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Potato consumption and all-cause and cardiovascular disease mortality – a long-term follow-up of a Norwegian cohort

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Abstract

Purpose. To examine the association between potato consumption and death of all-causes and cardiovascular disease (CVD) over a substantial follow-up period within a cohort predominantly consuming boiled potatoes.

Methods. Adults from three Norwegian counties were invited to three health screenings in 1974–1988 (>80% attendance). Dietary data were collected using semi-quantitative food frequency questionnaires at each screening to categorize weekly potato consumption (≤6, 7–13, or ≥14 potatoes/week) and calculate daily cumulative mean intakes (grams/day). Hazard ratios (HRs) and 95% confidence intervals (CIs) were estimated using multivariable Cox regression to estimate hazard ratios (HRs) and 95% confidence intervals (CIs) for the association between potato consumption and risk of death from all-causes, CVD, ischaemic heart disease (IHD), and acute myocardial infarction (AMI).

Results. Among 78,400 subjects with a mean baseline age of 41 years, we observed 27,737 deaths, including 9,028 deaths due to CVD, over a median follow-up of 33.5 years. Subjects who consumed ≥14 potatoes/week had a lower risk of all-cause death compared to subjects consuming ≤6potatoes/week (HR=0.88; 95% CI 0.84, 0.92). Potato consumption was associated with a small, inverse risk of death due to CVD, IHD, and AMI. In continuous analyses, each 100 g/day increment was associated with 4% lower risk of death from all-causes (HR=0.96; 95% CI 0.94, 0.98) and CVD (0.96; 0.93, 0.99), along with 5% (0.95; 0.91, 1.00) and 4% lower (0.96; 0.91, 1.01) risk of IHD and AMI death, respectively.

Conclusion. In this cohort with a generally high consumption of potatoes, we found modest, inverse associations between potato consumption and death of all-causes, CVD, and IHD.

Introduction

Potatoes are a ubiquitous, versatile staple food and one of the most consumed vegetables in the world [1]. Given their significant position in many traditional diets, the potential effects of potatoes on cardiovascular disease (CVD), one of the leading causes of death, is of interest.

Potatoes contribute to the intake of several nutrients linked with beneficial effects on CVD risk factors, including potassium, dietary fibre, vitamin C, and other bioactive compounds, such as phenolic acids [2]. However, due to their relatively high starch content (~15%), potatoes are often not included in the recommendations for vegetables [3]. Intake of potatoes has been suggested to increase the risk of cardiometabolic disease, presumably due to their high glycaemic index (GI), a measure of the blood glucose response to a carbohydrate food, although a direct association between GI and CVD risk is not established [4, 5].

The most recent Nordic Nutrition Recommendations stated that potatoes can be “included as a significant part of the regular dietary pattern”, but due to insufficient evidence no quantitative guideline was provided [3, 6]. Although several observational studies have examined the associations between

potato intake and risk of chronic diseases, methodological limitations have hindered the formulation of dietary guidelines for the general population [3, 6]. In particular, data on associations with mortality is limited [7]. One study found a lower risk of CVD mortality among women with high versus low intake of potatoes [8] and one study of Finnish males found a lower risk of coronary heart disease (CHD) mortality [9]. On the other hand, a Swedish study found no association between frequency of potato consumption and CVD mortality [10]. A lack of association with mortality was also found in more recent studies from the US, where the mean intakes and the difference in intake between high and low potato consumers were small [11, 12].

Some of the previous studies were performed among people with high risk of CVD and in countries where potatoes are mostly consumed fried or mashed. Moreover, the specific methods of preparation are often not detailed, yet they can significantly influence the nutritional profile of potatoes for instance through added fats and sodium. In Norway, potatoes have traditionally been consumed almost exclusively as boiled [13-15]. Another limitation in most previous studies is that intake was assessed only at one time-point. A systematic review from 2019 considered the quality of the evidence linking potato consumption and CVD mortality low, suggesting that the certainty of the evidence is likely to change in light of more and larger studies [16].

The aim of this study was to examine, in a sizeable population with a generally high consumption of predominately boiled potatoes, the associations between potato consumption and all-cause and CVD mortality during a long follow-up period.

Methods

Study design and population

The Norwegian Counties Study is a population-based prospective cohort study conducted in three Norwegian counties (Finnmark, Sogn og Fjordane, and Oppland), located in Northern, South-Western, and Central Norway, respectively. Three cardiovascular health screenings were performed in these counties by the National Health Screening Service between 1974 and 1988 [17, 18]. At screening I (1974–1976), all residents aged 35–49 years plus a 10% random sample of 20–34-year-olds, in total 65,624 individuals, were invited. Those invited to screening I were re-invited to screenings II (1977–1983) and III (1985–1988), along with random samples from younger and older birth cohorts. In a few municipalities, 17–19-year-olds were also invited to screenings II and III. Attendance was above 80% at all screenings. In total, 92,234 individuals attended at least one screening, 60,636 at least two, and 36,894 attended all three screenings.

A questionnaire covering civil status, health status, and lifestyle factors such as smoking and physical activity, was included in the invitation letter mailed to the invited residents. The questionnaire was brought to the examination and reviewed by a nurse. Each screening also included a physical

examination. Individuals with high CVD risk factor levels were referred to their general practitioners for follow-up.

Informed consent was obtained from the participants. For the present study, ethical approval was obtained from the Regional Committee for Medical Research Ethics Norway (no. 2018/1302), the University of Oslo's internal privacy protection commission, and the Norwegian Institute of Public Health.

Dietary assessment

At each screening, the participants received a 4-page semi-quantitative food-frequency questionnaire (FFQ) containing questions on habitual meal patterns and frequency, types, and amounts of foods (in total 80 questions), which was filled in at home and returned by mail. In Finnmark, the FFQ was only used in a subsample of municipalities at screening I. The FFQ was returned by 93%, 82%, and 84% of participants at screenings I, II, and III, respectively. Most questions on the FFQs were answered by 98-99% of the respondents [19].

Potato consumption was assessed by questions about frequency of weekly potato-containing main meals (0–2, 3–5, or 6–7 per week) and number of potatoes consumed (from <1 to ³5 per meal). These questions were identical at all three screenings. The total number of potatoes consumed per week was then calculated and categorized as 0–6, 7–13, and ³ 14 per week. We further converted the number of potatoes into grams/day, assuming a standard weight of 70 grams per potato [20]. Reproducibility of the FFQ was assessed in a subsample (1445 women) and median agreement for the different FFQ questions was 81% (range 50–98%) [19]. Comparison of the FFQ and 24-h recall assessments showed acceptable agreement for ranking daily food intakes and the amounts of potatoes consumed were similar with the two methods [21-23]. As the typical Norwegian diet at the time of the study consisted of 2-3 bread-based cold meals and one hot meal [15], we assumed that the potatoes were consumed only at dinner (the hot meal). Energy intake (excluding alcohol) was calculated for subjects with no more than 10 unanswered items on the FFQ, using the Norwegian Food Composition Table from 1991 [24].

The FFQ did not specify the type of potatoes consumed. However, household consumption surveys from the 1980s found that potatoes were almost always consumed as boiled; about 90% of dinners with fish and 80% of dinners with meat included boiled potatoes [13]. Processed potato products constituted less than 10% of the total potato consumption throughout the 1970s and 1980s [13, 25]. Consumption of potato chips/crisps was only assessed by a single yes/no question, and thus not included in the present study.

Covariates

In the questionnaire, current and previous smokers were asked to report how many years they had been smoking daily (mean 14 years among ex-smokers and 20 years among current smokers). Smoking status was categorized as never, previous <14 years, previous ³14 years, current <20 years, and current ³20 years. Participants who answered “never” at one screening but had answered former or current smoker on a previous screening, were classified as former smokers. Recreational and occupational physical activity levels were assessed by the questionnaires, each with four activity levels. Marital status (unmarried, married, widowed, divorced, separated) was also self-reported. Self-reported history of myocardial infarction (MI), angina, stroke, treatment of hypertension, use of nitroglycerine, and diabetes mellitus, was used to indicate presence of comorbidities.

Weight and height were measured at each screening, and body mass index (BMI) was calculated (kg/cm^2). Blood samples were drawn, and non-fasting serum total cholesterol was measured non-enzymatically (screening I) and enzymatically (screenings II and III) at the Ullevaal Hospital central laboratory in Oslo, by the same staff using the same equipment for all counties. The non-enzymatically measured cholesterol was corrected to be compatible with enzymatic analyses [26]. Systolic and diastolic blood pressure was measured by a nurse to the nearest 2 mmHg, twice with an auscultatory mercury sphygmomanometer at screenings I and II, and three times with an automatic DINAMAP instrument at screening III [27]. The second reading was used in screenings I and II, while the mean of the second and third readings was used in screening III.

Education was obtained from Statistics Norway and categorized according to the Norwegian Standard Classification of Education: compulsory (≤9 years), upper secondary (10–12 years), and higher education (≥ 13 years).

Outcomes and follow-up

Underlying causes of death from death certificates were obtained through linkage to the Norwegian Cause of Death Registry using the unique personal identification number assigned to all residents. Cause of death was classified according to the International Classification of Diseases (ICD) as CVD (ICD8: 390–458; ICD9: 390–459; ICD10: I00–I99), ischaemic heart disease (IHD) (ICD8–9: 410–414, 4140, 4143, 4148–9; ICD10:I20–I25)), and acute myocardial infarction (AMI) (ICD8–9: 410–11, ICD10: I21–22).

Follow-up started at a subject’s baseline screening, which we defined as the first screening in which intake of potatoes was reported, total energy intake could be calculated, age 18–64 years, the questions about smoking, physical activity, and comorbidities were answered, measurements of weight, height, and blood pressure were obtained, and a blood sample was collected. Hence, start of follow-up

for a subject may be later than the first attended screening. The subjects were followed until death, emigration, or 31 December 2018, whichever occurred first.

Statistical analysis

We estimated hazard ratios (HRs) and 95% confidence intervals (CIs) using Cox regression with age as the time scale. To account for birth cohort, all models were stratified by birth year (≤1929, 1930–34, 1935–39, 1940–44, and ≥1945). In analyses of cause-specific death, we censored for death due to competing causes. Smoothed scaled Schoenfeld residuals against age did not indicate violation of the proportional-hazards assumption. Potato intake was modelled as a time dependent variable. We calculated cumulative mean intakes using intake from screening I until screening II, the mean of screenings I and II from screening II until screening III, and the mean of screenings I–III from screening III until end of follow-up [28]. If intake was available only at baseline, this was used throughout follow-up. Associations between potato intake and risk of death were analysed according to categories of number of potatoes per week, with ≤6 potatoes/week as a reference, and with potatoes expressed as continuous energy-adjusted intake per 100 g/day increment. For the continuous analysis, the cumulative mean potato intake was log-transformed and energy-adjusted using the residual method, regressing potato intake on total energy intake [29]. All analyses were adjusted for sex and cumulative mean energy intake (kcal/day, continuous) (Model 1). Model 2 included additional adjustment for BMI (continuous), recreational and occupational physical activity, smoking status, and comorbidities. Since Norwegian consumer surveys have found that frequency of potato consumption was positively associated with being married and negatively associated with socio-economic status [14, 29, 30], we also adjusted for marital status and education in Model 2. In Model 3, we additionally adjusted for weekly number of dinner meals with meat and fish. All covariates, except sex, were time-dependent and updated at each screening. Linear trend was assessed with energy-adjusted potato intake as a continuous variable, expressed as increments of 100 grams/day (back-transformed). Potential non-linear dose-response associations were further evaluated using restricted cubic splines with 3 knots placed at the 10^{th}, 50^{th}, and 90^{th} percentiles of potato intake in energy-adjusted grams/day. Departure from linearity was examined by a Wald-type c^2 test. Participants without complete measurements of all covariates from at least one screening were excluded from the analysis, as the level of missing data was small and likely not related to the outcomes.

In secondary analyses based on Model 3, we stratified by sex, BMI (18-24.9, 25-29.9, ≥30 kg/m^2), smoking status, and comorbidities (dichotomous). Multiplicative interactions between potato intake and these covariates were tested using a likelihood ratio test. We performed sensitivity analyses where in addition to the covariates in Model 3, intake of boiled and fried meats and fish, sausages, meat balls, and fish products at dinner, use of melted margarine/butter with meat or fish, and grain-based dinners (e.g., pancakes or rice porridge) were included. Coffee intake (cups/day) was also included in addition to

these foods in a separate analysis. We also performed an analysis, based on Model 3, with adjustment for serum cholesterol and blood pressure, and another where subjects reporting presence of diabetes at the screenings were excluded, as they may have been likely to change their potato intake. Potential reverse causality was also addressed in a sensitivity analysis with Model 3 excluding the first 2 years of follow-up. Finally, we estimated HRs in the first and last half of the total follow-up period (22.5 years).

All analyses were performed using Stata software, version 18 (Stata Corp., Texas, USA).

Results

Of 92,234 participants attending screenings I–III, 80,564 were aged 18–64 years and reported both frequency and number of potatoes consumed in the FFQ from at least one screening (**Figure 1**). Participants with more than 10 unanswered questions in the FFQ (energy intake not quantifiable), implausible energy intake (<500 or >4000 kcal/day, i.e., less than the lowest/highest 1%) or missing covariate information (only 2%) were excluded, giving a study sample of 78,400 individuals.

Participant characteristics

Mean age at baseline was 41.2 years (range 18.0–63.9) and 50.5% of the participants were men (**Table 1**). Men had a higher potato consumption than women. Compared to those with the lowest potato consumption, high potato consumers were more likely to have only compulsory education, to be current smokers, have higher recreational and occupational physical activity, and less likely to have BMI ³30 kg/m^2. Although the overall prevalence of diabetes at baseline was low, it was highest in participants with low intake of potatoes.

TABLE 1

At baseline, 68.6% consumed 6–7 potato-containing meals per week, while this proportion was 62% at screening III. The median number of potatoes per week consumed at baseline was 13, and almost 90% consumed at least 2 potatoes per meal.

Potato consumption and all-cause, CVD, IHD, and AMI mortality

During 2,419,381 person-years (median 33.5 years, maximum 45 years) of follow up, there were 27,737 deaths, 9028 deaths from CVD, including 4576 deaths from IHD and 3181 deaths from AMI. Compared to subjects who consumed £6 potatoes/week, subjects who consumed ³14 potatoes/week had lower risk of death (HR=0.88; 95% CI 0.84, 0.92, p_{trend}<0.001; Model 3) (**Table 2**). Potato consumption was weakly associated with lower risk of death from CVD, IHD, and AMI (HRs (95% CIs) for ≥14 versus £6 potatoes/week were 0.95 (0.88, 1.04), 0.94 (0.83, 1.06), and 0.98 (0.84, 1.14), respectively; p_{trend} 0.02, 0.03, and 0.23 respectively; Model 3) (**Table 2**)

TABLE 2

Dose-response analyses using restricted cubic splines indicated deviation from linearity for all-cause mortality ($p_{non\text{-}linearity}$=0.01), with a flattening of the curve around 200 g/day, but not for CVD, IHD, or AMI mortality ($p_{non\text{-}linearity}$ 0.64, 0.12, and 0.96, respectively) (**Figure 2** and **Supplementary Figure 1).**

The inverse associations between potato intake (per 100 g/day) and all-cause mortality were similar among men and women ($p_{interaction}$=0.59) **(Supplementary Table 1)**, across categories of BMI ($p_{interaction}$=0.97) **(Supplementary Table 2),** and smoking status ($p_{interaction}$=0.60) (**Supplementary Table 3)** but was slightly stronger among subjects reporting comorbidities ($p_{interaction}$=0.04) **(Supplementary Table 4)**. Potato intake was significantly associated with lower risk only in men for CVD ($p_{interaction}$=0.28), IHD ($p_{interaction}$=0.04), and AMI ($p_{interaction}$=0.04) mortality **(Supplementary Table 1)**.

Sensitivity analyses

In sensitivity analyses with Model 3 additionally adjusted for intake of boiled and fried meats and fish, sausages, meat balls, fish products, use of melted fat (butter or margarine) on meat and fish at dinner, grain-based courses (e.g., pancakes or rice porridge), and coffee intake, gave similar results as Model 3 (**Supplementary Tables 5 and 6)**. Nor did additional adjustment of Model 3 for serum cholesterol and blood pressure change the results (**Supplementary Table 7**). Excluding subjects with self-reported diabetes marginally attenuated the HRs towards the null **(Supplementary Table 8).** Excluding the first 2 years of follow-up did not alter the results **(Supplementary Table 9)**. The associations tended to be slightly stronger during the first half of the follow-up, although there was no strong evidence of an interaction between follow-up period and mortality ($p_{interaction}$ 0.31 for all-cause, 0.39 for CVD, 0.69 for IHD, and 0.57 for AMI mortality) (**Supplementary Table 10).**

Discussion

In this long-term follow-up of a large, population-based cohort of Norwegian adults with a frequent intake of potatoes, we found inverse, but modest, associations between long-term habitual intake of potatoes and death from all-causes, CVD, and IHD. Each additional 100 g/day of potato was associated with 4–5% lower risk of death in the multivariable model. The associations were slightly stronger in men for IHD and AMI deaths.

Our findings are in accordance with previous studies that reported minor or null associations with all-cause and CVD related mortality [7, 11, 12, 31, 32]. The latest systematic review of cohort studies on potato consumption and mortality found a pooled relative risk for all-cause mortality of 0.90 (95% CI 0.80, 1.02) for the highest versus lowest category [7], but no summary estimate was calculated for CVD mortality due to few studies.

Previous studies often grouped processed potato products with whole potatoes. Veronese et al. found no association between total potato intake and all-cause mortality but a positive association with fried potatoes [33]. Another large-scale study found a positive association between French fry consumption and cancer-related mortality, but not all-cause or CVD mortality [31]. A recent European multi-cohort study noted an increased risk of all-cause mortality, but not CVD mortality, with daily potato consumption but did not differentiate by type of potato preparation [34]. A systematic review by Mazidi et al., based on only 2 studies that did not separate between minimally processed potatoes and potato products, suggested that a high intake of potatoes was associated with an increase in all-cause mortality (pooled RR = 1.25, 95% CI 0.98, 1.60) [11]. No associations with CVD or stroke mortality were found [11]. In contrast, a recent Norwegian study specifically assessing boiled potato consumption found no association with 10-year all-cause or CVD mortality [32]. However, neither portion sizes nor energy intake were assessed, and absolute intake could not be quantified.

Heterogeneous findings in the literature may be attributed to differing consumption practices and characteristics of potato consumers across countries and over time. Some studies analysed populations with low potato intakes, which may yield different associations and limit generalizability [7]. Most studies to date have relied on dietary intakes reported solely at baseline, which may not represent long-term intakes accurately [7]. To enhance further research on potato consumption and CVD, distinctions amongst various forms of potatoes should be made, as preparation methods alters the overall nutritional value of the potatoes [35].

According to 24H dietary recall data from a subsample of the cohort, potatoes were the second highest source of dietary fibre, providing 20% of the intake in men and 16% in women [23]. There is strong evidence for a protective effect of dietary fibre on all-cause mortality and CHD [36]. Potatoes were also the largest single source of vitamin C in men, accounting for 26% of their vitamin C intake, and contributed to 15% vitamin C in women in this cohort [23]. Dietary vitamin C intake is associated with

lower risk of all-cause mortality, CVD, and CHD [37] in cohort studies, and with beneficial effects on blood pressure [38] and potentially blood lipids [39] in randomized controlled trials (RCTs). The high content of potassium is also noteworthy, with about 14% of the recommended daily intake per 100 g boiled, unpeeled potatoes [3]. Urinary potassium excretion is inversely associated with CVD risk [40], while the evidence regarding all-cause mortality is insufficient [41].

On the other hand, the high GI of potatoes has been implicated in negative health outcomes as a high dietary GI is associated with increased risk of type 2 diabetes, but the evidence for an association with mortality or CVD is weak [4, 36]. The GI of potatoes is highly variable and may range from medium to high, depending on variety [42, 43]. For instance, early ("new") potatoes and cooled, boiled potatoes, which likely were consumed occasionally in this cohort, have a lower GI due to lower starch content and starch retrogradation. In any event, potatoes are usually eaten with other foods, which can greatly impact the glycaemic response [44]. Based on other metrics, potatoes, especially boiled, may also be considered a high-quality carbohydrate source, similar to other vegetables [45].

Notwithstanding the nutritional attributes, the overall associations between potato consumption and CVD risk factors are unclear. In cross-sectional studies, high consumption frequency of boiled potato was associated with prevalence of high waist-circumference, total cholesterol, triglycerides, and metabolic syndrome in a Norwegian cohort [46], while others found no associations with cardiometablic risk factors [47, 48]. Intake of both non-fried and fried potatoes were associated with increased risk of hypertension in prospective cohort studies from the US and China [49, 50], but not in two Spanish cohorts [51]. Some prospective cohort studies have found an association between potato consumption and weight gain, which was probably driven by fried potatoes [52, 53]. Evidence from clinical trials is scarce [54]. The few existing RCTs have not identified adverse cardiometabolic effects of increased potato intake within a generally healthy diet [55, 56]. While this is compatible with minor effects of potatoes on CVD and all-cause mortality, the studies were small and short-term and need to be corroborated.

Few studies have compared potatoes directly with other foods for cardiometabolic outcomes. Würtz et al. found that theoretical substitution of potatoes or other vegetables for red or processed meat was associated with lower risk of MI in a Danish prospective cohort study [57]. In the same cohort, replacement of 500 g/week of potatoes with other vegetables was not associated with risk of MI, while replacement with specifically fruiting vegetables was associated with lower risk of ischaemic stroke [58, 59]. Since our models included adjustment for total energy intake, they have an isoenergetic substitution interpretation [60]. It could be speculated that high consumers of potatoes had a concomitantly low intake of pasta or rice. However, use of pasta, rice, or other side dishes instead of potatoes was very uncommon in Norway when the present study was conducted [14, 22].

A major strength of this study is the long follow-up and high number of deaths compared to previous cohort studies assessing potato consumption and mortality risk [7]. Linkage with the Norwegian Causes

of Death Registry, which has high coverage and quality [61], is an additional strength. A high participation rate and an unselected, relatively young population likely reduced the risk of reverse causation and survivor bias. Inclusion of individuals reporting comorbidities, such as previous MI or diabetes, was accounted for in the analyses. The results were also robust to multiple sensitivity analyses.

Regarding the dietary assessment, the amounts of potatoes consumed were similar when assessed by FFQ and 24-h recall [21]. Both methods showed that about half of the women and men consumed 2 and 3–4 potatoes daily, respectively, and that 1% of the women and 9% of the men consumed ≥5 potatoes daily [21]. Another strength of this study is the use of repeated assessment of diet and covariates to capture changes in dietary patterns during the study period. Nonetheless, there was a lengthy interval between the last FFQ and the end of follow-up during which further changes in potato intake may have occurred [15]. While we could not capture changes in consumption after 1988, the decline in potato consumption in Norway has been described as a generational effect [15], largest among younger persons and in more urban areas than our study represents [14, 30, 62]. Thus, it seems reasonable to assume that the participants to a large extent maintained their potato consumption habits despite changes on national level. We found a stronger, inverse association between high potato consumption and all-cause and CVD mortality in the first half of the follow-up period than in the latter, which may reflect changing dietary habits during the later period.

The FFQ did not query about processed potato products or capture intake of potatoes as ingredient e.g., in bread. According to other household consumption surveys in the 1980s in Norway, 80% of all dinners (93% of all fish dinners) were served with boiled potatoes, while only 1% were served with baked or roasted potatoes and French-fried potatoes were not used at all [13]. However, we acknowledge that this may have changed later in the follow-up period as processed potatoes now account for more than half of the total potato consumption in Norway [63]. Some left-over, cold, boiled potatoes may also have been used as fillings on sandwiches or salads. Thus, measurement error must be considered, but we see no reason to believe it was related to the outcome.

Although we considered multiple potential confounding factors, unmeasured and residual confounding is possible. We lacked data of pasta and rice intake, which have become more common side dishes during later decades. Rice was used by only 1.5% in this cohort [22], and may mainly have been used for rice porridge and thus not in exchange for potatoes. Other Norwegian surveys found that rice or pasta was used in only 1–3% of the main meals in 1980s [14], but that people with higher education and income were more likely to replace potatoes with rice and pasta [14]. The FFQ was originally designed with an emphasis on dietary fats and consequently had few questions on fruits and vegetables. We did not adjust for intake of fruits and vegetables, assuming they were consumed in addition to, not interchangeably with, potatoes.

The study included a Norwegian population and diet during the 1970–80s, potentially limiting the generalizability to other and more current populations with other dietary habits and cultural factors. Additionally, the rise in average BMI in Norway in recent decades [64] may raise questions about the

current relevance of our findings. However, subgroup analyses showed similar results for individuals with a BMI ³30 kg/m² and those with lower BMI. This indicates that the upward trend in average BMI does not necessarily diminish the applicability of our data to today's conditions.

Conclusion

This long-term Norwegian cohort study indicated modest, inverse associations between habitual intake of potatoes and all-cause, CVD, and IHD mortality. There were no clear associations with AMI mortality. As potatoes are an important staple food in Norway and many other parts of the world, these findings are noteworthy. Our study adds to previous literature and guidelines suggesting that potato consumption, mostly boiled, does not adversely affect health outcomes and may be a significant part of a healthy diet [3, 6]. However, different consumption patterns and preparation methods across populations can lead to heterogeneous results.

Declarations

Author contributions

EKA designed the study with contributions from MHC and KR. EKA and KR obtained ethics approval and source data. IL calculated nutrient intake. EKA conducted data analyses and wrote the first draft of the paper. IL and MBV provided statistical advice. All authors contributed to the interpretation of the results and critical revision of the manuscript for important intellectual content and approved the final version. KR is the guarantor. The corresponding author attests that all listed authors meet authorship criteria and that no others meeting the criteria have been omitted.

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Ethics approval

The study was approved by the Regional Committee for Medical Research Ethics Norway (no. 2018/1302), the University of Oslo's internal privacy protection commission, and the Norwegian Institute of Public Health.

Conflict of interest

All authors have completed the ICMJE uniform disclosure form at http://www.icmje.org/disclosure-of-interest/ and declare: Dr. Retterstøl reports personal fees from Amgen, Amarin, Bayer, Norwegian Directorate of Health, Norwegian Medicines Agency, Norwegian Medical Association, and Sanofi, outside the submitted work. The other authors report no support from any organisation for the submitted work; no financial relationships with any organisations that might have an interest in the submitted work in the previous three years; no other relationships or activities that could appear to have influenced the submitted work.

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Tables

TABLE 1. Baseline characteristics according to weekly potato consumption and in total (n=78,400).

	Weekly potato intake (number/week)			
	£6	7-13	□14	Total
N	9,772	34,773	33,855	78,400
Potato consumption, mean (SD) grams/day (energy-adjusted)	72.9 (29.6)	141.8 (42.9)	215.9 (67.0)	165.5 (72.6)
Age (years), mean (SD)	40.9 (7.6)	41.2 (7.3)	41.2 (7.3)	41.2 (7.3)
Sex				
	18.7	33.1	77.4	50.5
1. - *Male, %*	81.3	66.9	22.6	49.5
2. - *Female, %*				
Marital status				
	78.9	82.9	79.9	81.1
1. - *Married, %*				
Education				
	42.6	44.1	48.1	45.6
1. - *Compulsory, %*				
Smoking status				
	39.5	41.1	48.1	43.9
1. - *Current, %*				
Recreational physical activity				
	19.9	18.9	18.0	18.7
1. - *Sedentary, %*	64.5	63.1	53.8	59.2
2. - *Moderate, %*	14.5	16.8	25.6	20.4
3. - *High, %*	1.1	1.1	2.6	1.8
4. - *Intensive, %*				
Occupational physical activity				
	22.4	22.0	23.5	22.7
1. - *Sedentary, %*	53.1	50.1	32.6	42.9
2. - *Walking, %*	19.2	19.5	23.3	21.1
3. - *Walking and lifting, %*	5.2	8.4	20.5	13.3
4. - *Heavy manual, %*				
BMI (kg/m^2), mean (SD)	24.8 (4.1)	24.6 (3.7)	25.0 (3.3)	24.8 (3.6)
BMI □30 kg/m^2, %	10.3	8.2	7.0	7.9
Total cholesterol (mmol/l), mean (SD)	6.03 (1.22)	6.10 (1.23)	6.15 (1.23)	6.11 (1.23)
Systolic blood pressure (mmHg), mean (SD)	130 (17)	132 (17)	135 (16)	133 (17)
Myocardial infarction, %	0.3	0.4	0.7	0.5
Stroke, %	0.3	0.2	0.1	0.2
Diabetes, %	2.2	0.8	0.2	0.7
Hypertension treatment, %	4.9	4.2	3.5	4.0
Energy intake, mean (SD) kJ/day	5213 (1903)	6343 (2075)	8422 (2477)	7104 (2540)

Numbers are mean (SD) for continuous variables, % for categorical variables. Abbreviations: BMI: Body mass index. kJ: kilo Joule. SD: standard deviation.

TABLE 2. Hazard ratios (95% confidence intervals) of all-cause, CVD, IHD, and AMI mortality according to potato consumption, n=78,400.

	Weekly potato intake (number/week)			Per 100 g/d increment[1]	p_{trend}[2]
	£6	7–13	14		
Person-years	252,861	1,087,178	1,079,342	2,419,381	
All-cause mortality					
Deaths, n	2496	11,536	13,705	27,737	
Incidence rate per 1000 person-years	9.87	10.61	12.70	11.46	
Model 1[3]	1 (ref.)	0.91 (0.87, 0.94)	0.88 (0.84, 0.93)	0.97 (0.96, 0.99)	0.005
Model 2[4]	1 (ref.)	0.92 (0.89, 0.96)	0.92 (0.88, 0.96)	0.96 (0.95, 0.98)	<0.001
Model 3[5]	1 (ref.)	0.89 (0.85, 0.93)	0.88 (0.84, 0.92)	0.96 (0.94, 0.98)	<0.001
CVD mortality					
Deaths, n	712	3,642	4,674		
Incidence rate per 1000 person-years	2.82	3.35	4.33		
Model 1[3]	1 (ref.)	0.97 (0.89, 1.05)	0.94 (0.86, 1.02)	0.98 (0.95, 1.01)	0.13
Model 2[4]	1 (ref.)	0.94 (0.86, 1.02)	0.95 (0.87, 1.03)	0.96 (0.93, 1.00)	0.03
Model 3[5]	1 (ref.)	1.00 (0.92, 1.08)	0.95 (0.88, 1.04)	0.96 (0.93, 0.99)	0.02
IHD mortality					
Deaths, n	320	1775	2481		
Incidence rate per 1000 person-years	1.27	1.63	2.30		
Model 1[2]	1 (ref.)	0.98 (0.87, 1.11)	0.91 (0.80, 1.03)	0.96 (0.92, 1.01)	0.01
Model 2[3]	1 (ref.)	1.03 (0.92, 1.17)	0.94 (0.83, 1.07)	0.95 (0.91, 1.00)	0.03
Model 3[4]	1 (ref.)	1.03 (0.91, 1.16)	0.94 (0.83, 1.06)	0.95 (0.91, 1.00)	0.03
AMI mortality					
Deaths, n	219	1250	1712		
Incidence rate per 1000 person-years	0.87	1.15	1.59		
Model 1[2]	1 (ref.)	1.03 (0.89, 1.19)	0.96 (0.82, 1.11)	0.97 (0.92, 1.02)	0.26
Model 2[3]	1 (ref.)	1.08 (0.93, 1.24)	0.98 (0.84, 1.14)	0.95 (0.91, 1.01)	0.09
Model 3[4]	1 (ref.)	1.08 (0.93, 1.25)	0.98 (0.84, 1.14)	0.96 (0.91, 1.01)	0.12

[1] Energy-adjusted

[2] *p* for linear trend, per 100 gram/day

[3] Hazard ratios (95% confidence intervals) from Cox regression stratified by birth year (<1930, 1930-34, 1935-39, 1940-44, 1945-49, 1950-54, and ≥1955) and with age as timescale, adjusted for sex and energy intake.

[4] Model 1 with further adjustment for body mass index, recreational and occupational physical activity, smoking status, marital status, attained education, and self-reported comorbidities.

[5] Model 2 with further adjustment for weekly consumption of fish and meat for dinner.

Figures

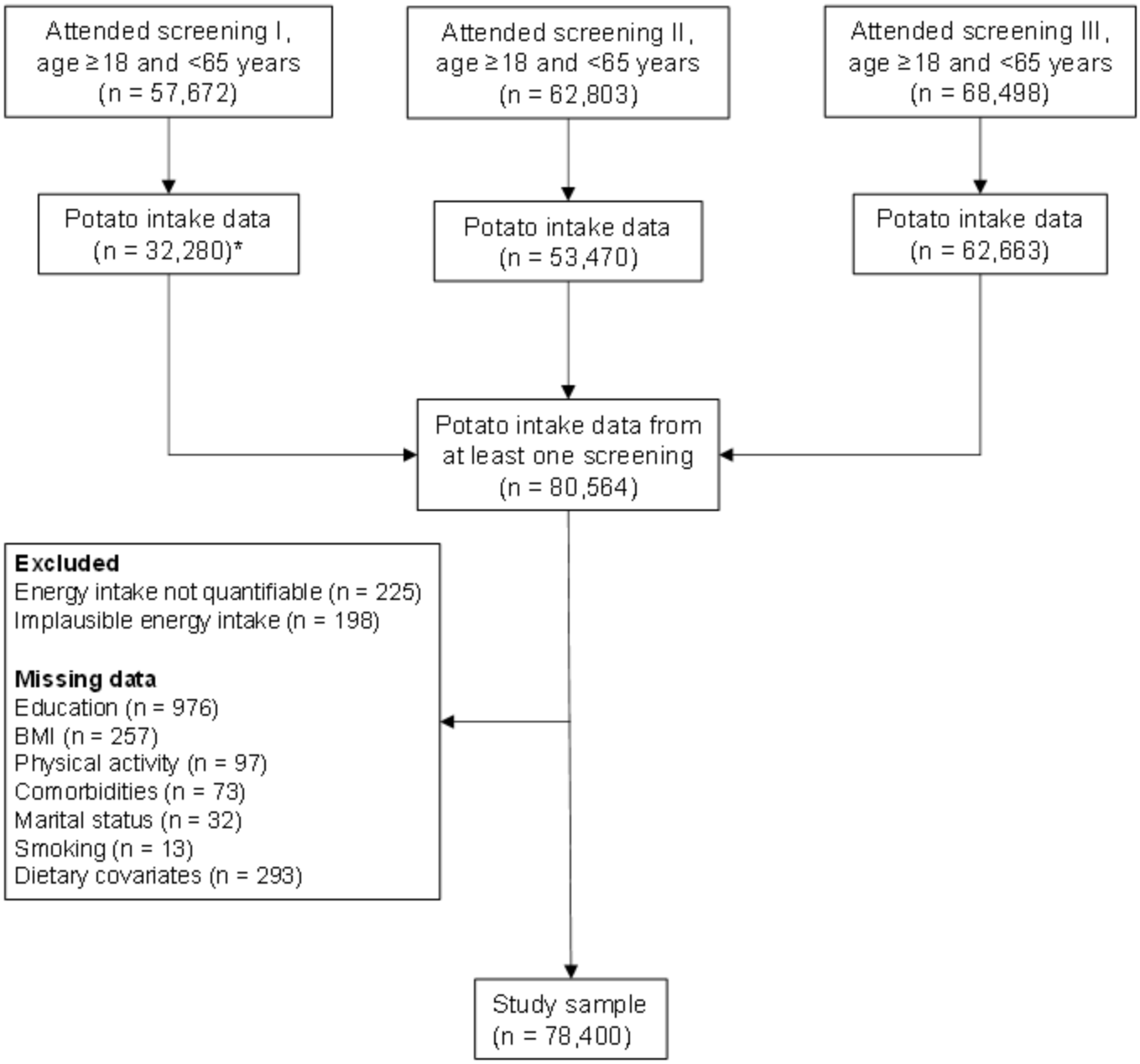


Figure 1

Flowchart of participants.
* Dietary assessments at screening I were included in two counties plus one municipality in the third county.

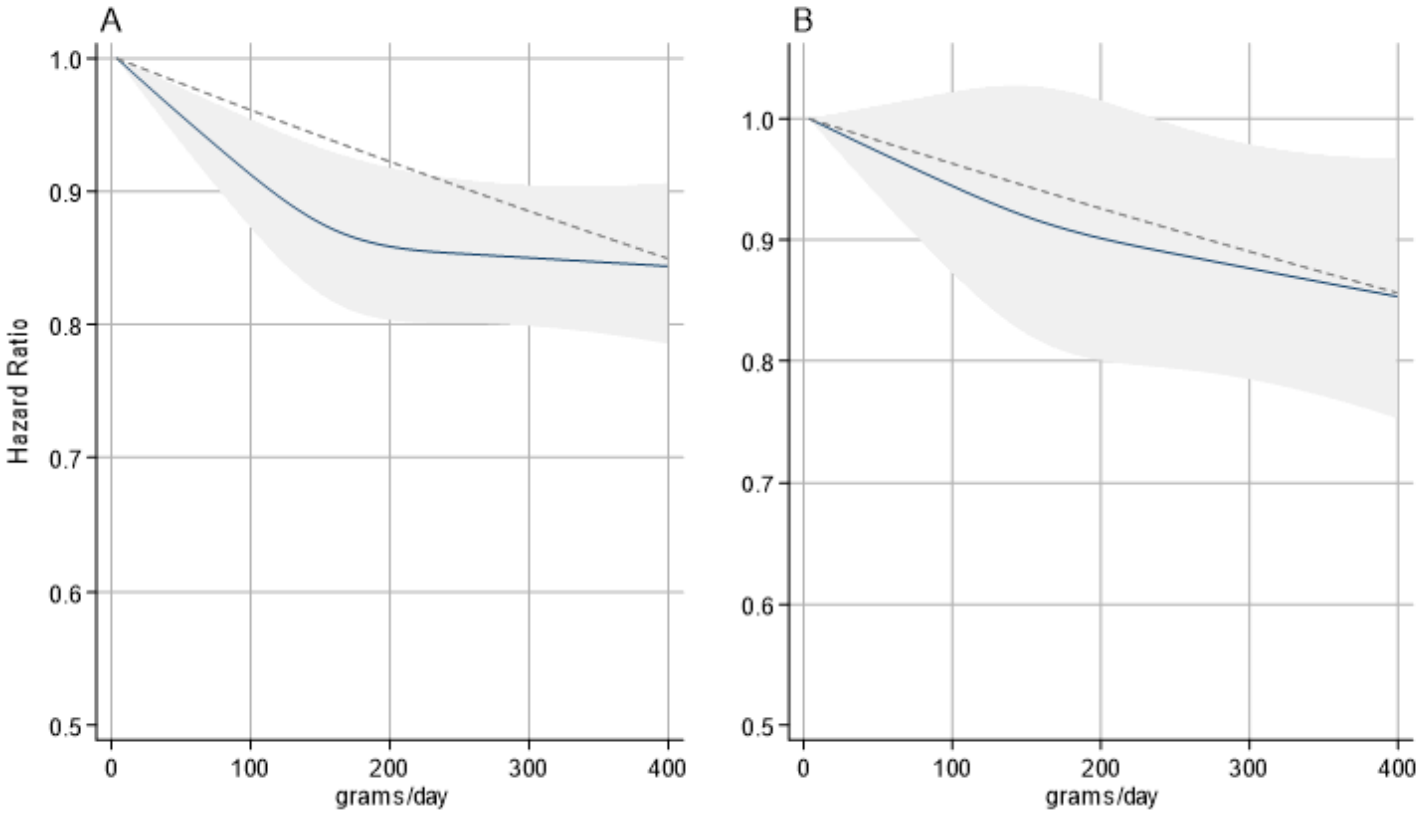


Figure 2

Multivariable dose-response relationship between cumulative mean potato intake (grams/day) and (A) all-cause and (B) cardiovascular disease (CVD) mortality. The solid curve and shaded area denote hazard ratios and 95% confidence in the restricted cubic spline model using 3 knots at the 10^{th}, 50^{th}, and 90^{th} percentiles. The dashed line represents the linear model. Estimated with Cox proportional hazard models with age as timescale, stratified by birth year (<1930, 1930-34, 1935-39, 1940-44, 1945-49, 1950-54, and ≥1955), and adjusted for sex, energy intake, body mass index, recreational and occupational physical activity, smoking habits, attained education, marital status, self-reported comorbidities, and weekly consumption of fish and meat for dinner.

Supplementary Files

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- PotatoconsumptionEurJNutrSupplI.pdf