Leisure-time cross-country skiing is associated with lower incidence of hypertension: A prospective cohort study

Running Head: Cross-country skiing and hypertension

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Abstract

Objective: The prospective relationship between cross-country skiing and hypertension is uncertain. We aimed to assess the associations of leisure time cross-country skiing habits with incident hypertension in a general population.

Methods: The frequency, average duration, and intensity of leisure cross-country skiing were assessed at baseline using a 12-month physical activity questionnaire in the KIHD prospective study of 1809 middle-aged men without hypertension. Hazard ratios (HRs) (95% confidence intervals) were calculated.

Results: New onset diagnosis of hypertension was observed in 279 participants during a median (interquartile range) follow-up of 24.7 (18.1-26.8) years. Total volume and duration of cross-country skiing were continuously associated with hypertension risk. In analyses adjusted for hypertension risk factors, when compared to men with no cross-country skiing activity, the HRs (95% CIs) of incident hypertension were 0.75 (0.57 to 0.99) and 0.57 (0.41 to 0.79) for men who did 1-200 and > 200 MET hours per year of cross-country skiing, respectively. Compared to men with no cross-country skiing activity, the corresponding adjusted HRs (95% CIs) for incident hypertension were 0.72 (0.55 to 0.94) and 0.62 (0.44 to 0.86) for men who did 1-60 mins per week and > 60 mins week of cross-country skiing respectively. In subsidiary analyses, there were age-adjusted associations of cross-country skiing habits with risk of stroke and acute coronary events, but these were attenuated on further adjustment for several confounders. Cross-country skiing habits were associated with reduced risk of type 2 diabetes.

Conclusion: Total volume as well as duration of leisure time cross-country skiing are each continuously, inversely and independently associated with future risk of hypertension in a Caucasian male population.

Keywords: Physical activity, cross-country skiing, high-intensity exercise training, hypertension, stroke

Abbreviations:

BMI, body mass index; CHD, coronary heart disease; CI, confidence interval; CRF, cardiorespiratory fitness; CVD, cardiovascular disease; DBP, diastolic blood pressure; HDL-C, high density lipoprotein cholesterol; HR, hazard ratio; IQR, interquartile range; KIHD, Kuopio Ischemic Heart Disease; SD, standard deviation; SBP, systolic blood pressure; VO_2, oxygen uptake

INTRODUCTION

Hypertension, which is a leading risk factor for the global burden of disease, is the most common modifiable risk factor for cardiovascular disease (CVD).[1] In addition to other factors, physical inactivity is a common antecedent factor shared by hypertension and CVD.[2] The health benefits of physical activity are very well established and these include the prevention of chronic diseases such as coronary heart disease (CHD), CVD, stroke, and diabetes[3,4] and as well as modulating beneficial levels of cardiovascular risk factors[5,6]. In addition to regular physical activity, other lifestyle measures such as maintaining a healthy body weight; salt restriction; limitation of alcohol consumption; high consumption of vegetables and fruits and low-fat; and elimination of smoking have been recommended as the cornerstone for the primary prevention of hypertension.[7] The recently published 2018 Physical Activity Guidelines Advisory Committee Scientific Report recommends 150-300 min/week of moderate-intensity or 75-150 min/week of vigorous-intensity physical exercise for adults, as this provides substantial health benefits in most people.[8] Moderate-intensity physical activities include brisk walking, tennis, and general gardening; whereas vigorous-intensity activities include jogging (> 10 minutes/mile), running (≤ 10 minutes/mile), bicycling, and swimming. Compared with moderate intensity physical activity, the chronic disease and mortality risk reduction associated with high and vigorous-intensity physical activity is more pronounced.[3,4,9-12]

Cross-country skiing is a high-intensity conditioning physical activity which is normally undertaken during the winter season. Emerging data suggests that long-term endurance and leisure-time cross-country skiing have potential benefits which include reduction in the risk of cardiovascular outcomes and mortality.[13-16] However, the prospective association of leisure-time cross-country skiing with hypertension has not been evaluated in population-based studies. In this context, we aimed to characterize and quantify the nature and magnitude of the associations of the total volume and duration of leisure-time cross-country skiing with the risk of future hypertension in the general population. To achieve this aim, we employed a large population-based sample of middle-aged men from the well-characterized Kuopio Ischemic Heart Disease (KIHD) cohort study, who were free of hypertension at baseline. Given that hypertension is a leading common modifiable risk factor for stroke[17] and also closely linked with diabetes and acute coronary events,[18,19] we also conducted subsidiary analyses of the associations of leisure-time cross-country skiing habits with the risk of these outcomes.

METHODS

Study participants

The present study is based on the KIHD risk factor study, a population-based prospective cohort study designed to investigate various established and emerging risk factors for CVD and other chronic diseases.[20] The study population involved a representative sample of men living in the city of Kuopio and its surrounding rural communities in Eastern Finland. Men who were 42-61 years of age were recruited into the study. Of 3433 potentially eligible and randomly selected men, 3235 were found to be eligible for the study. Of this number, 2682 (82.9 %) volunteered to participate, 186 did not respond to the invitation and 367 declined to give informed consent. Baseline examinations were performed between March 20, 1984 and December 5, 1989. For this analysis, men with a prevalent history of hypertension were excluded. Prevalent hypertension was defined as having a clinical diagnosis of hypertension, systolic blood pressure (SBP) ≥ 140 mm Hg and/or diastolic blood pressure (DBP) ≥ 90 mm Hg, or use of anti-hypertensive medication at baseline. The final cohort for the present analysis is based on 1,809 men with no missing data on the assessment of cross-country skiing activity, total physical activity, relevant covariates, and incident hypertension. The study was approved by the Research Ethics Committee of the University of Eastern Kuopio in accordance with the Declaration of Helsinki. All participants provided written informed consent. This study was performed following the STROBE (STrengthening the Reporting of OBservational studies in Epidemiology) guidelines for reporting observational studies in epidemiology (**Supplementary Material 1**).[21]

Assessment of leisure-time cross-country skiing and physical activity

Cross-country skiing activity as well as total physical activity were assessed using a 12-month physical activity questionnaire modified from the Minnesota Leisure-Time Physical Activity Questionnaire.[22] This is a detailed quantitative questionnaire which is based on the most common leisure-time physical activities of middle-aged Finnish men (conditioning physical activity, e.g. walking, skiing, bicycling, swimming, rowing, ball games, etc and non-conditioning physical activity, e.g. crafts, repairs, building, gardening, hunting, fishing, etc) and enables the assessment of all components of physical activity.[23,24] For each type of physical activity performed, participants were asked to record the frequency (number of sessions per month), average duration (hours and minutes per session), and intensity (scored as 0 for recreational activity, 1 for conditioning activity, 2 for brisk conditioning activity, and 3 for competitive, strenuous exercise). A trained interviewer collected missing data. The frequency, average duration, and intensity of cross-country skiing were assessed and based on the winter period, as this activity is limited to the winter months. Cross-country skiing was assigned an intensity of 9.6 MET, being the mean intensity of cross-country skiing activities. The total volume of cross-country skiing (MET hours per year) was estimated using the intensity in METs multiplied by the duration. Total physical activity (kcal/day) was classified as a conditioning physical activity or non-conditioning physical activity. The intensity of physical activity was expressed in metabolic units (MET, or metabolic equivalents of oxygen consumption). The four categories of intensity of activity (range of possible scores, 0 to 3) were assigned their own metabolic-unit values, revised on the basis of a synthesis of available empirical data.[24]

Ascertainment of incident outcomes

We included all incident cases of hypertension that occurred from study entry through to 2014. Hypertension was defined as a physician diagnosis of hypertension (ICD-10 codes I10–15), SBP ≥ 140 mm Hg and/or DBP ≥ 90 mm Hg, or use of anti-hypertensive medication (ATC codes C02–C04, C07–C09). Stroke diagnosis was based on sudden onset of clinical signs or focal or global disturbance of cerebral function lasting >24 h (except in the case of sudden death or if interrupted by surgical intervention) with no apparent cause other than a vascular origin.[25] A suspected stroke event [International Classification of Diseases, (ICD)-10 codes I60–I68 and G45–G46] was classified into: (i) a definite stroke, (ii) no stroke or (iii) unclassifiable events. An incident case of type 2 diabetes was defined as a fasting plasma glucose (FPG) ≥ 7.0 mmol/l, a 2 h glucose tolerance test plasma glucose ≥ 11.1 mmol/l, or use of glucose-lowering medication according to self-report. The diagnostic classification of acute coronary events (acute myocardial infarction, AMI) was based on symptoms, electrocardiographic findings and cardiac enzyme elevations. Each suspected coronary event was coded according to the ICD-9 (code numbers 410–414) or ICD-10 (code numbers I20–I25). All incident cases were ascertained by record linkage to the national hospital discharge registry maintained by the National Institute for Health and Welfare and to the Social Insurance Institution of Finland register for reimbursement of medicine expenses. No losses to follow-up were recorded as participants are under continuous annual surveillance for the development of new events.

Assessment of risk markers

The collection of blood specimens and the measurement of serum lipids, lipoproteins, creatinine and glucose have been described in previous reports.[26,27] Blood samples were taken between 8 and 10 a.m. In addition to fasting, subjects were instructed to abstain from drinking alcohol for at least 3 days prior and from smoking for at least 12 hours. Resting blood pressure was measured between 8:00 and 10:00 AM with a random-zero sphygmomanometer. Alcohol consumption was assessed using the Nordic Alcohol Consumption Inventory.[23] Body mass index (BMI) was calculated as the ratio of weight in kilograms to the square of height in meters.

Diabetes was defined as a fasting blood glucose level ≥7.0 mmol/L or clinical diagnosis of diabetes with dietary, oral, or insulin treatment. Peak oxygen uptake (VO_2) which was used as a measure of cardiorespiratory fitness (CRF), was assessed by using a respiratory gas exchange analyzer during a cycle ergometer exercise test, described in detail previously.[28]

Statistical methods

Descriptive analyses were used to summarise baseline characteristics of participants. We assessed the cross-sectional associations of total volume of cross-country skiing with several risk markers by calculating the partial correlation coefficients. Study participants were classified into groups on the basis of the total volume of cross-country skiing (0, 1-200 and > 200 MET hours per one year) and the weekly average duration of cross-country skiing (0, 1-60, > 60 minutes per week). Cox proportional hazards models were used to assess the associations of total volume and duration of cross-country skiing with incident hypertension risk after confirmation of no major departure from the proportionality of hazards assumptions using Schoenfeld residuals.[29] Hazard ratios were adjusted for age (Model 1) and BMI, baseline SBP, smoking status, history of diabetes, total cholesterol, high-density lipoprotein cholesterol (HDL-C), alcohol consumption, family history of hypertension, and total physical activity (Model 2). The shapes of the relationships of total volume and weekly duration of cross-country skiing with incident hypertension were explored using restricted cubic spline with three knots at user-specified percentiles of the distribution of the exposures in multivariate adjusted models. We used formal tests of interaction tests to assess statistical evidence of effect modification by individual characteristics, such as age, BMI, and other risk markers for hypertension. To minimize biases due to reverse causation, sensitivity analysis involved excluding the first five years of follow-up. All statistical analyses were conducted using Stata version 15 (Stata Corp, College Station, Texas).

RESULTS

Baseline characteristics and cross-sectional correlates

Baseline characteristics of the 1,809 participants without a known history of hypertension at baseline are shown in **Table 1**. The mean (standard deviation, SD) age of at baseline was 53 (5) years. The baseline median [interquartile, (IQR)] total volume and duration of cross-country skiing was 50.0 (0-220.0) MET hours per year and 60 (60-90) minutes per week respectively. There were weak inverse correlations of total volume of cross-country skiing with several risk markers of hypertension. Total volume of cross-country skiing was moderately strongly and positively correlated with average duration of cross-skiing (r=0.41), total physical activity (r = 0.39), and peak VO_2 (r=0.24).

Leisure-time cross-country skiing and incident hypertension

During a median (IQR) follow-up of 24.7 (18.1-26.8) years (39,275 person-years at risk), there were 279 incident hypertension cases (annual rate 7.10/1000 person-years at risk, 95% confidence interval (CI) 6.32 to 7.99). Cumulative hazard curves showed that men with no cross-country skiing activity had a higher risk for hypertension compared to men who did 1-200 and > 200 MET hours per year ($p < 0.0001$ for log-rank test; **Figure 1a**). A restricted cubic spline curve showed the risk of hypertension decreased continuously with increasing total volume of cross-country skiing, which was potentially consistent with a curvilinear shape (*p*-value for non-linearity=0.002; **Figure 2a**). In an age-adjusted analysis, compared to men with no cross-country skiing activity, the HRs (95% CIs) of incident hypertension were 0.69 (0.52 to 0.89) and 0.49 (0.36 to 0.67) for men who did 1-200 and > 200 MET hours per year of cross-country skiing respectively (**Table 2**). Following progressive adjustment for several established risk factors and other potential confounders (BMI, baseline SBP, smoking status, history of type 2 diabetes, total cholesterol, HDL-C, alcohol consumption, family history of hypertension, and total physical activity), the corresponding HRs (95% CIs) were minimally attenuated to 0.75 (0.57 to 0.99) for 1-200 and 0.57 (0.41 to 0.79) for > 200 MET hours per year of cross-country skiing respectively. When total physical activity was replaced with peak VO_2, the corresponding HRs (95% CIs) were 0.82 (0.62 to 1.08) for 1-200 and 0.68 (0.48 to 0.95) for > 200 MET hours per year of cross-country skiing respectively.

According to the average duration of cross-country skiing, cumulative hazard curves demonstrated the highest risk of hypertension among men with no cross-country skiing activity compared with the other groups ($p < 0.0001$ for log-rank test; **Figure 1b**). The risk of hypertension decreased with increasing duration of cross-country skiing from 30-480 minutes/week in a linear dose-response fashion (*p*-value for non-linearity=0.117; **Figure 2b**). In analysis adjusted for age, compared to men with no cross-country skiing activity, the HRs (95% CIs) of incident hypertension were 0.65 (0.50 to 0.84) and 0.52 (0.38 to 0.72) for men who did 1-60 and > 60 mins per week of cross-country skiing (**Table 2**). The respective HRs (95% CIs) were 0.72 (0.55 to 0.94) and 0.62 (0.44 to 0.86) following further adjustment for several established risk factors and other potential confounders. When total physical activity was replaced with peak VO_2, the corresponding HRs (95% CIs) were 0.80 (0.60 to 1.06) for 1-200 and 0.70 (0.50 to 0.99) for > 200 MET hours per year of cross-country skiing respectively.

The associations of both total volume and duration of cross-country skiing with incident hypertension risk remained consistent in analyses that excluded the first five years of follow-up (**Supplementary Materials 2**)

Associations of cross-country skiing habits with incident hypertension in subgroups

Figure 3 shows the associations of total volume and average duration of cross-country skiing with incident hypertension in clinically relevant subgroups. Except for evidence of a statistically significant interaction by total physical activity (*p* for interaction =0.030) for the association of duration of cross-country skiing with hypertension, there was no evidence of effect medication on the associations by other relevant clinical characteristic.

Associations of cross-country skiing habits with other outcomes

In age-adjusted analyses, total volume and duration of cross-country skiing were each associated with the risk of stroke; however, these associations were attenuated to null on further adjustment for other potential confounders (**Table 3**). In analyses adjusted for several confounders, when compared to men with no cross-country skiing activity, the HRs (95% CIs) for type 2 diabetes were 0.76 (0.63 to 0.92) and 0.60 (0.47 to 0.77) for men who did 1-200 and > 200 MET hours/year of cross-country skiing respectively. Compared to men with no cross-country skiing activity, the corresponding adjusted HRs (95% CIs) for type 2 diabetes were 0.73 (0.60 to 0.89) and 0.65 (0.51 to 0.82) for men who did 1-60 and > 60 mins/week of cross-country skiing respectively (**Supplementary Materials 3**). Total volume and duration of cross-country skiing were not significantly associated with the risk of AMI in analysis adjusted for several confounders (**Supplementary Material 4**).

DISCUSSION

Key findings

In this Finnish population-based prospective study comprising of men without a history of hypertension at baseline, we have shown that the total volume of leisure-time cross-country skiing was weakly and inversely correlated with several risk markers for hypertension. The correlations with duration of cross-country skiing and the total amount of physical activity were strong. On assessment of the associations, total volume and average duration of cross-country skiing were each inversely associated with future risk of hypertension. The associations were continuous and independent of conventional and emerging risk factors. However, they were somewhat attenuated on further adjustment for peak VO_2. For total volume of cross-country skiing, the shape of the relationship with hypertension was curvilinear; whereas that for duration of cross-country skiing was consistent with a linear dose-response relationship. Furthermore, the associations were not modified by levels or categories of relevant risk markers. Though there was statistically significant evidence of effect modification by total physical activity on the association between duration of cross-country skiing with hypertension, the magnitude and direction of the associations were comparable in higher and lower categories of total physical activity. Cross-country skiing habits were also associated with reduced risk of type 2 diabetes. However, the initial age-adjusted associations of cross-country skiing habits with risks of stroke and AMI were attenuated to null on further adjustment for several confounders.

Comparison with previous work

We are unable to compare the current findings in the context of previous studies as we did not find any previous study exploring the association of leisure-time cross-country skiing with the risk of incident hypertension. Substantial evidence from epidemiological studies as well as clinical trials have however demonstrated that vigorous-intensity physical activity is associated with decreased blood pressure or reduced risk of hypertension.[6,30,31] A number of reports on the associations of cross-country skiing with CVD outcomes and mortality, have demonstrated risk reductions of these outcomes in association with cross-country skiing.[13-16] These findings are therefore not unexpected since cross-country is a very high-intensity aerobic exercise which combines both a lower body and upper body workout, while simultaneously working both the “pulling” and “pushing” muscles of lower and upper body, which also requires a certain level of muscle strength of the back, abdomen, legs and arms. The high exercise intensity places increased demands on cardiovascular function and metabolism, hence improving the efficiency of the cardiovascular system. Our findings of no evidence of independent associations of cross-country skiing habits with the risk of stroke as well as AMI, seem to contrast with a recent study, which showed that skiers compared to non-skiers had a reduced risk of all-cause mortality, MI, and stroke outcomes.[15] However, this previous study was conducted in a large sample of long-distance endurance skiers (Vasaloppet skiers), whereas the current study involved leisure-time cross-country skiing. These findings may need further evaluation in other large-scale studies.

Explanation of findings

There are multiple pathways by which cross-country skiing may reduce the risk of hypertension. Though the mechanisms remain speculative, systemic inflammation and dyslipidaemia have been shown to provoke endothelial dysfunction,[32,33] which plays an integral role in the pathogenesis of hypertension. If inflammation, lipid disturbances, and endothelial dysfunction provoke hypertension, it is logical that any strategy that counteracts these effects will lower blood pressure. Physical activity improves endothelial function[34] and levels of lipids[35,36] and has anti-inflammatory effects.[37,38] As cross-country skiing is commonly undertaken during the winter season, its beneficial effects on health may reflect the high level of physical activity and healthy lifestyle of cross-country skiers.[15] Indeed, compared to any other group of athletes, it has been reported that elite cross-country skiers have the highest recorded levels of maximum oxygen uptake (VO_{2max}), which is the most accurate measure of CRF.[39] Evidence suggests that higher intensity exercise may effectively increase VO_{2max} and improve cardio-metabolic risk factors including blood pressure levels.[40,41] Furthermore, given that our observed associations of cross-country skiing habits with hypertension were somewhat attenuated on adjusting for CRF, these may reflect the total endurance physical activity of these individuals.

Implications of findings

During the winter months, physical activity can decrease by up to 40%.[42] This leads to adverse cardiometabolic risk profiles such as increase in blood pressure, weight gain, and harmful cholesterol levels, which are precursors for hypertension, type 2 diabetes, CVD, and mortality. Therefore, there is a need to identify attractive and feasible exercise or sports activities, such as cross-country skiing, that the wider population can engage in to promote health. Cross-country skiing can be undertaken as a leisure-time activity or long-term endurance sport and it is enjoyed by the general public as well as by athletes in competitive settings during the winter period. Leisure cross-country skiing is a potential activity that can be taken up by individuals to overcome the physical activity deficits during winter and its benefits include general overall health. The health benefits of cross-country skiing may also come with some disadvantages. There have been reports linking cross-country skiing with an increased risk cardiac arrests, sudden cardiac deaths (SCDs), and cardiac arrhythmias such as atrial fibrillation.[14,43,44] Other relatively uncommon adverse effects of skiing reported are chronic anterior compartment syndrome, back pain, injuries and deaths associated with trauma and accidents.[45-47] However, the concern for these adverse events is miniscule in leisure-time cross-country skiing, as they are relatively commoner in long-term endurance cross-country skiing and downhill skiing. Moreover, good CRF as measured by VO_{2max} and which can be improved and maintained by cross-country skiing, is protective against SCDs in the general population.[28]

Strengths and limitations

We have conducted the first investigation to quantify the nature and magnitude of the prospective associations of the total volume and duration of leisure-time cross-country skiing with the risk of future hypertension in a general male population. Other strengths include the representativeness of the sample in the male population; exclusion of hypertensive individuals at baseline which minimised any possibilities of reverse-causation bias; the prospective cohort design; the high participation rate and the zero loss to follow-up rate; the long-term follow-up duration; comprehensive data on lifestyle and biochemical factors which allowed control for several potential confounders; comprehensive analysis such as evaluating the shape of the association and effect modification by clinically relevant characteristics; and robustness of the findings in several sensitivity analyses. Several limitations deserve consideration. The findings were based on observational data, therefore reverse causality due the effects of underlying diagnosed or undiagnosed diseases on skiing habits and residual confounding due to errors in risk marker measurements and unmeasured confounders such as lifestyle changes which impact on hypertension, remain an alternative explanation. There were possible biases in outcome ascertainment, given that blood pressure was measured at study entry with a random zero sphygmomanometer, whereas incident hypertension on follow up was ascertained from either national hospital or medication records. Habits including duration and intensity of cross-country skiing as well as other physical activities were self-reported, leading to potential misclassification. The current analyses involved principally middle-aged white European male participants, so generalisability to females, other populations from different countries and age groups is limited. Given that study participants were middle-aged at study entry and the long observation period, skiing habits may have changed during the period due to effects of aging, diseases, and use of medications. Finally, because cross-country skiing habits may have changed during follow-up, this could have resulted in the phenomenon of regression dilution bias,[48] where there is underestimation of the associations. We had no data on repeat assessments of cross-country skiing habits and therefore could not correct for this.

Conclusions

Total volume as well as duration of leisure-time cross-country skiing are each continuously, inversely and independently associated with future risk of hypertension in a middle-aged Caucasian male population. Findings add to the growing body of evidence that participation in various sports or leisure-time high-intensity physical activity disciplines has the potential to promote public health.

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DISCLOSURES

None

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Table 1. Baseline participant characteristics and correlates of total volume of leisure-time cross-country skiing

	Mean (SD), median (IQR), or n (%)	Pearson correlation r (95% CI)[a]
Total volume of skiing (MET hours/year)	50.0 (0-220.0)	-
Duration of skiing (min/week)	60 (60-90)	0.41 (0.36, 0.46)***
Questionnaire/Prevalent conditions		
Age at survey (years)	52.7 (5.3)	-0.01 (-0.05, 0.04)
Alcohol consumption (g/week)	30.3 (6.4-88.0)	-0.06 (-0.10, -0.01)*
History of diabetes		
No	1,749 (96.7)	-
Yes	60 (3.3)	-
Smoking status		
Other	1,203 (66.6)	-
Current	606 (33.5)	-
Family history of hypertension		
No	1,054 (58.3)	-
Yes	755 (41.7)	-
Physical measurements		
BMI (kg/m^2)	26.3 (3.4)	-0.06 (-0.10, -0.01)*
SBP (mmHg)	130.0 (14.8)	-0.03 (-0.08, 0.02)
DBP (mmHg)	86.1 (9.5)	-0.03 (-0.08, 0.01)
Total physical activity (kcal/day)	281.8 (150.8-472.5)	0.39 (0.35, 0.43)***
Peak VO_2 (ml/min)	2,457 (635)	0.24 (0.19, 0.29)***
Lipid markers		
Total cholesterol (mmol/l)	5.90 (1.11)	-0.01 (-0.04, 0.05)
HDL-C (mmol/l)	1.32 (0.31)	0.06 (0.01, 0.10)*
Metabolic and renal markers		
Fasting plasma glucose (mmol/l)	5.25 (1.04)	-0.03 (-0.08, 0.02)
Serum creatinine (μmol/1)	88.8 (12.7)	0.06 (0.01, 0.11)*
Estimated GFR (ml/min/1.73 m^2)	87.7 (17.5)	-0.06 (-0.11, -0.01)*

BMI, body mass index; DBP, diastolic blood pressure; GFR, glomerular filtration rate;
HDL-C, high-density lipoprotein cholesterol; IQR, interquartile range; SBP, systolic blood pressure; [a] , Pearson correlation coefficients between duration of skiing and the row variables; asterisks indicate the level of statistical significance:
*, p<0.05; **, p<0.01; ***, p<0.001

Table 2. Associations of total volume and duration of leisure-time cross-country skiing with incident hypertension

Cross-country skiing exposure	Events/ Total	Model 1		Model 2	
		HR (95% CI)	*P*-value	HR (95% CI)	*P*-value
Total volume (MET hours/year)					
0	128 / 706	ref		ref	
1-200	95 / 628	0.69 (0.52 to 0.89)	0.005	0.75 (0.57 to 0.99)	0.04
> 200	56 / 475	0.49 (0.36 to 0.67)	< 0.001	0.57 (0.41 to 0.79)	0.001
P-value for trend			< 0.001		< 0.001
Duration (mins/week)					
0	128 / 706	ref		ref	
1-60	96 / 653	0.65 (0.50 to 0.84)	0.001	0.72 (0.55 to 0.94)	0.016
> 60	55 / 450	0.52 (0.38 to 0.72)	< 0.001	0.62 (0.44 to 0.86)	0.004
P-value for trend			< 0.001		0.002

Analysis conducted in participants with no history of hypertension at study entry

Model 1: Adjusted for age

Model 2: Model 1 plus body mass index, systolic blood pressure, smoking status, history of diabetes, total cholesterol, high-density lipoprotein cholesterol, alcohol consumption, family history of hypertension, and total physical activity

Table 3. Associations of total volume and duration of leisure-time cross-country skiing with incident stroke

Cross-country skiing exposure	Events/ Total	Model 1		Model 2	
		HR (95% CI)	*P*-value	HR (95% CI)	*P*-value
Total volume (MET hours/year)					
0	143 / 1,026	ref		ref	
1-200	98 / 896	0.70 (0.54 to 0.91)	0.007	0.80 (0.62 to 1.05)	0.105
> 200	66 / 615	0.66 (0.49 to 0.89)	0.006	0.79 (0.57 to 1.08)	0.134
Duration (mins/week)					
0	143 / 1,026	ref		ref	
1-60	97 / 912	0.67 (0.52 to 0.87)	0.002	0.78 (0.60 to 1.02)	0.071
> 60	67 / 599	0.71 (0.53 to 0.95)	0.020	0.82 (0.61 to 1.11)	0.206

Analysis conducted in participants with no history of stroke at study entry

Model 1: Adjusted for age

Model 2: Model 1 plus body mass index, systolic blood pressure, smoking status, history of diabetes, total cholesterol, high-density lipoprotein cholesterol, alcohol consumption, family history of hypertension, history of hypertension, and total physical activity

Figure legends

Figure 1. Cumulative Kaplan-Meier curves for incident hypertension during follow-up according to total volume and duration of cross-country skiing

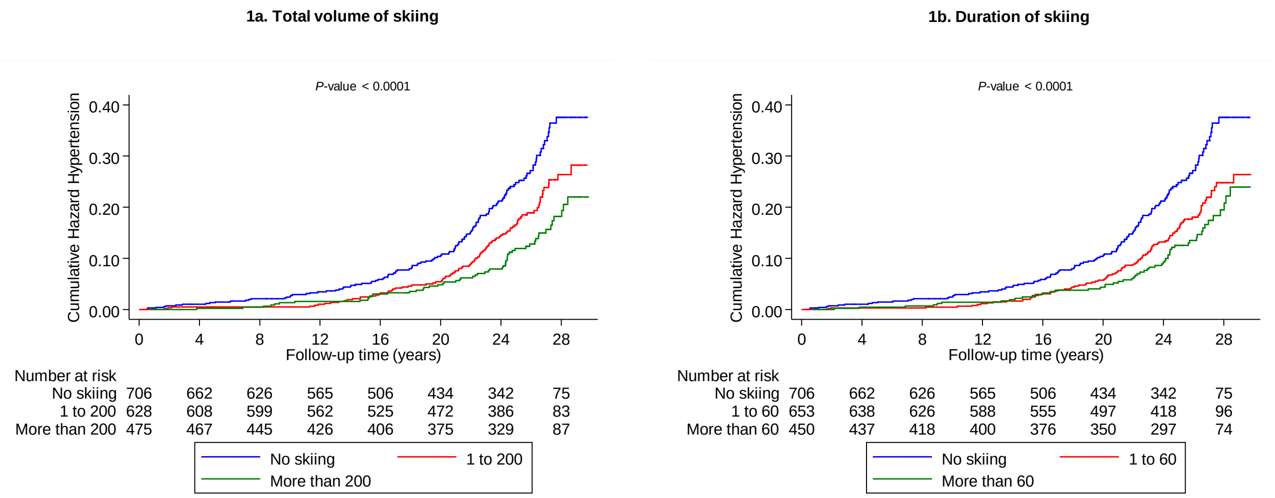
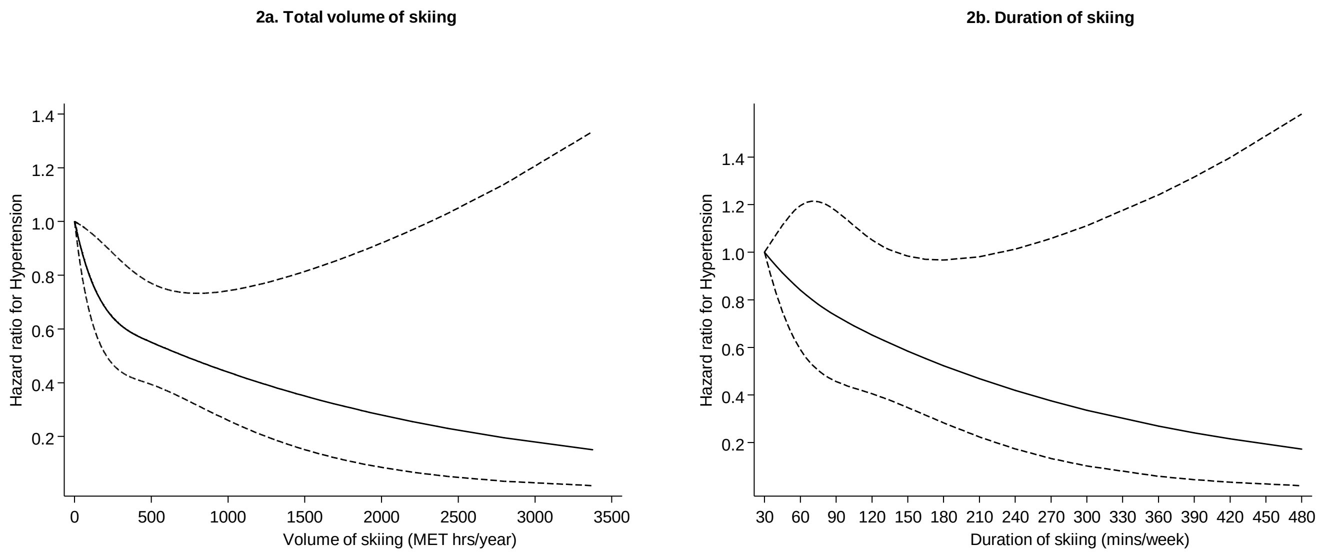


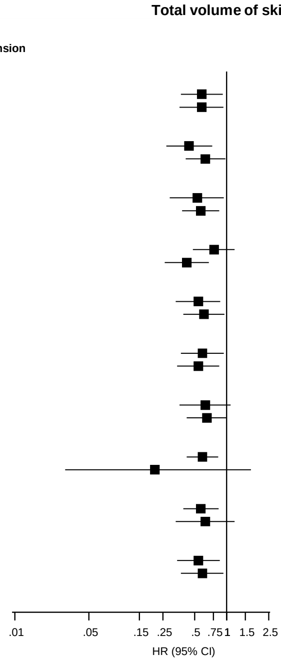
Figure 2. Restricted cubic splines of the hazard ratios of incident hypertension with total volume and duration of cross-country skiing

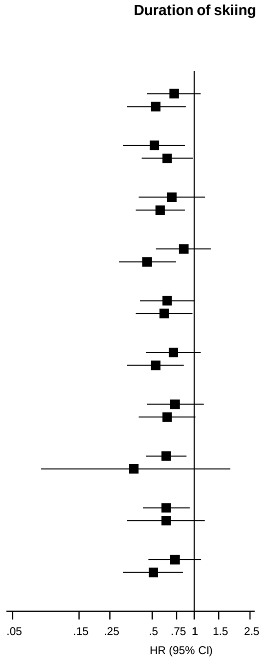


Models were adjusted for age, body mass index, systolic blood pressure, smoking status, history of diabetes, total cholesterol, high-density lipoprotein cholesterol, alcohol consumption, family history of hypertension, and total physical activity

Figure 3. Associations of total volume and duration of cross-country skiing with incident hypertension in clinically relevant subgroups

Subgroup	No. of participants	No. of hypertension cases	Total volume of skiing HR (95% CI)	Total volume of skiing *P*-value*	Duration of skiing HR (95% CI)	Duration of skiing *P*-value*
Age at survey (years)						
< 54.4	989	142	0.58 (0.37, 0.92)	.367	0.72 (0.46, 1.11)	.652
≥ 54.4	820	137	0.58 (0.36, 0.93)		0.53 (0.33, 0.87)	
Body mass index (kg/m²)						
< 26.03	905	114	0.44 (0.27, 0.73)	.548	0.52 (0.31, 0.86)	.672
≥ 26.03	904	165	0.63 (0.41, 0.97)		0.64 (0.42, 0.98)	
Systolic blood pressure (mmHg)						
< 129	910	91	0.53 (0.29, 0.94)	.480	0.69 (0.40, 1.20)	.827
≥ 129	899	188	0.57 (0.38, 0.85)		0.57 (0.38, 0.86)	
Total cholesterol (mmol/l)						
< 5.83	908	135	0.76 (0.48, 1.19)	.194	0.84 (0.53, 1.32)	.183
≥ 5.83	901	144	0.42 (0.26, 0.68)		0.46 (0.29, 0.74)	
HDL-C (mmol/l)						
< 1.25	918	137	0.54 (0.33, 0.87)	.796	0.64 (0.41, 1.01)	.605
≥ 1.25	891	142	0.61 (0.39, 0.95)		0.61 (0.38, 0.97)	
Alcohol consumption (g/week)						
< 30.3	905	137	0.59 (0.37, 0.94)	.493	0.71 (0.45, 1.11)	.640
≥ 30.3	904	142	0.54 (0.34, 0.85)		0.53 (0.33, 0.84)	
Total PA (Kcal/day)						
< 280.6	905	147	0.63 (0.36, 1.09)	.074	0.73 (0.46, 1.17)	.030
≥ 280.6	904	132	0.65 (0.42, 1.00)		0.64 (0.40, 1.02)	
History of diabetes						
No	1749	269	0.59 (0.42, 0.83)	.099	0.63 (0.45, 0.88)	.101
Yes	60	10	0.21 (0.03, 1.69)		0.37 (0.08, 1.81)	
Smoking status						
Non-smokers	1203	200	0.57 (0.39, 0.84)	.170	0.63 (0.43, 0.93)	.407
Current smokers	606	79	0.63 (0.33, 1.19)		0.63 (0.33, 1.19)	
Family history of hypertension						
No	1054	150	0.54 (0.34, 0.86)	.513	0.73 (0.47, 1.12)	.475
Yes	755	129	0.59 (0.37, 0.93)		0.51 (0.31, 0.83)	





Hazard ratios were adjusted for age, body mass index, systolic blood pressure, smoking status, history of diabetes, total cholesterol, high-density lipoprotein cholesterol, alcohol consumption, family history of hypertension, and total physical activity; CI, confidence interval; HDL-C, high-density lipoprotein cholesterol; HR, hazard ratio; PA, physical activity; *, *P*-value for interaction; cut-offs used for age, body mass index, systolic blood pressure, total cholesterol, HDL-C, and total physical activity are median values. For total volume of cross-country skiing, HRs are reported comparing > 200 MET hours/year of cross-country skiing with no skiing activity; for duration of cross-country skiing, HRs are reported comparing > 60 minutes of cross-country skiing/week with no skiing activity.

SUPPLEMENTARY MATERIAL

Supplementary Material 1	STROBE 2007 Statement—Checklist of items that should be included in reports of cohort studies
Supplementary Material 2	Associations of total volume and duration of cross-country skiing with incident hypertension on exclusion of first five years of follow-up
Supplementary Material 3	Associations of total volume and duration of leisure-time cross-country skiing with incident type 2 diabetes
Supplementary Material 4	Associations of total volume and duration of leisure-time cross-country skiing with incident acute myocardial infarction

Supplementary Material 1: STROBE 2007 Statement—Checklist of items that should be included in reports of cohort studies

Section/Topic	Item #	Recommendation	Reported on page #
Title and abstract	1	(*a*) Indicate the study's design with a commonly used term in the title or the abstract	Page 1
		(*b*) Provide in the abstract an informative and balanced summary of what was done and what was found	Page 2
Introduction			
Background/rationale	2	Explain the scientific background and rationale for the investigation being reported	Page 3-4
Objectives	3	State specific objectives, including any prespecified hypotheses	Page 3-4
Methods			
Study design	4	Present key elements of study design early in the paper	Study participants
Setting	5	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection	Study participants
Participants	6	(*a*) Give the eligibility criteria, and the sources and methods of selection of participants. Describe methods of follow-up	Study participants
		(*b*) For matched studies, give matching criteria and number of exposed and unexposed	Not applicable
Variables	7	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable	Assessment of leisure cross-country skiing and physical activity; Assessment of risk markers
Data sources/ measurement	8*	For each variable of interest, give sources of data and details of methods of assessment (measurement). Describe comparability of assessment methods if there is more than one group	Assessment of leisure cross-country skiing and physical activity; Assessment of risk markers
Bias	9	Describe any efforts to address potential sources of bias	Statistical methods
Study size	10	Explain how the study size was arrived at	Statistical methods
Quantitative variables	11	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why	Statistical methods
Statistical methods	12	(*a*) Describe all statistical methods, including those used to control for confounding	Statistical methods
		(*b*) Describe any methods used to examine subgroups and interactions	Statistical methods
		(*c*) Explain how missing data were addressed	Not applicable
		(*d*) If applicable, explain how loss to follow-up was addressed	Not applicable
		(*e*) Describe any sensitivity analyses	Statistical methods
Results			
Participants	13*	(a) Report numbers of individuals at each stage of study—eg numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analysed	Participants and Study Setting
		(b) Give reasons for non-participation at each stage	Participants and Study Settings
		(c) Consider use of a flow diagram	

Descriptive data	14*	(a) Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders	Results; Table 1
		(b) Indicate number of participants with missing data for each variable of interest	
		(c) Summarise follow-up time (eg, average and total amount)	Results
Outcome data	15*	Report numbers of outcome events or summary measures over time	Results
Main results	16	(*a*) Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (eg, 95% confidence interval). Make clear which confounders were adjusted for and why they were included	Results; Tables 2 and 3
		(*b*) Report category boundaries when continuous variables were categorized	Results; Tables 2 and 3
		(*c*) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period	
Other analyses	17	Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses	Results; Figure 2; Supplementary Material 2
Discussion			
Key results	18	Summarise key results with reference to study objectives	Discussion - Summary of main findings
Limitations			
Interpretation	20	Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence	Discussion
Generalisability	21	Discuss the generalisability (external validity) of the study results	Discussion
Other information			
Funding	22	Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based	Page 11

Supplementary Material 2: Associations of total volume and duration of cross-country skiing with incident hypertension on exclusion of first five years of follow-up

Cross-country skiing exposure	Events/ Total	Model 1		Model 2	
		HR (95% CI)	*P*-value	HR (95% CI)	*P*-value
Total volume (MET hours/year)					
0	119 / 655	ref		ref	
1-200	92 / 604	0.71 (0.54 to 0.93)	0.012	0.77 (0.58 to 1.01)	0.063
> 200	55 / 463	0.51 (0.37 to 0.70)	< 0.001	0.58 (0.41 to 0.81)	0.002
Duration (mins/week)					
0	119 / 655	ref		ref	
1-60	94 / 634	0.67 (0.51 to 0.88)	0.004	0.74 (0.56 to 0.97)	0.030
> 60	53 / 433	0.54 (0.39 to 0.74)	< 0.001	0.62 (0.44 to 0.87)	0.006

Model 1: Adjusted for age

Model 2: Model 1 plus body mass index, systolic blood pressure, smoking status, history of type 2 diabetes, total cholesterol, high-density lipoprotein cholesterol, alcohol consumption, family history of hypertension, and total physical activity

Supplementary Material 3: Associations of total volume and duration of leisure-time cross-country skiing with incident type 2 diabetes

Cross-country skiing exposure	Events/ Total	Model 1		Model 2	
		HR (95% CI)	*P*-value	HR (95% CI)	*P*-value
Total volume (MET hours/year)					
0	253 / 995	ref		ref	
1-200	189 / 883	0.70 (0.58 to 0.85)	< 0.001	0.76 (0.63 to 0.92)	0.005
> 200	97 / 605	0.49 (0.38 to 0.61)	< 0.001	0.60 (0.47 to 0.77)	< 0.001
Duration (mins/week)					
0	253 / 995	ref		ref	
1-60	183 / 898	0.65 (0.54 to 0.78)	< 0.001	0.73 (0.60 to 0.89)	0.002
> 60	103 / 590	0.55 (0.44 to 0.69)	< 0.001	0.65 (0.51 to 0.82)	< 0.001

Analysis was based on 2,483 participants and 539 incident cases of type 2 diabetes; participants had no history of diabetes at study entry

Model 1: Adjusted for age

Model 2: Model 1 plus body mass index, systolic blood pressure, smoking status, total cholesterol, plasma glucose, high-density lipoprotein cholesterol, alcohol consumption, family history of diabetes, and total physical activity

Supplementary Material 4: Associations of total volume and duration of leisure-time cross-country skiing with incident acute myocardial infarction

Cross-country skiing exposure	**Events/ Total**	**Model 1**		**Model 2**	
		HR (95% CI)	*P*-value	HR (95% CI)	*P*-value
Total volume (MET hours/year)					
0	204 / 702	ref		ref	
1-200	175 / 704	0.79 (0.65 to 0.97)	0.023	0.92 (0.75 to 1.13)	0.451
> 200	109 / 523	0.61 (0.48 to 0.77)	< 0.001	0.79 (0.61 to 1.01)	0.057
Duration (mins/week)					
0	204 / 702	ref		ref	
1-60	164 / 721	0.70 (0.57 to 0.86)	0.001	0.87 (0.70 to 1.07)	0.192
> 60	120 / 506	0.73 (0.58 to 0.91)	0.005	0.88 (0.69 to 1.11)	0.266

Analysis was based on 1,929 participants and 488 cases of acute myocardial infarction; participants had no history of coronary heart disease at study entry
Model 1: Adjusted for age
Model 2: Model 1 plus body mass index, systolic blood pressure, smoking status, history of diabetes, total cholesterol, high-density lipoprotein cholesterol, medication for cholesterol, alcohol consumption, history of hypertension, and total physical activity