending Tromsø7.[83] This introduces the potential for non-participation bias, which may impact the external validity of our study.

Another limitation of our study is its reliance on self-reported data for behavioural risk factors and medication use, which may introduce biases related to recall and social desirability. This could potentially impact the accuracy of our data, particularly regarding intake levels of fruit/vegetables and alcohol. Despite efforts to standardise and align with official guidelines, caution is needed when interpreting results based on self-reported data.

Misclassification may occur due to our use of indicators to represent complex constructs. Educational level as an indicator of socioeconomic position has advantages, being obtainable from all adults regardless of age or working circumstances,[15] and with a high response proportion (98%) in our study. Moreover, our additional assessments of alternative indicators supported the robustness of educational level in this study. Nevertheless, the validity of educational level as a measure of socioeconomic position is debated. Concerns include its static nature over a lifespan, limited sensitivity compared with income or wealth and contextual variations related to age, birth cohort, social class, ethnicity and gender.[20] Older cohorts in our sample are over-represented among those classified with a lower educational level and are also more likely to have accumulated NCD risk factors. While adjusting for age and sex helps mitigate confounding, residual confounding remains possible.

Another limitation of this study concerns how our choices of risk factor thresholds define the study outcome, despite the fact that NCD risk factors exist on a continuum. While we may not be able to capture the true NCD risk for individual participants, we nevertheless provide an overview of NCD risk factor distribution on a national level, considering international definitions.

CONCLUSION

We found significant educational gradients in both women and men for all WHO-established leading NCD risk factors within a Nordic general population, as well as for the burden of having ≥2 behavioural or ≥ 2 biological risk factors. All associations were in favour of higher educational levels, except for harmful alcohol use, which was less frequent at lower educational levels. There is a need for further research to explore any mediating factors and pathways that might link education to NCD risk factors and NCDs. Nevertheless, our study supports existing knowledge suggesting that addressing inequity can contribute to reducing the unevenly distributed burden of NCD risk factors.[9]

X Rebecca A Hetland @RebeccaHetland and Laila Arnesdatter Hopstock @lailahopstock

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ORCID iDs
Rebecca A Hetland http://orcid.org/0009-0003-6998-9697
Tom Wilsgaard http://orcid.org/0000-0002-2709-9472
Laila Arnesdatter Hopstock http://orcid.org/0000-0003-0072-7421
Inger Ariansen http://orcid.org/0000-0001-8529-4826
Jonas Johansson http://orcid.org/0000-0001-7912-5786
Bjarne K Jacobsen http://orcid.org/0000-0003-0781-3349

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