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RESEARCH

Unhealthy behaviours and disability in older adults: Three-City Dijon cohort study

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Abstract

Objectives To examine the individual and combined associations of unhealthy behaviours (low/intermediate physical activity, consuming fruit and vegetables less than once a day, current smoking/short term ex-smoking, never/former/heavy alcohol drinking), assessed at start of follow-up, with hazard of disability among older French adults and to assess the role of potential mediators, assessed repeatedly, of these associations.

Design Population based cohort study.

Setting Dijon centre of Three-City study.

Participants 3982 (2410 (60.5%) women) French community dwellers aged 65 or over included during 1999-2001; participants were disability-free at baseline when health behaviours were assessed.

Main outcome measure Hierarchical indicator of disability (no, light, moderate, severe) combining data from three disability scales (mobility, instrumental activities of daily living, basic activities of daily living) assessed five times between 2001 and 2012.

Results During the 12 year follow-up, 1236 participants (861 (69.7%) women) developed moderate or severe disability. Interval censored survival analyses (adjusted for age, sex, marital status, and education) showed low/intermediate physical activity (hazard ratio 1.72, 95% confidence interval 1.48 to 2.00), consuming fruit and vegetables less than once a day (1.24, 1.10 to 1.41), and current smoking/short term ex-smoking (1.26, 1.05 to 1.50) to be independently associated with an increased hazard of disability, whereas no robust association with alcohol consumption was found. The hazard of disability increased progressively with the number of unhealthy behaviours independently associated with disability (P<0.001); participants with three unhealthy behaviours had a 2.53 (1.86 to 3.43)-fold increased hazard of disability compared with those with none. Reverse causation bias was verified by excluding participants who developed disability in the first four years of follow-up; these analyses on 890 disability events yielded results similar to those in the main analysis. 30.5% of the association between the unhealthy behaviours score and disability was explained by body mass index, cognitive function, depressive symptoms, trauma, chronic conditions, and cardiovascular disease and its risk factors; the main contributors were chronic conditions and, to a lesser extent, depressive symptoms, trauma, and body mass index.

Conclusions An unhealthy lifestyle is associated with greater hazard of incident disability, and the hazard increases progressively with the number of unhealthy behaviours. Chronic conditions, depressive symptoms, trauma, and body mass index partially explained this association.

Introduction

Disability is commonly defined as a "difficulty or dependency in carrying out activities essential to independent living, including essential roles, tasks needed for self-care and living independently in a home, and desired activities important to one's quality of life."[1] As the risk of disability increases with age, the burden of disability is expected to increase owing to the ageing of populations worldwide, despite declining trends in prevalence of disability in some European studies.[2 3] The number of disabled people in France is projected to increase by 50% between 2000 and 2040.[4] Identifying potentially modifiable risks factors of disability may help to define preventive strategies and slow this progression.

Previous research has shown that unhealthy behaviours (physical inactivity, poor diet, smoking, alcohol abstinence or consumption beyond recommended limits) have an adverse effect on health. Increasing evidence shows that some unhealthy

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behaviours tend to cluster in individuals.[5 6] The risk of obesity, diabetes, cancer, poor cognitive function, stroke, sudden cardiac death, and mortality increases with the number of unhealthy behaviours.[7-18] Unhealthy behaviours such as lack of physical activity, poor diet, smoking, alcohol abstinence, and heavy alcohol consumption have also been shown to be associated with an increased risk of disability in older people.[19-28] However, few studies have examined the combined effect of unhealthy behaviours on disability.[21 29 30] Furthermore, pathways involved in the association between unhealthy behaviours and disability are poorly understood.

Our objective was to investigate the relation between unhealthy behaviours, with each behaviour examined separately and in combination, and the hazard of disability over a 12 year follow-up in a cohort of French older people from the Dijon centre of the Three-City (3C) study. To assess the robustness of associations between unhealthy behaviours and disability, we used repeated measures of disability and a statistical method that takes into account interval censoring and competing risks of death. A further objective was to examine the role of potential mediators (body mass index, cognitive function, depressive symptoms, trauma, chronic conditions, and cardiovascular disease and its risk factors) in the association between unhealthy behaviours and disability.

Methods

Study population

The 3C study is a prospective cohort study that recruited community dwelling older people aged 65 years or over from electoral rolls in three French cities (Bordeaux, Dijon, Montpellier) in 1999-2001.[31] The first six years of follow-up were common to the three study centres; subsequently, each centre had specific aims. The study reported here is based on data from Dijon (n=4931; response rate 35%), where investigators were particularly interested in physical function and disability.

After the baseline examination (wave 0), participants were interviewed in person after two (wave 1, 2001-02), four (wave 2, 2003-04), seven (wave 4, 2006-07), nine (wave 5, 2008-09), and 11 years (wave 6, 2010-12); wave 3 (2005-06) consisted of a self administered questionnaire that did not include disability measures. During the follow-up, every effort was made to contact participants directly or through their relatives and physicians. Over the follow-up, an increasing proportion of participants were seen at their residence (including institutions) rather than at the study centre.

Disability

Disability status was assessed six times over 12 years, at baseline and waves 1, 2, 4, 5, and 6. Three domains of disability were assessed (see supplementary methods): mobility, instrumental activities of daily living, and basic activities of daily living. Mobility was assessed with the French translation of the Rosow and Breslau scale, which evaluates the ability to do heavy work around the house, walk half a mile, and climb stairs.[32] The French version of the Lawton-Brody instrumental activities of daily living scale evaluates the ability to use a telephone, manage drugs and money, use public or private transport, and do shopping and, additionally for women, to prepare meals and do housework and laundry.[33] Basic activities of daily living were assessed through the French version of the Katz scale that evaluates whether participants need help with bathing, dressing, toileting, transferring from bed to chair, and eating; we excluded incontinence as it reflects organ impairment rather than functional limitation.[34] For each disability domain, we considered participants to be disabled if they could not perform at least one activity without a given level of help, as defined by the respective instrument.

We constructed a hierarchical disability indicator,[35] which defines four levels of increasing disability by summing up responses to the three dichotomised disability items in a hierarchy (0=fully independent; 1=dependent only in relation to the Rosow scale; 2=dependent on the Rosow and instrumental activities of daily living scales but not the basic activities of daily living scale; 3=dependent in all domains). This approach has the advantage of taking three disability domains into account simultaneously; this indicator has a reproducibility coefficient of 0.99 and a scalability coefficient of 0.98.[35 36] Few people were disabled in the three domains, and we compared people in groups 2/3 (moderate/severe) with those in groups 0/1 (no/light disability).

Unhealthy behaviours

Data on health behaviours came from the baseline questionnaire. We categorised behaviours as healthy/unhealthy a priori on the basis of previous findings; we did sensitivity analyses to ensure that findings were robust to categorisations used in the analysis.

Physical activity was assessed through questions on frequency of daily walking and exercise (for example, gym, swimming, cycling) and categorised as high (walking more than one hour a day and exercising more than once a week), low (walking less than one hour a day and exercising less than once a week), and intermediate (all others). We considered low or intermediate physical activity levels to be unhealthy behaviours.

Consumption of fruit and vegetables was assessed through questions on frequency of consumption of raw and cooked fruit and vegetables. Responses were on a six point scale (“never” to “at least once a day”). We classified participants as consuming fruit or vegetables at least once a day, four to six times a week, and less than four times a week. We considered eating fruit or vegetables less than once a day to be an unhealthy behaviour in the analysis.

Smoking status was assessed through questions on cigarettes smoked during different periods of adult life and age at which participants started or quit smoking. Using these data, we categorised smoking status as never smoker, long term ex-smoker (quit smoking at least 15 years before baseline), short term ex-smoker (quit smoking less than 15 years before baseline), and current smoker. The 15 year cut-off allows a distinction to be made between people who stopped smoking in midlife and those who stopped smoking later in life, close to the baseline examination, when smoking cessation is more likely to be due to health problems.[15 29] We considered current smoking and short term ex-smoking to be unhealthy behaviours.

Consumption of alcohol was assessed by questions on weekly number of alcoholic drinks. We categorised alcohol consumption as never drinker, former drinker, light to moderate drinker (1-21 alcoholic drinks a week for men and 1-14 for women),[37] and heavy drinker. Other studies among older adults have also used this definition.[12 16 38] We considered alcohol drinking other than light to moderate to be an unhealthy behaviour.

Covariates

Baseline sociodemographic measures considered to be potential confounders included age, sex, education (no education/primary school, secondary school, high school/university), and marital status (married, divorced/separated/widowed, single).

On the basis of previous literature, we identified characteristics that may mediate the relation between unhealthy behaviours and disability. Cardiovascular disease, stroke, diabetes, cognitive and visual impairment, dyspnoea, and depression have been associated with the hierarchical indicator of disability.[36] Depressive symptoms, falls, and hearing/visual impairment have been associated with greater risk of incident disability in basic activities of daily living in women.[39] Finally, high body mass index, osteoarthritis, hip fracture, and cancer are also associated with an increased risk of disability.[40-43] These covariates were assessed at baseline and each wave of data collection.

Body mass index was calculated as weight divided by height squared and categorised as less than 25 (normal weight), 25 to less than 30 (overweight), and 30 or above (obese). Cognitive function was assessed through a global test (mini-mental state examination), with higher scores corresponding to better function; we categorised the scores in thirds. Depressive symptoms were measured by the Centre for Epidemiologic Studies depression scale; scores of 16 and above correspond to high depressive symptoms.[44] Trauma included a history of bone fracture or recurrent falls (at least two falls) in the previous two years. Chronic conditions included self reported diabetes, Parkinson's disease, vision difficulties (difficulty in recognising familiar faces at a distance of 4 m or less, with or without glasses), deafness, dyspnoea (New York Heart Association classification), non-steroidal anti-inflammatory drug use for joint pain, and cancer. Cardiovascular disease and its risk factors included stroke, coronary heart disease, lower limb arteritis, hypertension (systolic blood pressure ≥140 mm Hg, diastolic blood pressure ≥90 mm Hg, or antihypertensive drugs), and lipid lowering drugs as a surrogate for hypercholesterolaemia. Incident stroke and coronary heart disease events were validated by expert committees set up by the study to classify these events by using hospital and medical records.[45]

Statistical analysis

We described participants' characteristics as a function of disability status at the end of the follow-up and the number of unhealthy behaviours at baseline. Disability was assessed at each wave, but the precise date of onset was unknown. In addition, participants could have become disabled between two visits and died before the next visit without having been seen and identified as being disabled. To take into account the interval censored nature of our data and competing risks of death, we used a multistate model with transitions between three states (disease-free, disabled, dead) and a Weibull distribution for the hazards. This approach takes interval censoring into account and allows those who die between two waves of data collection to become disabled before dying.[46] All participants who developed disability over the follow-up were interval censored between the wave when disability was ascertained and the previous wave. Participants who remained alive without disability over the follow-up were right censored at the last wave. We used age as the timescale, with entry time defined as the participant's age at baseline. Models were adjusted for confounders (sex, education, marital status) and the interaction between sex and marital status, because preliminary analyses showed that the association between marital status and disability was modified by sex.

We estimated the hazard of disability over the follow-up associated with baseline unhealthy behaviours, for each behaviour on its own and in combination. We firstly did analyses for the dichotomised hierarchical indicator of disability and then repeated them for each domain separately; because few participants were disabled in basic activities of daily living, we combined those disabled in basic activities of daily living or instrumental activities of daily living.[23] People disabled for the corresponding domain at baseline were excluded from the analyses.

We first built separate models for each unhealthy behaviour (model 1). To assess their independent effects, we then included all unhealthy behaviours in a single multivariable model, either as categorical (model 2) or binary variables (unhealthy/healthy) (model 3). Finally, we examined the relation between disability and an unhealthy behaviours score (hazard ratio per unit increase in the unhealthy behaviours score), constructed as the number of unhealthy behaviours independently associated with disability in model 3 (low/intermediate physical activity; consumption of fruit and vegetables less than once a day; current smoking and short term ex-smoking) and ranging from zero to three.[9 12-15]

Interactions between unhealthy behaviours and sex were not statistically significant; our primary analyses are therefore reported for men and women combined, with adjustment for sex. In supplementary tables, we show analyses stratified by sex because the hazard of disability was higher in women and behaviours varied as a function of sex.

We ran several sensitivity analyses. We examined alternative definitions of unhealthy behaviours to assess the pertinence of the a priori definitions used. Disability is a progressive process, and declining function preceding onset of disability may influence health behaviours at baseline, particularly for disability occurring shortly after the baseline examination (reverse causation); to assess this potential bias, we excluded participants with incident disability at waves 1 or 2 (that is, those who developed disability during the first four years of the follow-up). Our main analyses do not take into account the possibility that some participants may recover from disability; we therefore excluded these cases and repeated the analysis. Time to event analyses require a binary outcome; to take into account the ordinal nature of the disability indicator, we used multinomial logistic regression at each wave, with the hierarchical score as the dependent variable.

We examined the extent to which the association between unhealthy behaviours and disability was explained by mediators (body mass index, cognitive function, depressive symptoms, trauma, chronic conditions, cardiovascular disease and risk factors) by estimating the percentage reduction as $100\times(\beta_{model\ 1}-\beta_{model\ i})/\beta_{model\ 1}$, where β is a regression coefficient from a survival model including time dependent covariates.

We did analyses with SAS 9.3 and the R (2.14) SmoothHazard package. P values are two sided, and we considered those of 0.05 or below to be statistically significant.

Results

At baseline, 488 (9.9%) of 4931 participants were disabled and excluded from the analyses; a further 195 participants dropped out of the study before wave 1 and did not die during the follow-up. These participants were less physically active (17.7% *v* 24.7% in the high category; P=0.05) and less likely to consume alcohol lightly to moderately (49.5% *v* 63.7%; P<0.001) than were those who remained in the study; no major differences existed in age, sex, diet, smoking, and number of unhealthy behaviours (all P>0.05). Moreover, 266 participants had missing data on at least one health behaviour (n=254) or the outcome (n=12). Our analyses are therefore based on 3982 participants (2410 (60.5%) women) (supplementary figure A). Compared with participants included in the analyses, those excluded (n=461) were older (75.1 *v* 73.9 years; P<0.001), more likely to consume fruit and vegetables less than once a day (72.1% *v* 66.9%; age adjusted P=0.02), and less likely to drink alcohol lightly to moderately (56.3% *v* 63.7%; age adjusted P=0.01). No differences existed for sex, physical activity, smoking, and number of unhealthy behaviours (all age adjusted P>0.05).

During a total follow-up of 12 years (mean 6.8 (SD 3.4) years), 3982 participants contributed 27 141 person years and 1236 (861 (69.7%) women) developed disability (incidence 45.5/1000 person years). Incidence of disability increased from 3.4/1000 in participants aged 65-70 years to 288.0/1000 in those over 90 years. During the follow-up, 992 participants died, of whom 702 were not disabled at their last examination before death. Among participants who remained disability-free and alive, 937 were last seen at wave 6, 296 at wave 5, 293 at wave 4, 361 at wave 2, and 155 at wave 1; no differences existed for diet (age adjusted P=0.37), smoking (age adjusted P=0.90), and alcohol consumption (age adjusted P=0.70) between participants seen at wave 6 and those censored before; participants censored before wave 6 tended to be older (73.1 *v* 70.9 years; P<0.001) and less physically active (24.5% *v* 37.4% in the high category; age adjusted P<0.001).

Table 1⇓ shows participants' characteristics overall and by disability status. Participants who developed disability were older and less likely to be men, less likely to be married, and less educated than were participants without disability. They were also less physically active, consumed fewer fruits and vegetables, and had a higher number of unhealthy behaviours and a worse health profile. Overall, those who became disabled were less often ever-smokers, but this pattern resulted from confounding by sex and age. Unhealthy behaviours clustered in individuals; those with one unhealthy behaviour were more likely to also have other unhealthy behaviours (odds ratios ranging from 1.2 to 1.5). Approximately 26% of participants had one unhealthy behaviour, 42% had two, 23% had three, 3% had four, and 6% had none. Unhealthy behaviours were more frequent in older participants and in men. In age and sex adjusted analyses, lower education and being married were associated with a greater number of unhealthy behaviours (supplementary table A).

Table 2⇓ shows that in separate models for each unhealthy behaviour (model 1), participants reporting low or intermediate physical activity had a 1.76 (95% confidence interval 1.51 to 2.05)-fold higher hazard of disability. Participants who consumed fruit and vegetables less than once a day had a 1.29 (1.14 to 1.45)-fold increased hazard of disability. Current smokers and short term ex-smokers had a 1.29 (1.09 to 1.54)-fold increased hazard of disability compared with never smokers and long term ex-smokers. Only former drinkers had a higher hazard of disability (hazard ratio 1.49, 1.05 to 2.12) compared with light to moderate drinkers. Model 2 included all four unhealthy behaviours simultaneously as categorical variables; hazard ratios were similar to those in model 1. Model 3 corresponds to similar analyses with behaviours simplified as dichotomous variables, showing that smoking, low/intermediate physical activity, and poor diet remained associated with disability.

Supplementary table B shows analyses for mobility and disability in activities of daily living (basic or instrumental). Low/intermediate physical activity and low consumption of fruit and vegetables were associated with impairment of mobility; we found no association for smoking and alcohol. Low/intermediate physical activity, low consumption of fruit and vegetables, and smoking were associated with disability in basic or instrumental activities of daily living, whereas alcohol was not.

Although the interactions between sex and unhealthy behaviours were not statistically significant (all P>0.30), stratified analyses showed some sex differences (supplementary table C). The association of physical activity with disability was of a similar magnitude in both sexes, and hazard ratios were higher in men than in women for consumption of fruit and vegetables and number of unhealthy behaviours. We found no association with smoking in women; in men, short term ex-smokers had an increased hazard of disability compared with never smokers. For alcohol, we found no association in men; in women, former drinkers had an increased hazard of disability compared with light to moderate drinkers.

The hazard of disability increased with the number of unhealthy behaviours (figure⇓). The hazard ratio per unit increase in the unhealthy behaviour score was 1.39 (1.29 to 1.51) for the hierarchical indicator, 1.24 (1.16 to 1.33) for mobility impairment, and 1.31 (1.22 to 1.40) for disability in basic or instrumental activities of daily living. For the hierarchical indicator, participants with three unhealthy behaviours had a 2.53 (1.86 to 3.43)-fold increased hazard of disability. This association seemed stronger in men (hazard ratio 3.23, 1.88 to 5.54) than in women (1.94, 1.28 to 2.95) (P for difference=0.60) (supplementary table C). Hazard ratios for disability in basic or instrumental activities of daily living (2.11, 1.60 to 2.78, overall; 2.40, 1.52 to 3.80, in men; 1.70, 1.14 to 2.54, in women) and mobility impairment (1.91, 1.50 to 2.44, overall; 2.05, 1.43 to 2.96, in men; 1.92, 1.33 to 2.79, in women) were lower. In sensitivity analyses, we added alcohol consumption to the score; hazard ratios increased with the number of unhealthy behaviours but were smaller than hazard ratios based on the original score (supplementary figure B).

We examined alternative definitions of unhealthy behaviours. For physical activity, a small number of people (n=212) who did not walk but exercised regularly did not have an increased hazard of disability. However, grouping them with those who walked and exercised instead of in the unhealthy category had a small effect (hazard ratio 1.85, 1.61 to 2.12) (supplementary table D). Including this definition in the score of unhealthy behaviours also had little effect (supplementary table E). Using different lag times to distinguish short term and long term ex-smokers had little influence on the association between current smoking/short term ex-smoking and disability (supplementary table F) and minimal influence on the association between the score of unhealthy behaviours and disability (data not shown). For alcohol, we excluded first heavy drinkers and then abstainers from the analyses to assess the suitability of grouping them together and found similar results (supplementary table G); using alternative thresholds to define light to moderate drinkers (for example, 1-11 drinks a week; 1-11 drinks a week in men and 1-7 in women) yielded similar conclusions (data not shown).

In further sensitivity analyses, we excluded 346 participants (28% of those who developed disability) who developed disability during the first four years of follow-up; these analyses were based on 2584 participants, of whom 890 developed disability (table 3⇓). Hazard ratios were similar for physical activity and strengthened for consumption of fruit and vegetables and for smoking compared with original analyses. Conclusions for alcohol consumption were unchanged.

During the follow-up, 297 participants (24% of those who developed disability) recovered from disability; 243 of them remained disability-free throughout the follow-up. Analyses excluding these participants yielded similar results to those in the main analysis (supplementary table H). Analyses based on multinomial logistic regression showed that odds ratios increased in both rows and columns, leading us to conclude that for a given number of unhealthy behaviours the hazard increased with increasing levels of disability and that for each level of disability the hazard increased with the number of unhealthy behaviours (supplementary table I).

Table 4⇓ shows the role played by potential mediators in the association between the number of unhealthy behaviours and disability. For the score of unhealthy behaviours, 30.5% of the association was explained by the mediators included in the model. The highest percentage reductions were for chronic conditions (11.5%), followed by depressive symptoms (9.0%), trauma (7.1%), and body mass index (5.6%).

Discussion

In analyses based on a large cohort of French community dwelling older adults, three modifiable unhealthy behaviours—physical inactivity, poor diet, and smoking—were independently associated with an increased hazard of disability over a 12 year follow-up. The hazard of disability increased progressively with the number of unhealthy behaviours. Compared with people without unhealthy behaviours, those with three unhealthy behaviours had a 2.5-fold increased hazard of disability. Among several potential mediators, chronic conditions, and, to a lesser extent, depressive symptoms, trauma, and body mass index partially explained this association.

What this study adds

Previous research has shown an increased risk of disability in physically inactive people,[19-22] those with an unhealthy diet,[23-25] current smokers,[19 21 26 27] alcohol abstainers,[19 21 22 28] and heavy alcohol drinkers.[21] However, not all studies took into account multiple behaviours simultaneously. Thus, confounding cannot be ruled out as a potential explanation because unhealthy behaviours are known to cluster.[5 6] For instance, one study showed that the inverse association between moderate alcohol consumption and incident limitation of mobility was considerably attenuated after adjustment for education, income, body mass index, and other lifestyle variables such as smoking and physical activity.[28] In our study, physical inactivity, low consumption of fruit and vegetables, and smoking were associated with disability and remained associated in models in which all unhealthy behaviours were included simultaneously. Our results thus suggest independent associations for three of the four behaviours considered.

Moreover, apart from notable exceptions, most studies have examined health behaviours separately and not their combined effect. One study examined the combined effect of smoking, alcohol consumption, physical activity, and sleep on the risk of walking and bathing disability in people aged 60 years and over in Taiwan.[21] Not smoking, moderate alcohol consumption, regular exercise, and sleeping six to eight hours a day were inversely and independently associated with the risk of disability. Another study examined the association of smoking, alcohol intake, physical activity, and diet with impairment of mobility in obese and non-obese people aged 70-79 years in the United States.[29] Current and former smoking, former alcohol intake, low physical activity, and an unhealthy diet were risk factors for incident limitation of mobility in non-obese older people, whereas in obese people the association was evident only for low physical activity. In agreement with our findings, both studies showed that behaviours had cumulative effects and that the risk of disability increased progressively with the number of unhealthy behaviours. A third study also showed, in both men and women, a combined effect of smoking, body mass index, and physical activity on the risk of disability in basic activities of daily living.[30]

Disability is a progressive process, and declining function is likely to influence health behaviours and therefore contribute to some of the observed associations between unhealthy behaviours and disability (reverse causation), particularly for physical activity and diet. An important contribution of our study was to examine the association between unhealthy behaviours at study inception and incident disability after exclusion of the participants who developed disability in the first four years of follow-up (about 30% of all incident cases). The results of these analyses, discussed below for each of the behaviours, yielded findings largely consistent with our main analyses, thus ruling out reverse causation as an explanation of our findings. Only one previous study, based on a total of 6.5 years of follow-up, considered reverse causation by excluding participants who developed disability in the first two years.[29] Our study, which had a longer follow-up and allowed us to exclude participants who developed disability in the first four years, provides more convincing evidence that the association between unhealthy behaviours and disability does not result from reverse causation.

Our findings are in line with studies on mortality,[12-15 17 18] chronic diseases,[8] or cognition,[9] showing unhealthy behaviours to have cumulative effects. These findings have important public health implications, as these behaviours are potentially modifiable, and interventions aimed at promoting a healthy lifestyle may help to prevent the onset of disability. In addition, our findings suggest that interventions targeting multiple behaviours may carry greater benefit than simpler interventions.

Possible explanations

In our study, low or intermediate physical activity was strongly associated with disability. This association may partly reflect the fact that declining function preceding disability could affect physical activity (reverse causation); excluding participants disabled at baseline may not be sufficient to remove this effect. In analyses excluding the first years of follow-up, the association of physical activity with disability was very similar, suggesting that reverse causation does not fully account for this association. Regarding diet, previous analyses based on the Bordeaux-3C study showed that adherence to a Mediterranean-type diet was associated with the risk of disability in basic or instrumental activities of daily living in women but not in men, although reasons for this difference were unclear.[23] In our study, consumption of fruit and vegetables was associated with disability in both sexes, even in analyses excluding the first years of follow-up. Regarding smoking, participants who quit smoking more than 15 years before study inception did not have an increased hazard of disability compared with never smokers, whereas more recent ex-smokers and current smokers had an increased hazard of disability that persisted in analyses excluding the first years of follow-up.

Our results for alcohol consumption were less robust. Former drinkers represented a small proportion of the sample (2.2%) and had a 50% greater hazard of disability; this association was no longer statistically significant after adjustment for other behaviours. In older populations, it has been suggested that poor health increases the likelihood of not drinking alcohol. However, in our analysis this association remained present and strengthened in analyses excluding the first years of follow-up, suggesting that it was not fully explained by former drinkers developing disability soon after baseline. Abstainers and heavy drinkers did not have an increased hazard of disability.

Participants reporting heavy drinking at baseline probably represent a selected group who survived until at least 65 years despite heavy drinking.

The most important contributors to the association between unhealthy behaviours and disability were chronic conditions (especially dyspnoea), depressive symptoms, trauma, and higher body mass index. Dyspnoea is a hallmark of heart failure, which is a major cause of disability in older people. Body mass index is an important risk factor for disability,[19 29 47 48] and the prevalence of obesity increases with the number of unhealthy behaviours.[7] A previous study also showed that body mass index partially explained the association between alcohol consumption and impairment of mobility.[28] Cognitive function and cardiovascular disease and its risk factors made modest contributions to the association in our study. For some of these covariates (such as hypertension), results can be explained by a lack of strong associations with health behaviours. Although we considered these covariates measured over the follow-up to mediate the association between unhealthy behaviours measured at baseline and disability, some of the mediators may have a bidirectional association with behaviours over the follow-up.

Strengths and weaknesses of study

Our findings need to be considered in the light of some limitations. Firstly, disability was self reported, even though the validity of this measure has been well established with respect to objective measures of physical and cognitive function.[49-51] Secondly, the main analyses did not take into account the possibility that some people recover from disability. However, analyses excluding these people did not change our results. Thirdly, time to event analyses do not allow categorical outcomes, leading us to dichotomise the hierarchical indicator of disability; analyses based on multinomial logistic regression showed that risk increased with increasing levels of disability and with the number of unhealthy behaviours. Fourthly, health behaviours were assessed at baseline and we were not able to take into account changes before baseline or over the follow-up. Owing to the potential for reverse causation, time dependent health behaviours may in fact lead to overestimate some of the associations. In addition, health behaviours are relatively stable over time in older people, except in those with serious illness or just before death.[52 53] Fifthly, health behaviours were assessed using relatively simple questions and a risk of some misclassification exists; this, however, would bias the examined associations towards the null. We defined behaviours a priori, on the basis of previous studies; sensitivity analyses that assessed alternative definitions yielded results largely consistent with our main findings. Sixthly, participants excluded from the analyses were older at baseline but not significantly different from other participants except for alcohol consumption and fruit and vegetable intake. Although we probably underestimated the absolute risk of disability, this would be unlikely to bias the estimate of the association between unhealthy behaviours and disability. Seventhly, we have probably underestimated the role of some mediators, particularly stroke, because participants with severe stroke during the follow-up may have dropped out of the study. Finally, at baseline, participants were community dwelling, well functioning older adults and therefore in better health than people who did not participate. Although this may lead to underestimation of the incidence of disability, provided that follow-up is adequate, the association between baseline exposures and the incidence of an outcome is unlikely to be biased.[54] Selection bias may, however, have an effect on estimation of the role of mediators by biasing their baseline association with unhealthy behaviours[55]; our use of time dependent covariates attenuates this concern.

This study's main strengths include its large size and length of follow-up with regular assessments of disability. The main outcome is a hierarchical indicator of disability that combines information from three disability scales ordered in a hierarchy that better describes the evolution of disability.[35] In addition, we used a statistical method that takes interval censoring and competing risk of death into account. Finally, associations between unhealthy behaviours and disability remained present after exclusion of the first years of follow-up, suggesting that the associations of disability with low physical activity and poor diet were not explained by disability occurring close to the assessments of these behaviours. For people who quit smoking recently (defined as stopping smoking in the 15 years before the baseline examination), the observed hazard of disability also suggests that reverse causation did not contribute to the association between smoking and disability.

Conclusion

This cohort study among French older adults suggests that an unhealthy lifestyle, characterised by physical inactivity, an unhealthy diet, and smoking, is associated with greater hazard of disability, which increased progressively with the number of unhealthy behaviours. Health behaviours are potentially modifiable, and our findings may be useful for policy makers regarding the potential benefit of multi-behaviour interventions compared with single behaviour interventions.

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What is already known on this topic

Some evidence shows that unhealthy behaviours are associated with an increased risk of disability in older people, but their independent contribution to disability remains unclear

Few studies have examined the combined association of unhealthy behaviours with disability, and reverse causation may have contributed to the association in previous studies

The pathways involved in the association between unhealthy behaviours and disability are poorly understood

What this study adds

Low/intermediate physical activity, a diet poor in fruit and vegetables, and smoking, were independently associated with an increased hazard of disability

The hazard of disability increased progressively with the number of unhealthy behaviours; people with three unhealthy behaviours had more than a twofold increased hazard of disability

Similar conclusions were reached in analyses restricted to participants who developed disability more than four years after the assessment of behaviours, ruling out reverse causation as a major explanation

Chronic conditions, and to a lesser extent depressive symptoms, trauma, and body mass index, partially explained this association

no other non-financial interests that may be relevant to the submitted work.

Ethical approval: The study protocol was approved by the ethical committee of the Kremlin-Bicêtre University-Hospital (France), and all participants gave written informed consent.

Data sharing: No additional data available.

1 Fried LP, Ferrucci L, Darer J, Williamson JD, Anderson G. Untangling the concepts of disability, frailty, and comorbidity: implications for improved targeting and care. *J Gerontol A Biol Sci Med Sci* 2004;59:255-63.
2 Peres K, Helmer C, Letenneur L, Jacqmin-Gadda H, Barberger-Gateau P. Ten-year change in disability prevalence and related factors in two generations of French elderly community dwellers: data from the PAQUID study. *Aging Clin Exp Res* 2005;17:229-35.
3 Donald IP, Foy C, Jagger C. Trends in disability prevalence over 10 years in older people living in Gloucestershire. *Age Ageing* 2010;39:337-42.
4 Duée M, Rebillard C. La dépendance des personnes âgées: une projection en 2040. *Données sociales—La société française* 2006;édition 2006:613-9.
5 Poortinga W. The prevalence and clustering of four major lifestyle risk factors in an English adult population. *Prev Med* 2007;44:124-8.
6 Pronk NP, Anderson LH, Crain AL, Martinson BC, O'Connor PJ, Sherwood NE, et al. Meeting recommendations for multiple healthy lifestyle factors: prevalence, clustering, and predictors among adolescent, adult, and senior health plan members. *Am J Prev Med* 2004;27(2 suppl):25-33.
7 Harrington J, Perry IJ, Lutomski J, Fitzgerald AP, Shiely F, McGee H, et al. Living longer and feeling better: healthy lifestyle, self-rated health, obesity and depression in Ireland. *Eur J Public Health* 2010;20:91-5.
8 Ford ES, Bergmann MM, Kroger J, Schienkiewitz A, Weikert C, Boeing H. Healthy living is the best revenge: findings from the European Prospective Investigation Into Cancer and Nutrition-Potsdam study. *Arch Intern Med* 2009;169:1355-62.
9 Sabia S, Nabi H, Kivimaki M, Shipley MJ, Marmot MG, Singh-Manoux A. Health behaviors from early to late midlife as predictors of cognitive function: the Whitehall II study. *Am J Epidemiol* 2009;170:428-37.
10 Chiuve SE, Rexrode KM, Spiegelman D, Logroscino G, Manson JE, Rimm EB. Primary prevention of stroke by healthy lifestyle. *Circulation* 2008;118:947-954.
11 Chiuve SE, Fung TT, Rexrode KM, Spiegelman D, Manson JE, Stampfer MJ, et al. Adherence to a low-risk, healthy lifestyle and risk of sudden cardiac death among women. *JAMA* 2011;306:62-9.
12 Hamer M, Bates CJ, Mishra GD. Multiple health behaviors and mortality risk in older adults. *J Am Geriatr Soc* 2011;59:370-2.
13 Khaw KT, Wareham N, Bingham S, Welch A, Luben R, Day N. Combined impact of health behaviours and mortality in men and women: the EPIC-Norfolk prospective population study. *PLoS Med* 2008;5:e12.
14 Kvaavik E, Batty GD, Ursin G, Huxley R, Gale CR. Influence of individual and combined health behaviors on total and cause-specific mortality in men and women: the United Kingdom health and lifestyle survey. *Arch Intern Med* 2010;170:711-8.
15 Knoops KT, de Groot LC, Kromhout D, Perrin AE, Moreiras-Varela O, Menotti A, et al. Mediterranean diet, lifestyle factors, and 10-year mortality in elderly European men and women: the HALE project. *JAMA* 2004;292:1433-9.
16 Loef M, Walach H. The combined effects of healthy lifestyle behaviors on all cause mortality: a systematic review and meta-analysis. *Prev Med* 2012;55:163-70.
17 Van Dam RM, Li T, Spiegelman D, Franco OH, Hu FB. Combined impact of lifestyle factors on mortality: prospective cohort study in US women. *BMJ* 2008;337:a1440.
18 Van den Brandt PA. The impact of a Mediterranean diet and healthy lifestyle on premature mortality in men and women. *Am J Clin Nutr* 2011;94:913-20.
19 LaCroix AZ, Guralnik JM, Berkman LF, Wallace RB, Satterfield S. Maintaining mobility in late life: II. Smoking, alcohol consumption, physical activity, and body mass index. *Am J Epidemiol* 1993;137:858-69.
20 Landi F, Russo A, Barillaro C, Cesari M, Pahor M, Danese P, et al. Physical activity and risk of cognitive impairment among older persons living in the community. *Aging Clin Exp Res* 2007;19:410-6.
21 Liao WC, Li CR, Lin YC, Wang CC, Chen YJ, Yen CH, et al. Healthy behaviors and onset of functional disability in older adults: results of a national longitudinal study. *J Am Geriatr Soc* 2011;59:200-6.
22 Wang L, van Belle G., Kukull WB, Larson EB. Predictors of functional change: a longitudinal study of nondemented people aged 65 and older. *J Am Geriatr Soc* 2002;50:1525-34.
23 Feart C, Peres K, Samieri C, Letenneur L, Dartigues JF, Barberger-Gateau P. Adherence to a Mediterranean diet and onset of disability in older persons. *Eur J Epidemiol* 2011;26:747-56.
24 Houston DK, Stevens J, Cai J, Haines PS. Dairy, fruit, and vegetable intakes and functional limitations and disability in a biracial cohort: the Atherosclerosis Risk in Communities Study. *Am J Clin Nutr* 2005;81:515-22.
25 Vercambre MN, Boutron-Ruault MC, Ritchie K, Clavel-Chapelon F, Berr C. Long-term association of food and nutrient intakes with cognitive and functional decline: a 13-year follow-up study of elderly French women. *Br J Nutr* 2009;102:419-27.
26 Chakravarty EF, Hubert HB, Krishnan E, Bruce BB, Lingala VB, Fries JF. Lifestyle risk factors predict disability and death in healthy aging adults. *Am J Med* 2012;125:190-7.
27 Tsubota-Utsugi M, Ito-Sato R, Ohkubo T, Kikuya M, Asayama K, Metoki H, et al. Health behaviors as predictors for declines in higher-level functional capacity in older adults: the Ohasama study. *J Am Geriatr Soc* 2011;59:1993-2000.
28 Maraldi C, Harris TB, Newman AB, Kritchevsky SB, Pahor M, Koster A, et al. Moderate alcohol intake and risk of functional decline: the Health, Aging, and Body Composition study. *J Am Geriatr Soc* 2009;57:1767-75.
29 Koster A, Penninx BW, Newman AB, Visser M, van Gool CH, Harris TB, et al. Lifestyle factors and incident mobility limitation in obese and non-obese older adults. *Obesity (Silver Spring)* 2007;15:3122-32.
30 Vita AJ, Terry RB, Hubert HB, Fries JF. Aging, health risks, and cumulative disability. *N Engl J Med* 1998;338:1035-41.
31 3C Study Group. Vascular factors and risk of dementia: design of the Three-City Study and baseline characteristics of the study population. *Neuroepidemiology* 2003;22:316-25.
32 Rosow I, Breslau N. A Guttman health scale for the aged. *J Gerontol* 1966;21:556-9.
33 Lawton MP, Brody EM. Assessment of older people: self-maintaining and instrumental activities of daily living. *Gerontologist* 1969;9:179-86.
34 Katz S, Ford AB, Moskowitz RW, Jackson BA, Jaffe MW. Studies of illness in the aged: the index of ADL: a standardized measure of biological and psychological function. *JAMA* 1963;185:914-9.
35 Barberger-Gateau P, Rainville C, Letenneur L, Dartigues JF. A hierarchical model of domains of disablement in the elderly: a longitudinal approach. *Disabil Rehabil* 2000;22:308-17.
36 Peres K, Verret C, Alioum A, Barberger-Gateau P. The disablement process: factors associated with progression of disability and recovery in French elderly people. *Disabil Rehabil* 2005;27:263-76.
37 Andrews G, Jenkins R. Management of mental disorders (UK edition). World Health Organization Collaborating Centre for Mental Health and Substance Abuse, 1999.
38 Sabia S, Singh-Manoux A, Hagger-Johnson G, Cambois E, Brunner EJ, Kivimaki M. Influence of individual and combined healthy behaviours on successful aging. *CMAJ* 2012;184:1985-92.
39 Rosso AL, Eaton CB, Wallace R, Gold R, Stefanick ML, Ockene JK, et al. Geriatric syndromes and incident disability in older women: results from the Women's Health Initiative Observational Study. *J Am Geriatr Soc* 2013;61:371-9.
40 Wong E, Stevenson C, Backholer K, Mannan H, Pasupathi K, Hodge A, et al. Adiposity measures as predictors of long-term physical disability. *Ann Epidemiol* 2012;22:710-6.
41 Ling SM, Xue QL, Simonsick EM, Tian J, Bandeen-Roche K, Fried LP, et al. Transitions to mobility difficulty associated with lower extremity osteoarthritis in high functioning older women: longitudinal data from the Women's Health and Aging Study II. *Arthritis Rheum* 2006;55:256-63.
42 Leibson CL, Tosteson AN, Gabriel SE, Ransom JE, Melton LJ. Mortality, disability, and nursing home use for persons with and without hip fracture: a population-based study. *J Am Geriatr Soc* 2002;50:1644-50.
43 Hewitt M, Rowland JH, Yancik R. Cancer survivors in the United States: age, health, and disability. *J Gerontol A Biol Sci Med Sci* 2003;58:82-91.
44 Fuhrer R, Rouillon F. La version française de l'échelle CES-D (Center for Epidemiologic Studies—depression scale): description et traduction de l'échelle d'autoévaluation. *Psychiatrie et psychobiologie* 1989;4:163-6.
45 Blachier M, Dauvilliers Y, Jaussent I, Helmer C, Ritchie K, Jouven X, et al. Excessive daytime sleepiness and vascular events: the Three City Study. *Ann Neurol* 2012;71:661-7.
46 Joly P, Commenges D, Helmer C, Letenneur L. A penalized likelihood approach for an illness-death model with interval-censored data: application to age-specific incidence of dementia. *Biostatistics* 2002;3:433-43.
47 Koster A, Patel KV, Visser M, van Eijk JT, Kanaya AM, de Rekeneire N, et al. Joint effects of adiposity and physical activity on incident mobility limitation in older adults. *J Am Geriatr Soc* 2008;56:636-43.
48 Larrieu S, Peres K, Letenneur L, Berr C, Dartigues JF, Ritchie K, et al. Relationship between body mass index and different domains of disability in older persons: the 3C study. *Int J Obes Relat Metab Disord* 2004;28:1555-60.
49 Fried LP, Young Y, Rubin G, Bandeen-Roche K. Self-reported preclinical disability identifies older women with early declines in performance and early disease. *J Clin Epidemiol* 2001;54:889-901.
50 Young Y, Boyd CM, Guralnik JM, Fried LP. Does self-reported function correspond to objective measures of functional impairment? *J Am Med Dir Assoc* 2010;11:645-53.

51 Barberger-Gateau P, Fabrigoule C, Amieva H, Helmer C, Dartigues JF. The disablement process: a conceptual framework for dementia-associated disability. *Dement Geriatr Cogn Disord* 2002;13:60-6.
52 Buck B, Frosini F. Clustering of unhealthy behaviours over time: implications for policy and practice. King's Fund, 2012 (available at www.kingsfund.org.uk/publications/unhealthy_behaviours.html).
53 Glynn RJ, Bouchard GR, LoCastro JS, Laird NM. Aging and generational effects on drinking behaviors in men: results from the normative aging study. *Am J Public Health* 1985;75:1413-9.
54 Criqui MH. Response bias and risk ratios in epidemiologic studies. *Am J Epidemiol* 1979;109:394-9.
55 Morimoto LM, White E, Newcomb PA. Selection bias in the assessment of gene-environment interaction in case-control studies. *Am J Epidemiol* 2003;158:259-63.

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Tables

Table 1| **Characteristics of participants at baseline—overall and according to disability status at end of follow-up. Values are numbers (percentages) unless stated otherwise**

Characteristic	Overall	Not disabled	Disabled*	P value†	P value† (age and sex adjusted)
Baseline covariates					
No (%)	3982	2746 (69.0)	1236 (31.0)	—	—
Mean (SD) age	73.9 (5.2)	73.0 (4.8)	75.7 (5.5)	<0.001	<0.001
Male sex	1572 (39.5)	1197 (43.6)	375 (30.3)	<0.001	<0.001
Marital status:				<0.001	0.002
Married	2358 (59.2)	1664 (60.6)	694 (56.1)		
Divorced, separated, or widowed	1294 (32.5)	840 (30.6)	454 (36.7)		
Single	330 (8.3)	242 (8.8)	88 (7.1)		
Education:				0.004	0.02
No education or primary school	1368 (34.4)	899 (32.7)	469 (37.9)		
Secondary school	1277 (32.1)	900 (32.8)	377 (30.5)		
High school or university	1337 (33.6)	947 (34.5)	390 (31.6)		
Physical activity‡:				<0.001	<0.001
High	981 (24.6)	773 (28.2)	208 (16.8)		
Intermediate	2036 (51.1)	1406 (51.2)	630 (51.0)		
Low	965 (24.2)	567 (20.6)	398 (32.2)		
Consumption of fruit and vegetables:				0.14	0.03
At least once a day	1317 (33.1)	947 (34.5)	370 (29.9)		
4-6 times a week	1496 (37.6)	988 (36.0)	508 (41.1)		
<4 times a week	1169 (29.4)	811 (29.5)	358 (29.0)		
Smoking:				<0.001	0.12
Never smoker	2428 (61.0)	1601 (58.3)	827 (66.9)		
Long term ex-smoker (quit ≥15 years)	1056 (26.5)	790 (28.8)	266 (21.5)		
Short term ex-smoker (quit <15 years)	284 (7.1)	194 (7.1)	90 (7.3)		
Current smoker	214 (5.4)	161 (5.9)	53 (4.3)		
Alcohol:				0.07	0.39
Never drinker	726 (18.2)	488 (17.8)	238 (19.3)		
Former drinker	87 (2.2)	54 (2.0)	33 (2.7)		
Light to moderate drinker§	2538 (63.7)	1745 (63.5)	793 (64.2)		
Heavy drinker	631 (15.8)	459 (16.7)	172 (13.9)		
No of unhealthy behaviours:				<0.001	<0.001
0	355 (8.9)	279 (10.2)	76 (6.1)		
1	1378 (34.6)	1000 (36.4)	378 (30.6)		
2	1961 (49.2)	1274 (46.4)	687 (55.6)		
3	288 (7.2)	193 (7.0)	95 (7.7)		
Time dependent covariates					
No (%)	3844	2613 (68.0)	1231 (32.0)	—	—
Mean (SD) body mass index¶	25.8 (4.0)	25.6 (3.7)	26.1 (4.3)	<0.001	<0.001
Mean (SD) mini-mental state examination score¶	27.1 (2.0)	27.3 (1.8)	26.8 (2.4)	<0.001	<0.001
Depressive symptoms**	1337 (34.8)	831 (31.8)	506 (41.1)	<0.001	<0.001
Bone fracture**	581 (15.1)	364 (13.9)	217 (17.6)	0.003	0.43
Falls**	1175 (30.6)	725 (27.7)	450 (36.6)	<0.001	0.002

Table 1 (continued)

Characteristic	Overall	Not disabled	Disabled*	P value†	P value† (age and sex adjusted)
Diabetes**	506 (13.2)	335 (12.8)	171 (13.9)	0.36	0.03
Parkinson's disease**	77 (2.0)	34 (1.3)	43 (3.5)	<0.001	<0.001
Vision difficulties**	668 (17.4)	392 (15.0)	276 (22.4)	<0.001	<0.001
Deafness**	803 (20.9)	481 (18.4)	322 (26.2)	<0.001	<0.001
Dyspnoea**	876 (22.8)	469 (17.9)	407 (33.1)	<0.001	<0.001
NSAIDs for joint pain**	907 (23.6)	598 (22.9)	309 (25.1)	0.13	0.70
Cancer**	585 (15.2)	411 (15.7)	174 (14.1)	0.20	0.48
Stroke**	226 (5.9)	129 (4.9)	97 (7.9)	<0.001	<0.001
Coronary heart disease or lower limb arteritis**	697 (18.1)	445 (17.0)	252 (20.5)	0.01	0.002
Hypertension**	3369 (87.6)	2275 (87.1)	1094 (88.9)	0.11	0.46
Hypercholesterolaemia**	1739 (45.2)	1213 (46.4)	526 (42.7)	0.03	0.09

NSAID=non-steroidal anti-inflammatory drug.

*Dependent for Rosow and instrumental activities of daily living scales ± basic activities of daily living scale (dichotomised hierarchical indicator of disability).

†Analysis of covariance for continuous variables and Mantel-Haenszel χ^2 test for categorical variables.

‡High=walking more than one hour a day and exercising more than once a week; low=walking less than one hour a day and exercising less than once a week; intermediate=all others.

§1-21 drinks a week in men; 1-14 drinks a week in women.

¶Mean of all measures taken during follow-up.

**At least one report over follow-up.

Table 2| **Hazard ratio of disability according to physical activity, consumption of fruit and vegetables, smoking, and alcohol drinking**

	Model 1*			Model 2†			Model 3†	
Characteristic	**HR (95% CI)**	**P value**	**P value**	**HR (95% CI)**	**P value**	**P value**	**HR (95% CI)**	**P value**
Physical activity‡:								
High	1.00 (reference)	—		1.00 (reference)	—		—	—
Intermediate	1.58 (1.35 to 1.86)	<0.001		1.53 (1.31 to 1.78)	<0.001		—	—
Low	2.16 (1.82 to 2.56)	<0.001	<0.001¶	2.10 (1.77 to 2.48)	<0.001	<0.001¶	—	—
Low or intermediate *v* high	1.76 (1.51 to 2.05)	<0.001		—	—		1.72 (1.48 to 2.00)	<0.001
Consumption of fruits and vegetables:								
At least once a day	1.00 (reference)	—		1.00 (reference)	—		—	—
4-6 times a week	1.27 (1.11 to 1.45)	<0.001		1.27 (1.11 to 1.45)	0.001		—	—
<4 times a week	1.31 (1.13 to 1.52)	<0.001	<0.001¶	1.25 (1.08 to 1.44)	0.003	0.003¶	—	—
Less than once a day *v* at least once a day	1.29 (1.14 to 1.45)	<0.001		—	—		1.24 (1.10 to 1.41)	0.001
Smoking:								
Never smoker	1.00 (reference)	—		1.00 (reference)	—		—	—
Long term ex-smoker (quit ≥15 years)	1.02 (0.88 to 1.19)	0.78		1.05 (0.90 to 1.24)	0.51		—	—
Short term ex-smoker (quit <15 years)	1.42 (1.14 to 1.76)	0.002		1.44 (1.15 to 1.80)	0.001		—	—
Current smoker	1.13 (0.85 to 1.51)	0.39	0.02	1.14 (0.85 to 1.53)	0.37	0.02	—	—
Current smoker or short term ex-smoker *v* never smoker or long term ex-smoker	1.29 (1.09 to 1.54)	0.004		—	—		1.26 (1.05 to 1.50)	0.01
Alcohol:								
Never drinker	1.05 (0.90 to 1.22)	0.53		1.04 (0.89 to 1.20)	0.64		—	—
Former drinker	1.49 (1.05 to 2.12)	0.03		1.38 (0.96 to 1.97)	0.08		—	—
Light to moderate drinker§	1.00 (reference)	—		1.00 (reference)	—		—	—
Heavy drinker	0.98 (0.83 to 1.16)	0.80	0.18	0.93 (0.79 to 1.10)	0.40	0.26	—	—
Never, former, or heavy drinker *v* light to moderate drinker	1.04 (0.93 to 1.17)	0.49		—	—		1.01 (0.90 to 1.13)	0.84

HR=hazard ratio.

*Adjusted for sex, marital status, their interaction, and education.

†Adjusted for sex, marital status, their interaction, education, and other behaviours.

‡High=walking more than one hour a day and exercising more than once a week; low=walking less than one hour a day and exercising less than once a week; intermediate=all others.

§1-21 drinks a week in men; 1-14 drinks a week in women.

¶P value for trend.

Table 3| **. Hazard ratio of disability according to physical activity, consumption of fruit and vegetables, smoking, alcohol drinking, and number of unhealthy behaviours, excluding first four years of follow-up (n=2584)**

Characteristics	Events (n/N)	Model 1*			Model 2†			Model 3†	
		HR (95% CI)	P value	P value	HR (95% CI)	P value	P value	HR (95% CI)	P value
Physical activity‡:									
High	180/731	1.00 (reference)			1.00 (reference)			—	—
Intermediate	454/1295	1.59 (1.34 to 1.90)	<0.001		1.54 (1.29 to 1.84)	<0.001		—	—
Low	256/558	2.14 (1.77 to 2.60)	<0.001	<0.001¶	2.09 (1.71 to 2.54)	<0.001	<0.001¶	—	—
Low or intermediate *v* high		1.76 (1.49 to 2.08)	<0.001		—	—		1.71 (1.45 to 2.03)	<0.001
Consumption of fruit and vegetables:									
At least once a day	274/883	1.00 (reference)	—		1.00 (reference)	—		—	—
4-6 times a week	374/999	1.33 (1.14 to 1.56)	<0.001		1.31 (1.12 to 1.54)	0.001		—	—
<4 times a week	242/702	1.34 (1.13 to 1.60)	0.001	<0.001¶	1.25 (1.05 to 1.50)	0.01	0.01¶	—	—
Less than once a day *v* at least once a day		1.33 (1.15 to 1.54)	<0.001		—	—		1.27 (1.10 to 1.47)	0.001
Smoking:									
Never smoker	585/1609	1.00 (reference)	—		1.00 (reference)	—		—	—
Long term ex-smoker (quit ≥15 years)	195/657	1.01 (0.85 to 1.19)	0.94		1.03 (0.86 to 1.25)	0.72		—	—
Short term ex-smoker (quit <15 years)	68/184	1.39 (1.08 to 1.79)	0.01		1.39 (1.07 to 1.80)	0.01		—	—
Current smoker	42/134	1.26 (0.91 to 1.73)	0.16	0.06	1.25 (0.90 to 1.74)	0.18	0.08	—	—
Current smoker or short term ex-smoker *v* never smoker or long term ex-smoker		1.34 (1.10 to 1.65)	0.01		—	—		1.31 (1.07 to 1.60)	0.01
Alcohol:									
Never drinker	172/486	1.06 (0.89 to 1.26)	0.51		1.04 (0.87 to 1.23)	0.70		—	—
Former drinker	22/51	1.68 (1.08 to 2.64)	0.02		1.48 (0.96 to 2.29)	0.08		—	—
Light to moderate drinker§	573/1647	1.00 (reference)	—		1.00 (reference)	—		—	—
Heavy drinker	123/400	0.96 (0.78 to 1.17)	0.66	0.15	0.90 (0.74 to 1.11)	0.32	0.23	—	—
Never, former, or heavy drinker *v* light to moderate drinker		1.05 (0.91 to 1.20)	0.53		—	—		1.00 (0.92 to 1.09)	0.97
No of unhealthy behaviours:									
0	68/260	1.00 (reference)			—	—	—	—	—
1	278/949	1.26 (0.97 to 1.65)	0.08		—	—	—	—	—
2	474/1202	1.89 (1.46 to 2.44)	<0.001		—	—	—	—	—
3	70/173	2.68 (1.91 to 3.76)	<0.001	<0.001¶	—	—	—	—	—

HR=hazard ratio.

These analyses included 2584 participants (1602 (62.0%) women), of whom 890 (613 (68.9%) women) developed disability.

*Adjusted for sex, marital status, their interaction, and education.

†Adjusted for sex, marital status, their interaction, education, and other behaviours.

‡High=walking more than one hour a day and exercising more than once a week; low=walking less than one hour a day and exercising less than once a week; intermediate=all others.

Table 3 (continued)

Characteristics	Events (n/N)	Model 1*		P value	Model 2†		P value	Model 3†	
		HR (95% CI)	P value		HR (95% CI)	P value		HR (95% CI)	P value

§1-21 drinks a week in men; 1-14 drinks a week in women.

¶P value for trend.

Table 4| Role of potential mediators in explaining association between number of unhealthy behaviours and disability

Model	Hazard ratio (95% CI)*	Percentage reduction†
Model 1‡	1.40 (1.29 to 1.51)	—
Model 1 + body mass index	1.37 (1.26 to 1.49)	5.6
Model 1 + cognitive function§	1.39 (1.28 to 1.50)	2.1
Model 1 + depressive symptoms¶	1.36 (1.25 to 1.47)	9.0
Model 1 + trauma**	1.36 (1.26 to 1.48)	7.1
Model 1 + chronic conditions††	1.34 (1.24 to 1.46)	11.5
Model 1 + cardiovascular disease and its risk factors‡‡	1.38 (1.27 to 1.49)	3.9
Fully adjusted model§§	1.26 (1.16 to 1.37)	30.5

Analyses based on 3844 participants without missing values for any covariates.

*Per increase of one unhealthy behaviour.

†$100\times(\beta_{model\ 1}-\beta_{model\ i})/(\beta_{model\ 1})$.

‡Adjusted for sex, marital status, their interaction, and education.

§Mini-mental state examination score.

¶Centre for Epidemiologic Studies depression scale.

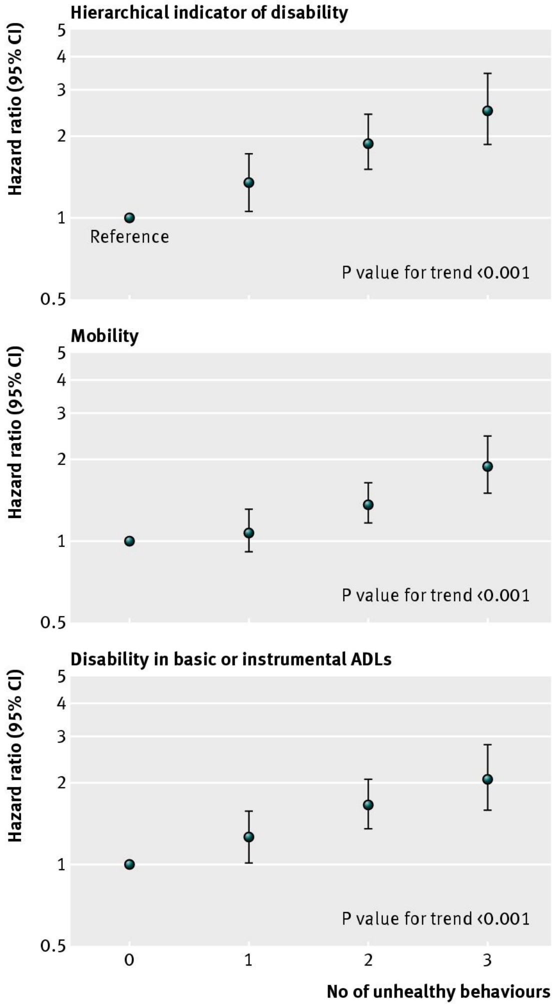
**Bone fracture, recurrent falls.

††Diabetes, Parkinson's disease, vision difficulties, deafness, dyspnoea, non-steroidal anti-inflammatory drug use for joint pain, cancer.

‡‡Stroke, coronary heart disease, lower limb arteritis, hypertension, hypercholesterolaemia.

§§All covariates included in model.

Figure



Hazard ratio of disability according to number of unhealthy behaviours (low/intermediate physical activity, consumption of fruit and vegetables less than once a day, and current smoking or short term ex-smoking): hierarchical indicator of disability (top panel), mobility (middle panel), and disability in basic or instrumental activities of daily living (ADLs) (bottom panel). Hazard ratios (95% CIs) were computed using interval censored survival models with age as timescale and were adjusted for sex, marital status, their interaction, and education