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Déterminants of diet in the population, and the contribution of diet to socioeconomic inequalities in cardiometabolic disorders in high-income countries

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Déterminants de l'alimentation dans la population et la contribution de l'alimentation aux inégalités socioéconomiques face aux maladies cardiométaboliques dans les pays à revenu élevé

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Manuscripts based on the studies presented in this thesis

Chapter 2

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Chapter 3

de Mestral C, Stringhini S, Marques-Vidal P. Barriers to healthy eating in Switzerland: a nationwide study. *Clin Nutr*. 2016; 35(6): 1490-8. doi: 10.1016/j.clnu.2016.04.004

Chapter 4

de Mestral C, Khalatbari-Soltani S, Stringhini S, Marques-Vidal P. Fifteen-year trends in the prevalence of barriers to healthy eating in a high-income country. *Am J Clin Nutri* 2017. doi: 10.3945/ajcn.116.143719

Chapter 5

de Mestral C, Marques-Vidal P. Barriers to healthy eating and adherence to dietary guidelines: a nationwide study. *Manuscript in preparation*.

Chapter 6

de Mestral C, Chatelan A, Marques-Vidal P Stringhini S, Bochud M. The contribution of diet to socioeconomic inequalities in obesity markers. *Manuscript in preparation*.

Chapter 7

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List of publications

Publication	Author contribution	Status
de Mestral C, Stringhini S, Marques-Vidal P. Barriers to healthy eating in Switzerland: a nationwide study. *Clin Nutr*. 2016 Dec;35(6):1490-1498	CdM and PMV generated the idea and analytical plan. CdM conducted analysis and wrote the manuscript, on which all coauthors commented.	Published
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2. Swiss Nutrition Society National Congress, 2016, *Bern, Switzerland*: **de Mestral C**, Stringhini S, Marques-Vidal P. Barriers to healthy eating in Switzerland: a nationwide study. Clinical Nutrition. 2016.	Oral
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4. *Objective*: To review the literature on the latest evidence linking socioeconomic status with cardiovascular disease across countries at different levels of socioeconomic development, as an invited review.
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5. *Objective*: To test for independent association of education, income, and occupation with macro- and micronutrient intake in pooled samples of the Bus Santé study.
   - **de Mestral C**, Marques-Vidal P, Gaspoz JM, Theler JM, Guessous I. Independent association between socioeconomic indicators and macro- and micro-nutrient intake in Switzerland. *PLoS One*. 2017 Apr 3;12(4):e0174578
6. *Objective*: To systematically review the literature on the promotion of healthy eating to reduce socioeconomic inequalities in diet in low- and middle-income countries.
   - Mayén AL, **de Mestral C**, Zamora G, Paccaud F, Marques-Vidal P, Bovet P, Stringhini S. Interventions promoting healthy eating as a tool for reducing social inequalities in diet in low- and middle-income countries: a systematic review. *Int J Equity Health.* 2016 Dec;15(1):205.
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Summary

Most people in wealthy societies do not eat healthily. Additionally, the greater the socioeconomic deprivation of individuals, the worse the quality of their diets. These phenomena are reflected in the unrelenting growth of the obesity epidemic, and the persistent socioeconomic inequalities in chronic disease. While the links between socioeconomic status (SES), diet, and chronic disease are firmly established, many questions remain. Thus, to further the evidence on these complex associations, this project had three aims. First, we conducted a systematic review and meta-analysis of the association between SES and sodium intake, confirming that more socioeconomic deprivation is linked to higher sodium intake; specifically, we found that less privileged people consume about 500 milligrams more sodium per day. In the second aim, we examined barriers to healthy eating in the Swiss population. We revealed a high prevalence of barriers—daily habits, price, taste, time and availability of healthy food options—and that reporting these barriers followed clear sociodemographic patterns. We also showed that these barriers have remained consistently high over a 15-year period. Furthermore, we reported complex associations between these barriers and adherence to the dietary guidelines. In the third aim, we assessed the mediating role of diet in the association between SES and cardiometabolic disorders. In a sample of the Swiss population, we found clear educational inequalities in obesity indicators, that education was associated with diet quality and that diet quality was associated with obesity markers. We observed that diet quality contributed to 20—35% of educational inequalities in obesity. Finally, in a multi-cohort analysis, we confirmed that education was associated with obesity, diabetes, hypertension, and cardiovascular disease (CVD). We also showed that education was associated with diet quality, and that diet quality was associated with obesity, hypertension, and CVD. We found that, among men, diet quality contributed to 7% of inequalities in CVD, and to 8% of inequalities in hypertension; among women, diet quality contributed only to 2-3% of inequalities in obesity and hypertension, but to 17% of inequalities in CVD. Overall, this project provided important information on the factors influencing diet, and how diet, in turn, contributes to inequalities in health. Interventions are needed to create environments conducive to and supportive of healthy eating to combat the burden of disease and inequalities in health.

Résumé

La plupart des gens dans les pays riches ne mangent pas sainement. De plus, plus les individus sont défavorisés, pire est la qualité de leur alimentation. Ces phénomènes se traduisent par une épidémie d'obésité et par des inégalités socioéconomiques face aux maladies chroniques. Bien que les liens entre statut socioéconomique (SSE), alimentation et maladies chroniques soient bien établis, de nombreuses questions subsistent. Ainsi, pour mieux comprendre ces associations complexes, ce projet avait trois objectifs. Premièrement, nous avons effectué une revue systématique et une méta-analyse de l'association entre le SSE et l'apport en sodium. Ce travail a confirmé que le SSE bas est associé à un apport en sodium plus élevé : les personnes défavorisées consomment environ 500 milligrammes de sodium en plus par jour. Dans le deuxième objectif, nous avons examiné les obstacles à une alimentation saine dans la population suisse. Nous avons constaté une forte prévalence d'obstacles, tels que les habitudes quotidiennes, le prix, le goût, le manque de temps et de disponibilité d'options alimentaires saines. Nous avons également montré que ces obstacles sont restés constamment élevés sur une période de 15 ans et qu'ils étaient différents selon les facteurs sociodémographiques. Enfin, nous avons trouvé des liens complexes entre ces obstacles et le respect des recommandations alimentaires. Dans le troisième objectif, nous avons évalué la contribution de la qualité de l'alimentation dans l'association entre le SSE et les troubles cardiométaboliques. Dans un échantillon de la population suisse, nous avons constaté des inégalités face à l'obésité selon le niveau de formation. Le niveau de formation était associé à la qualité de l'alimentation et cette dernière était associée à divers indicateurs de l'obésité. Nous avons observé que l'alimentation contribuait entre 20 à 35% aux inégalités d'obésité. Finalement, dans une analyse multi-cohorte, nous avons confirmé que le niveau de formation était associé à l'obésité, au diabète, à l'hypertension et aux maladies cardiovasculaires (MCV). Nous avons également montré que le niveau de formation était associé à l'alimentation, et que l'alimentation était associée à l'obésité, à l'hypertension et aux MCV. Nous avons trouvé que, chez les hommes, la qualité de l'alimentation contribuait à 8% aux inégalités face à l'hypertension, et chez les femmes, à 17% aux inégalités face aux MCV. Dans l'ensemble, ce projet a fourni des informations importantes sur les facteurs qui influencent l'alimentation, et sur la manière dont l'alimentation contribue aux inégalités de santé. Des interventions sont nécessaires pour créer des environnements favorables à une alimentation saine afin de prévenir les maladies et réduire les inégalités de santé.

List of abbreviations

AHEI	Alternate Healthy Eating Index
BMI	Body mass index
CHF	Swiss francs
CI	Confidence interval
CVD	Cardiovascular disease
HICs	High-income countries
LMICs	Low- and middle-income countries
mAHEI	Modified Alternate Healthy Eating Index
MCCS	Melbourne Collaborative Cohort Study
MDS	Mediterranean Diet Score
MET	Metabolic Equivalent of Task
MTE	Marginal total effect
NDE	Natural direct effect
NIE	Natural indirect effect
OR	Odds ratio
PM	Proportion mediated
SD	Standard deviation
SES	Socioeconomic status
SHS	Swiss Health Survey
WC	Waist circumference
WHR	Waist-to-hip ratio
WHtR	Waist-to-height ratio

"Food is not just fuel. Food is about family, food is about community, food is about identity. And we nourish all those when we eat well"

- Michael Pollan, *The Omnivore's Dilemma*

"We have a food system that promotes the most and makes most of its profits from the foods that are least recommended by public health experts."

- Marion Nestle, *Nobel Week Dialogue*

"Inequalities in health and the social determinants of health are not a footnote to the determinants of health. They are the main issue."

- Michael Marmot, *The Health Gap*

"The test of a civilization is in the way that it cares for its helpless members."

- Pearl Buck, *My Several Worlds*

"Progress is more plausibly judged by the reduction of deprivation than by the further enrichment of the opulent."

- Amartya Sen, *Will There Be Any Hope for the Poor?*

Chapter 1 Introduction

Nutrition, demographic, and epidemiological transitions

Diet constitutes a major determinant of health, whereby the human body obtains essential nutrients without which its physiological systems cannot develop and function optimally (1). Throughout human evolutionary history, nomadic hunter-gatherer peoples occupied diverse ecological niches that provided—in abundance or scarcity—a variety of plant and animal food sources to meet the needs for essential nutrients in a sustainable way. The average hunter-gatherer diet was likely nutritionally rich, season-dependent, highly adaptable, and included a diversity of wild-animal meat, honey, tubers, berries and other fruits, nuts and seeds, and a wide range of other edible plants (2-4). The inception of agriculture and permanent settlements profoundly transformed the average human diet, introducing cultivated grains—wheat, barley, sorghum, corn, and rice—as the main staple foods (2). This pivotal shift caused the average diet to become less nutritionally diverse, but it brought food security—animal farming provided meat and milk, and crops provided predictable, dependable, and storable staple foods (2). In turn, improved food security paved the way for populations to grow and diversify, and for societies to develop socioeconomically, culturally, technologically, and scientifically.

Nevertheless, life expectancy at birth remained below 50 years for millennia (5), and as paleoanthropological evidence shows, diseases caused by severe nutrient deficiency—such as anemia, goiter, pellagra, and scurvy—were widespread (6, 7). Together with infectious diseases and precarious, unsanitary and often crowded living conditions, these nutritional deficiency-related diseases contributed to persistently high infant and overall death rates (8). It took thousands of years for societies to attain levels of sufficient socioeconomic development to enter a new period of profound societal transformations that led to the current population dynamics in high-income countries (HICs).

Around the turn of the 19th century, sustained socioeconomic development in present industrialized HICs began to drive mortality rates down, which in turn contributed to lower fertility rates and to increased life expectancy (8-10). This early stage of what is known as the demographic transition was driven by major

improvements in the water supply system, sewerage, hygiene practices, and crucially, the agricultural revolution that unfolded at the time (8-10). The introduction of industrial, large-scale agriculture and farming in Western countries, along with the identification and synthesis of essential vitamins and minerals in the early 20th century, enabled population-wide efforts to prevent malnutrition-related diseases across the industrialized world via nutrient fortification of staple foods (10, 11).

Closely alongside this demographic transition, another major change began to unfold, known as the nutrition transition, during which the average human diet experienced a major shift once again, from a diet rich in complex carbohydrates and fiber to one high in animal protein and fats, particularly saturated fat, and simple sugars (10, 12). This shift coincided with profound societal changes that saw women progressively enter the work force and the major evolution of household food production and food processing technologies (refrigeration, freezing, canning, packaging, and improved cookware) (10). Government investments and subsidies went towards the mass production of cheaply available calories from staples, which facilitated the rapid expansion of mass livestock farming and the manufacturing of highly processed foods that today dominate the food system (13). This nutrition transition, as well as the demographic transition, evolved tightly intertwined with the epidemiological transition, during which the burden of disease in the population shifted from infectious and malnutrition-related diseases towards non-communicable, chronic diseases—that is, cardiovascular diseases (CVD), type 2 diabetes, and cancers (8-10).

In present day, populations in HICs enjoy high standards of living and can expect to live long lives—life expectancy at birth was 81 years in 2015 across wealthy countries (14). However, the high burden of chronic diseases and the even greater and continuously increasing prevalence of obesity and hypertension (15, 16) diminish the quality of life and overall health of populations. The food system most people depend on for their diet promotes the consumption of unhealthy foods and thus acts as a main driver of the obesity epidemic (10, 13). This insidious relationship undermines the public health progress achieved over decades and presents enormous challenges for the near future.

Although this thesis focuses on populations of HICs, it is important to note that in populations of low- and middle-income countries (LMICs), the aforementioned transitions are also currently underway, often at a much faster pace than they did in Western countries (17-19). For instance, in the context of the demographic transition, it took 139 years for life expectancy at birth to double in Switzerland to 83 years in 2015 (20), while it took only 65 years for Nepal to double its life expectancy from 34 years in 1950 to 70 years in 2015 (14). In the context of the nutrition transition, as another example of rapid change is the fact that between 1989 and 1993, the proportion of the population in China whose diet was composed of >30% fat doubled from 18% to 36% among low-income groups, and almost tripled among high-income groups from 23% to 67% (12).

As LMICs progressively transform into modern industrialized societies, their populations will reach the advanced stages of the demographic, epidemiological, and nutrition transitions. This means that their enormous populations, accounting for 85% of the world's population, are on track to resemble those of HICs with rapidly expanding older populations, poor quality diets, and a high burden of chronic diseases (9, 21-23). At the same time, populations in many LMICs continue to suffer from hunger and malnutrition (16) and infectious diseases, rendering theirs a double burden of disease that presents enormous strains and challenges to their public health systems (24).

Diet and chronic diseases

Diet plays a critical role in the development of the most common chronic conditions including obesity, hypertension, type 2 diabetes, CVD, and many cancers (25-27). A robust body of evidence spanning decades of nutritional epidemiology, molecular biology, and population-level intervention studies lends strong support to the link between diet and disease (13, 25-27). Owing to studies of nutritional deficiency-related diseases, the association between diet and chronic diseases focused for decades on single macronutrients, such as fats or sugars, or micronutrients, such as beta carotene or sodium (11). This research approach has yielded strong evidence indicating, for instance, that high sodium intake increases the risk of hypertension (28-30), coronary heart disease and stroke (26, 31), and certain cancers (32, 33). While this approach remains important, particularly in the context of vulnerable population groups whose diets may

be deficient of essential nutrients, the focus has now shifted to food groups and food patterns (11, 27).

In investigations of food groups, consistent findings show that higher consumption of whole grains is associated with lower risk of type 2 diabetes (34), CVD (35, 36), and cancer (37, 38), while higher consumption of processed and unprocessed meat is associated with higher risk of these diseases (13, 26, 27, 34-38). Higher consumption of fruit and vegetables is associated with lower risk of CVD and cancer (35-37). Regarding dairy foods, the growing evidence indicates that its association with disease risk may depend on the type of dairy. While higher milk and total dairy food intakes appear to be associated with lower risk of colorectal cancer (39), consistent evidence indicates that milk consumption is associated with an increased risk of prostate cancer (40, 41). Sugar sweetened beverages are associated with higher risk of diabetes and CVD (27).

Investigations of food patterns have relied on exploratory analyses such as principal component and factor analyses (27), but also on a priori defined diet quality indices, such as the Alternate Healthy Eating Index (AHEI)(42) and the Mediterranean Diet Score (MDS) (43). These indices quantify the quality of the diet based on the amount of healthy and unhealthy foods they consume, based on their established associations with disease prevention and risk (27). As such, the concept of diet quality is not based on single food groups, but on the overall composition of several food groups (27). To obtain a high score in the MDS indicating a healthier diet, for instance, participants need to consume high amounts of fruits and vegetables, nuts and seeds, legumes, olive oil, fish, and wholegrains, but low to no amounts of meat, dairy, and processed foods (43, 44). Extensive evidence demonstrates that adherence to the Mediterranean diet, as well as other healthy dietary patterns as quantified by diet indices, is associated with lower risk of CVD, cancer, and type 2 diabetes (27, 45).

Socioeconomic inequalities in chronic diseases

The occurrence of the diet-related diseases described above follows a clear socioeconomic gradient, whereby more disadvantaged people disproportionally suffer and die more and earlier from chronic diseases compared with more advantaged people

(46-48). Most commonly approximated by the level of education or income of an individual, or their occupation (49), socioeconomic status (SES) is also strongly linked to specific health behaviors and risk factors; people with lower SES tend to have higher levels of harmful alcohol consumption, insufficient physical activity, tobacco smoking, hypertension, diabetes and obesity (46, 48, 50). It is important to note that these inequalities are not merely a dichotomy between the well-educated and wealthy versus the uneducated and poor; instead, the socioeconomic gradient indicates that at every step below the most advantaged in society, the prevalence of unhealthy behaviors, risk factors, and disease worsens.

Figures 1 and 2 illustrate the socioeconomic gradient in risk factors and mortality. The former shows the prevalence of tobacco smoking in the US population across levels of education; in 2017, the prevalence of smoking among people with less than a high school education was 22%, while it was only 5% among people with a graduate degree or higher, and a clear gradient is evident between the lowest and highest educational groups (51). The latter displays the gradient for mortality among women in England and Wales for the period 1991-2011 across different occupations; women in unskilled and manual occupations had the highest mortality rate, while those in business, public service, and scientific professions had the lowest mortality rates, and a clear gradient is evident among women in intermediate occupations (52).

Figure 1. Prevalence of cigarette smoking by educational level, US population, 2017, adapted from (51)

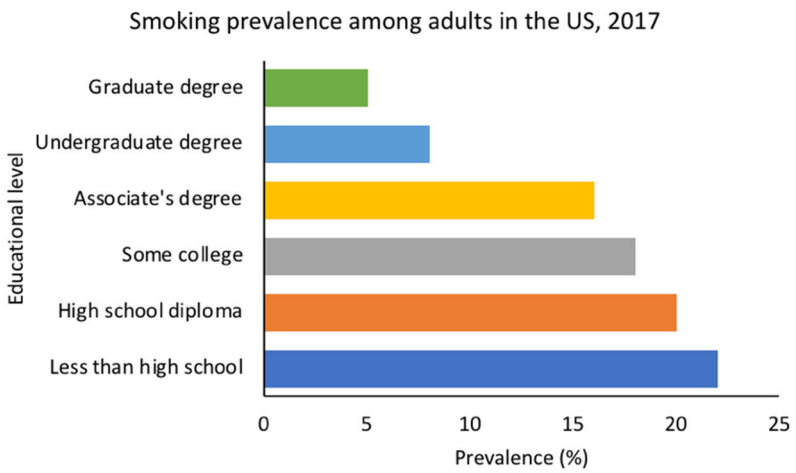
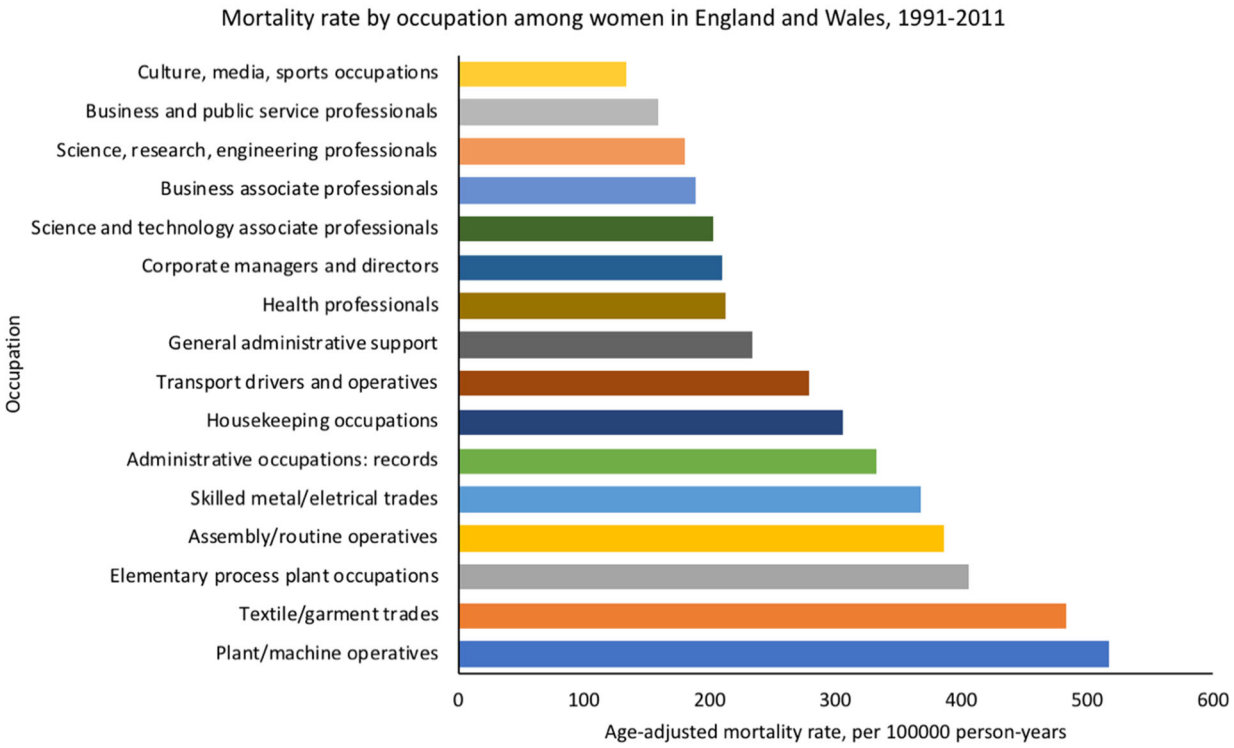


Figure 2. Age-adjusted mortality rates among women in England and Wales according to occupation, 1991-2011, adapted from (52)



Evidence indicates that at least relative socioeconomic inequalities in chronic disease risk factors have widened over time, generally driven by a decrease in prevalence of risk factors among the more socioeconomically privileged and either no change or an increase in prevalence among the less privileged groups (53, 54). The smoking prevalence in the UK, for instance, decreased from 20% to 14% among people in managerial or professional occupations between 2001 and 2012, while it remained unchanged (33%) among people in routine or manual occupations (55). Similarly, evidence from four large representative birth cohorts in the UK reveals that socioeconomic inequalities in childhood and adolescent obesity have increased during the past five decades (56). In general, inequalities in mortality have decreased in absolute terms between the more and less socioeconomically privileged across most HICs in recent decades; however, they have increased in relative terms, due to greater proportional decreases in mortality in the higher socioeconomic groups and less or no decreases in the more disadvantaged groups (47, 57-59). Importantly, due to the long latency until chronic disease onset, the increasing inequalities in risk factors are likely

to exacerbate the socioeconomic gap in chronic disease incidence and mortality in the coming decades.

Socioeconomic inequalities in risk factors and diseases are the result of the fact that social, cultural, economic and environmental conditions strongly influence and shape the manner in which individuals are born and nurtured, grow, eat, play, behave, work, and age (60). To briefly illustrate this complex concept, as shown above, individuals with university-level education tend to rarely smoke, but they are also more likely to secure stable employment with a healthy effort-reward balance, which in turn allows them to earn enough to afford living in comfortable homes located in safe neighborhoods, and to afford healthy foods, gym membership and access to physical and leisure activities, social groups, and green spaces (60, 61). As such, privileged individuals benefit from a wide range of socioeconomic characteristics that are conducive to healthier lifestyle behaviors, which in turn are protective against obesity, diabetes, hypertension, and chronic disease development (46, 60, 61). Less privileged individuals, those with fewer years of education, for instance, are less likely to secure stable and well-remunerated employment, and more likely to live in suboptimal housing and in neighborhoods with fewer green spaces and stores that offer healthy foods (60, 61). As such, underprivileged individuals tend to live with financial insecurity and chronic stress, less likely to have a vision for the long-term, and more likely to pursue unhealthy lifestyle behaviors, in turn increasing their risk of chronic disease development (60, 61).

SES is a complex social and economic construct that relates to specific exposures, resources, and susceptibilities that influence lifestyle behaviors and health outcomes over the life course, and across time and space (49, 62). In order to comprehensively capture the SES of an individual, it is necessary to evaluate several socioeconomic and demographic characteristics. Indeed, different socioeconomic indicators may relate differently to specific health behaviors, exposures, risk factors, and outcomes (49, 62). A frequently used socioeconomic indicator at the individual level is education, which not only relates to an individual's level of knowledge, but also to certain levels of occupation and income, thus making it a valuable tool to approximate SES (49). Still, education does not capture the full spectrum of SES, and it is necessary to complement education with

other markers of SES. Other individual-level indicators include income, which directly relates to material resources and financial ability to access and procure services, and occupation, which relates to social standing, social networks, work exposures, and stress levels (49). Composite measures of SES are also used, albeit less frequently, to minimize potential for residual confounding related to socioeconomic conditions. However, composite measures are less optimal when precise mechanisms linking socioeconomic exposures to health behaviors and outcomes are the main interest of research (62). Therefore, it is recommended to utilize several socioeconomic indicators, instead of a global or composite SES indicator, to precisely assess the inequalities in health risk factors and health outcomes.

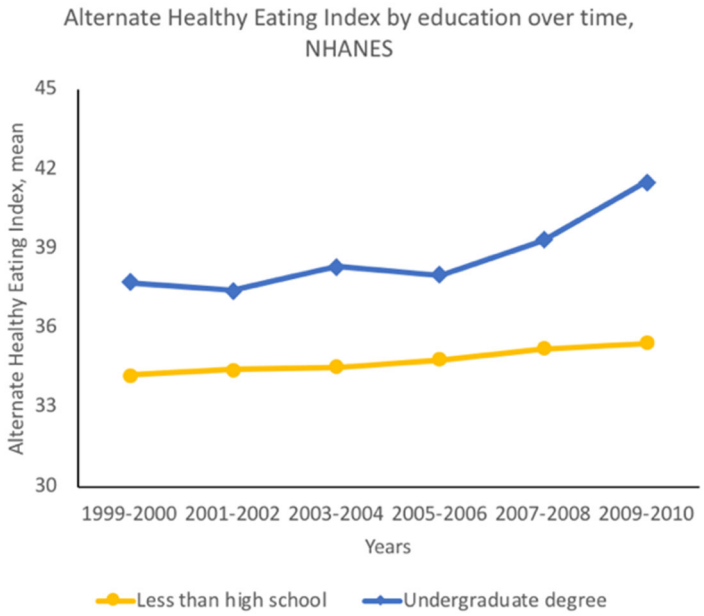
Socioeconomic determinants of diet

As seen with other behaviors that influence health outcomes, diet quality also follows a clear socioeconomic gradient. Extensive evidence indicates that the lower the socioeconomic status of individuals, the less they consume fruits and vegetables, whole grains, nuts and seeds, lean meats, fish, and low-fat dairy products, and the more they consume highly processed foods and meats, refined grains, and sugar sweetened beverages (63-68). More disadvantaged people tend to be less likely to adhere to dietary recommendations, and thus they consistently score lower in dietary indices, indicating a diet of poorer quality (64, 65, 69-71). Worryingly, some evidence points to widening socioeconomic disparities in dietary quality over time (64, 72, 73). Figure 3 shows the adjusted mean of the AHEI among those with less than high school education and those with an university degree in the USA; although both groups showed an improvement in their mean AHEI, the more privileged group followed a steeper increase, and thus the gap between the two groups widened between 1991 and 2010 (64).

Additionally, systematic reviews have confirmed that more disadvantaged populations tend to fail to reach recommended levels of essential micronutrients (74, 75). Yet, whether sodium intake differs across socioeconomic groups has yet to be confirmed. This is an important gap in the literature as sodium is present in high levels in unhealthier processed foods (76), of which people of lower socioeconomic status tend to consume more(63). If sodium intake is socioecomically patterned, this disparity may

in turn help explain the higher chronic disease burden among more disadvantaged populations. **Thus, the first aim of this thesis work was to conduct a systematic review and meta-analysis of the literature on the association between socioeconomic status and sodium intake**.

Figure 3. Alternate Healthy Eating Index by educational level over time, National Health and Nutrition Examination Survey, 1991-2010, adapted from (64)



Research has pointed to barriers to healthy eating as important factors that influence diet choice and behavior (77-79). These barriers include lack of access and affordability of healthier foods, lack of time to shop for and prepare foods, and taste preferences for unhealthier foods, and are directly related to the social determinants of health (78). A recent systematic review demonstrated that a majority of the population perceive multiple environmental, social, and cultural factors to influence their healthy eating behavior (77). Importantly, the predominant barriers among more disadvantaged groups were the higher price of healthier foods as well as the lower availability of stores offering healthy food options in their neighborhoods (77). Consequently, as confirmed in another systematic review, the high price of healthy foods acts a major contributor to socioeconomic inequalities in diet (80).

As previously stated, the association between SES and diet quality is best assessed by using several different socioeconomic indicators (67). For instance, in a large sample of adults living in canton Geneva, educational level, income, and occupational position were each independently and differently associated with intake levels of several macro- and micro-nutrients (81). Among women, inequalities were observed across levels of education, income, and occupation, whereas among men, inequalities were evident only across levels of education and income. Furthermore, while education was only associated with intake of micronutrients, income was only associated with intake of total energy and macronutrients. Hence, the relationships between SES and diet are way more complex than initially thought, and cannot be reduced to the bivariate associations between one socioeconomic indicator and diet.

Diet, social determinants, and chronic disease in Switzerland

Switzerland has historical precedent for interventions at the interception of nutritional epidemiology and public health. Switzerland was among the first countries to fortify their food supply to prevent nutritional deficiency-related diseases; in 1922, Swiss cantons began fortifying salt with iodine to prevent goiter in the population (82). Today, the Swiss population enjoys one of highest life expectancies globally, and has access, on average, to comfortable and safe housing, high quality healthcare, diverse education and professional opportunities, economic security, as well as access to leisure activities and green spaces (83). Compared with the populations of bordering countries, the Swiss population exhibits relatively low rates of CVD risk factors and mortality (26, 84).

Nevertheless, evidence from the Global Burden of Disease study revealed that dietary factors constitute the single biggest risk factor for mortality in the Swiss population, contributing to 15% of all deaths, a higher contribution than tobacco smoking and high blood pressure (Figure 4) (85). Recent evidence also shows that the prevalence of overweight and obesity has increased between 1980 and 2015 among adults and children in the Swiss population (15). Findings from the CoLaus study indicate that the prevalence of obesity and diabetes follows a clear socioeconomic gradient. As seen

in Figure 5, there is an almost three-fold increase in prevalence of both disorders between the high education group and the low education group (86).

Figure 4. Percentage contribution of risk factors to all-cause mortality in Switzerland, Global Burden of Disease 2016, created using GBD Compare tool (85)

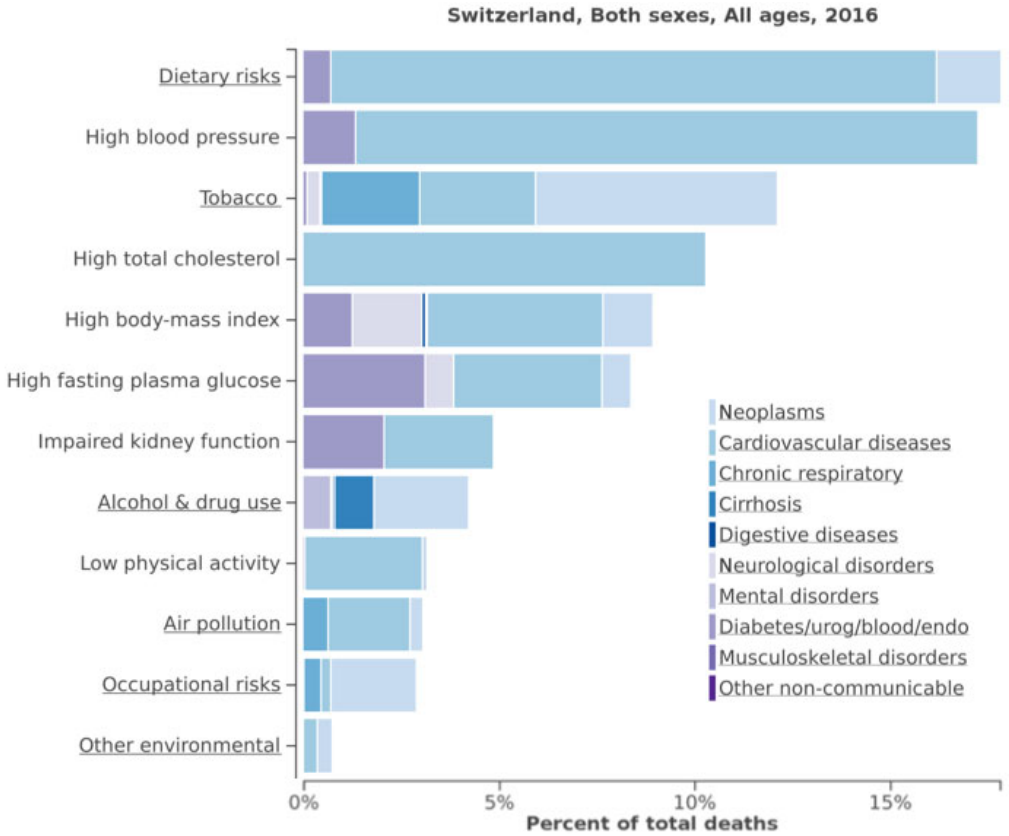
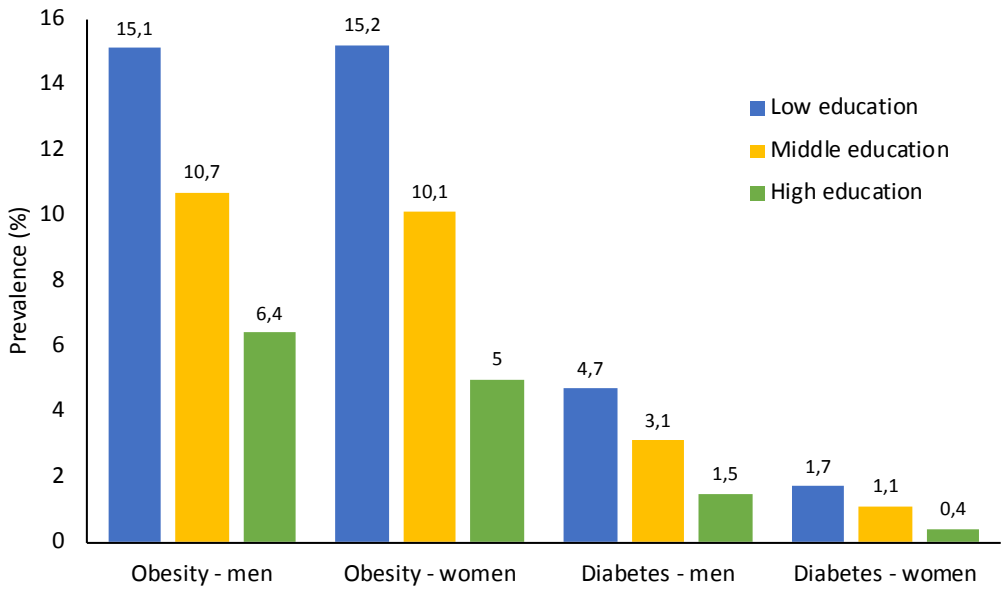


Figure 5. Prevalence of obesity and diabetes according to educational level among men and women aged 35-54 years, CoLaus study, adapted from (86)



Until recently, little empirical data were available to describe the diet of the Swiss population. In the last two decades, a series of studies have been established with diet measurement as one of their objectives: the Bus Santé study in canton of Geneva (87), the CoLaus study in the city of Lausanne (88), and the nationwide menuCH survey (89). Evidence from the CoLaus study shows that those with higher education are more likely to follow healthier diets, as measured by dietary quality indices (90). Similarly, findings from the Bus Santé study in Geneva indicate that individuals with higher education are more likely to adhere to the Swiss dietary guidelines (88). Importantly, overall compliance to the Swiss dietary guidelines has remained low and shown little to no improvement over time, as observed in the population of canton Geneva (87, 91).

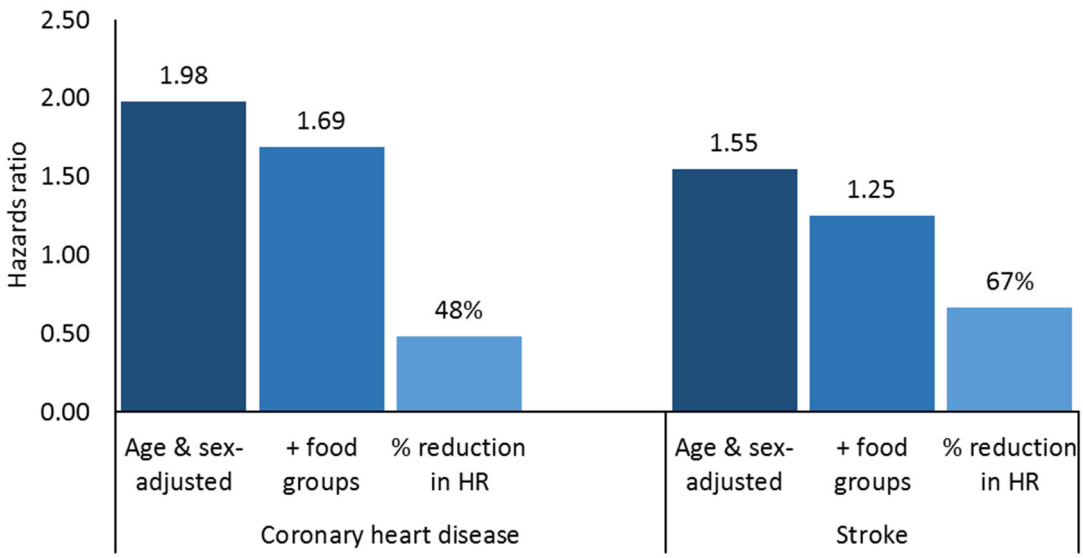
Nevertheless, to date there has been no evaluation of potential barriers to healthy eating that may help explain the persistent low adherent to the dietary guidelines. Thus, **the second aim of this thesis was to assess the prevalence of self-reported barriers to healthy eating in the Swiss population, and to characterize their demographic and socioeconomic determinants**.

Diet as mediator of socioeconomic inequalities in chronic diseases

In a related body of work, the well-established relationship between lower SES and chronic disease incidence and mortality is known to be partially explained by controlling for modifiable health behaviors, particularly tobacco smoking, but also excessive alcohol consumption, physical inactivity, and diet quality (50, 92, 93). Quantifying the mediation, or contribution, of modifiable health behaviors in socioeconomic inequalities in health constitutes an important tool for potential public health interventions to reduce these inequalities. Notably to date, most studies that have examined the role of diet quality as a mediator of socioeconomic inequalities in chronic disease have relied on a narrow measure of diet: fruits and vegetables consumption (92). While fruits and vegetables consumption is associated with healthier overall diets, it is important to assess the role of diet using measures that are more comprehensive. One such study from the Netherlands examined the mediating role of diet using several food groups in the relationship between educational level and cardiovascular incidence. As shown in figure 6, diet explained 48% of the higher risk of coronary heart disease, and

67% of the higher risk of stroke for participants with low education. This attenuation was assessed comparing the age- and sex-adjusted effects to those additionally adjusted for diet (94). Importantly, a main limitation of this study was the method used to assess mediation—the difference method—which fails to account for potential interaction between the mediator and the exposure (95). Furthermore, the model with diet included 25 food groups as continuous variables. Therefore, there remains a need to examine diet using comprehensive and established dietary quality indices and to assess its mediation using methods that are more precise. **Thus, the third aim of this thesis was to assess the contribution of diet quality to socioeconomic inequalities in cardiometabolic disorders**.

Figure 6. The contribution of diet to educational inequalities in the cardiovascular events risk, EPIC-Netherlands, adapted from (94)



Objectives

To summarize, in light of the evidence and the gaps identified above, the three main objectives for this thesis were:

1. To conduct a systematic review and meta-analysis of the literature on the association between socioeconomic status and sodium intake.

2. To assess the prevalence of self-reported barriers to healthy eating in the Swiss population, and to characterize their demographic and socioeconomic determinants.

3. To evaluate the contribution of diet quality to socioeconomic inequalities in cardiometabolic disorders.

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Chapter 2 Socioeconomic determinants of sodium intake in adult populations of high-income countries: a systematic review and meta-analysis

Socioeconomic Determinants of Sodium Intake in Adult Populations of High-Income Countries: A Systematic Review and Meta-Analysis

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Background. A poorer quality diet among individuals with low socioeconomic status (SES) may partly explain the higher burden of noncommunicable disease among disadvantaged populations. Because there is a link between sodium intake and noncommunicable diseases, we systematically reviewed the current evidence on the social patterning of sodium intake.

Objectives. To conduct a systematic review and a meta-analysis of the evidence on the association between SES and sodium intake in healthy adult populations of high-income countries.

Search Methods. We followed the PRISMA-Equity guidelines in conducting a literature search that ended June 3, 2016, via MEDLINE, Embase, and SciELO. We imposed no publication date limits.

Selection Criteria. We considered only peer-reviewed articles meeting the following inclusion criteria: (1) reported a measure of sodium intake disaggregated by at least 1 measure of SES (education, income, occupation, or any other socioeconomic indicator); (2) were written in English, Spanish, Portuguese, French, or Italian; and (3) were conducted in a high-income country as defined by the World Bank (i.e., per capita national gross income was higher than $12 746). We also excluded articles that exclusively sampled low-SES individuals, pregnant women, children, adolescents, elderly participants, or diseased patients or that reported results from a trial or intervention.

Data Collection and Analysis. As summary measures, we extracted (1) the direction (positive, negative, or neutral) and the magnitude of the association between each SES indicator and sodium intake, and (2) the estimated sodium intake according to SES level. When possible and if previously unreported, we calculated the magnitude of the relative difference in sodium intake between high- and low-SES groups for each article, applying this formula: ([value for high-SES group − value for low-SES group]/[value for high-SES group]) × 100. We considered an association significant if reported as such, and we set an arbitrary 10% relative difference as clinically relevant and significant. We conducted a meta-analysis of the relative difference in sodium intake between high- and low-SES groups. We included articles in the meta-analysis if they reported urine-based sodium estimates and provided the total participant numbers in the low- and high-SES groups, the estimated sodium intake means for each group (in mg/day or convertible units), and the SDs (or transformable measures). We chose a random-effects model to account for both within-study and between-study variance.

Main Results. Fifty-one articles covering 19 high-income countries met our inclusion criteria. Of these, 22 used urine-based methods to assess sodium intake, and 30 used dietary surveys. These articles assessed 171 associations between SES and sodium intake. Among urine-based estimates, 67% were negative (higher sodium intake in people of low SES), 3% positive, and 30% neutral. Among diet-based estimates, 41% were negative, 21% positive, and 38% neutral. The random-effects model indicated a 14% relative difference between low- and high-SES groups (95% confidence interval [CI] = −18, −9), corresponding to a global 503 milligrams per day (95% CI = 461, 545) of higher sodium intake among people of low SES.

Conclusions. People of low SES consume more sodium than do people of high SES, confirming the current evidence on socioeconomic disparities in diet, which may influence the disproportionate noncommunicable disease burden among disadvantaged socioeconomic groups.

Public Health Implications. It is necessary to focus on disadvantaged populations to achieve an equitable reduction in sodium intake to a population mean of 2 grams per day as part of the World Health Organization's target to achieve a 25% relative reduction in noncommunicable disease mortality by 2025. (*Am J Public Health.* 2017;107:e1–e12. doi:10.2105/AJPH.2016.303629)

See also Capewell and Kypridemos, p. 499.

PLAIN-LANGUAGE SUMMARY

People with high socioeconomic status (SES) tend to have diets that are healthier than are those of people with low SES. This disparity in diet quality may partly contribute to the higher burden of noncommunicable diseases among people with low SES. Because sodium intake higher than the recommended level of 2 grams per day is associated with an increased risk of developing hypertension, cardiovascular disease, and certain cancers, we systematically reviewed the current evidence of the social patterning of sodium intake in healthy adult populations of high-income countries.

The 51 articles we reviewed, representing 19 high-income countries, indicate that people of low SES consumed 14% more sodium (approximately 503 mg/day) than did people of high SES.

High sodium intake increases the risk of several noncommunicable diseases (NCDs), including hypertension,[1,2] cardiovascular disease,[3,4] and certain cancers,[5,6] that disproportionally affect low-SES populations[7,8] In high-income countries (HICs), SES influences diet quality, whereby low-SES people tend to follow unhealthier diets—characterized by high intakes of highly processed foods and insufficient intakes of some essential nutrients—than do high-SES people.[9–12] As highly processed foods—those with added sugar, salt, preservatives, and colors to enhance or preserve palatability, look, and freshness[13]—are generally high in sodium,[14,15] it is possible that low-SES individuals consume more sodium than do their more advantaged counterparts, which could partly explain the higher NCD burden in low-SES populations.[16]

The World Health Organization targets a global 25% relative reduction in NCD mortality by 2025, and a reduction in sodium intake to a population mean of 2 grams per day is 1 of the identified instruments.[17] A recent report found that the estimated global mean sodium intake was 3.95 grams per day, nearly twice the World Health Organization's recommended limit. In North America, Western Europe, and Australia and New Zealand, the estimated sodium intake ranged from 3.4 to 3.8 grams per day; in East Asia, it was 5.0 grams per day.[18] Concurrently, the Global Plan of Action on Social Determinants of Health aims to eliminate avoidable health inequalities.[19] Thus, quantifying the impact of SES on sodium intake can provide evidence needed to guide public health policy.

A systematic review of differences in micronutrient intakes in Europe found positive associations between intake of most micronutrients and SES.[10] Notably, this review failed to include sodium intake. Another review examined dietary intake in exclusively low-income European populations, finding much higher than recommended sodium intakes in 2 of 3 studies.[12] Yet another systematic review, this one by Imamura et al., examining international trends in dietary quality from 1990 to 2010, found that consumption of unhealthy foods (including sodium) increased significantly worldwide, with HICs faring much worse than low- and middle-income countries (LMICs).[20] However, the authors did not assess food intake trends by SES.

This gap in the literature—and the need for evidence to guide public health policy to reduce NCDs and health inequalities—prompted us to conduct a systematic review of the social patterning of sodium intake in HICs. We also conducted a meta-analysis of social differences in sodium intake for studies that assessed sodium intake through urine-based collection methods.

METHODS

Following the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses)–Equity guidelines,[21] we conducted the last literature search on June 3, 2016, via MEDLINE, Embase, and SciELO. We considered only peer-reviewed articles meeting the following inclusion criteria: (1) reported a measure of sodium intake disaggregated by at least 1 measure of SES (education, income, occupation, or any other SES indicator); (2) were written in English, Spanish, Portuguese, French, or Italian; and (3) were conducted in a HIC as defined by the World Bank (per capita national gross income above $12 746).[22]

We imposed no publication date limits. Details of the electronic database search strategy are available as a supplement to this article at http://www.ajph.org as Table A. Three reviewers (C. d. M., A.-L. M. and D. P.) independently screened all the titles and abstracts of articles returned in the electronic search, removed articles clearly failing to meet the inclusion criteria, and retrieved potentially eligible articles for full-text review. We also screened the reference lists of reviewed articles for potentially relevant articles that the electronic search failed to identify. As our review focused only on healthy adult populations of HICs, C. d. M., A.-L. M. and D. P. applied the following exclusion criteria during title and abstract screening and full-text reviewing: (1) sampled populations were from LMICs; (2) did not disaggregate sodium intake by a measure of SES; (3) exclusively included low-SES individuals, pregnant women, children, adolescents, elderly participants, or diseased patients; or (4) reported results from a trial or intervention.

To minimize the effect of a single study, we also excluded articles that reported previously published data, unless the analyses conducted were substantially different (e.g., one used income but another education as the predictor variable). After removing duplicates, C. d. M., A.-L. M., and D. P. agreed on a final list of articles to include in the systematic review.

Data Extraction

C. d. M. extracted the data from included articles, A.-L. M. and D. P. verified this by checking the table with all extracted data against data presented in each article, and a senior reviewer (S. S.) was consulted in case of disagreement. Extracted data included the following:

1. country of population sample,
2. study period,
3. sample size (total and for the low- and high-SES groups),
4. age group,
5. percentage of women,
6. sodium intake assessment method,
7. SES indicators measured, and
8. type of adjustment for potential confounders.

As summary measures, we extracted (1) the direction (positive, negative, or neutral) and the magnitude of the association between each SES indicator and sodium intake

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on the basis of previous systematic reviews,[23–27] and (2) the estimated sodium intake according to SES level.

When the association between sodium intake and SES indicator was reported per year, we extracted the information for each year; however, to prevent any single study from providing a disproportionately high number of associations, we included only the oldest and most recent reported data estimates from periodically repeated cross-sectional studies (e.g., the National Health and Nutrition Examination Survey). To minimize misclassification bias in intermediate categories, we selected only the lowest and highest categories per SES indicator, as recommended[28] and done by previous systematic reviews.[10,23–26,29–31]

Quality Assessment

We performed a quality assessment of included articles' strengths and limitations according to 3 criteria: (1) sample (2 possible points), (2) analysis (3 possible points), and (3) presentation (1 possible point), with a maximum possible score of 6, which we adapted from a previously published quality score assessment[31] to better fit the objectives of our article (Table 1).

We considered the article quality as higher (scores ≥ 4), intermediate (scores 2 or 3), or lower (score ≤ 1). C. d. M. and D. P. independently assigned scores, discussed differences, and agreed on a final score.

Statistical Analysis

When possible and if previously unreported, we calculated the magnitude of relative difference in sodium intake between high- and low-SES groups for each article applying the formula: ([value for high-SES group − value for low-SES group]/[value for high-SES group]) × 100.[24,32] We contacted the corresponding authors to request data results whenever these were not reported in the article; 7 provided data results. (All contacted authors and the outcome are available as a supplement to this article at http://www.ajph.org as Table B.) When possible, we calculated the sodium to potassium ratio. We considered an association significant if reported as such, and we set an arbitrary 10% relative difference as clinically relevant and significant, as previously done.[24,26,32,33]

After assessing data comparability across articles, we conducted a meta-analysis of the relative difference in sodium intake between high- and low-SES groups, and we have reported the standardized mean difference (SMD). We included articles in the meta-analysis if they (1) reported urine-based sodium estimates (because questionnaire-based estimates were too heterogeneous or failed to provide necessary data points); and (2) provided the total participant numbers in the low- and high-SES groups, the estimated sodium intake means for each group (in mg/day or convertible units), and the SDs (or transformable measures). When both adjusted and unadjusted estimates were provided within each article, we incorporated the former into the meta-analysis. We chose a random-effects model to account for both within-study and between-study variance, as recommended.[34] We conducted 6 different sensitivity analyses by doing the following:

1. applying a fixed-effects model assuming an equal effect size across studies,
2. presenting the effect size according to SES indicator,
3. presenting effect sizes separately for models adjusted for potential confounders and for unadjusted models,
4. limiting analysis to higher-quality articles,
5. repeating the meta-analysis with each study removed sequentially, and
6. meta-regressing estimated sodium intake against the level of SES (1 = lowest SES; ≥ 2 = higher SES).

We assessed the presence and effect of publication bias using the Kendall tau and the Egger test.[35] We performed statistical analyses in Stata version 14 (Stata Corp., College Station, TX).

TABLE 1—Strengths and Limitations of the Criteria Used for the Review Quality Score

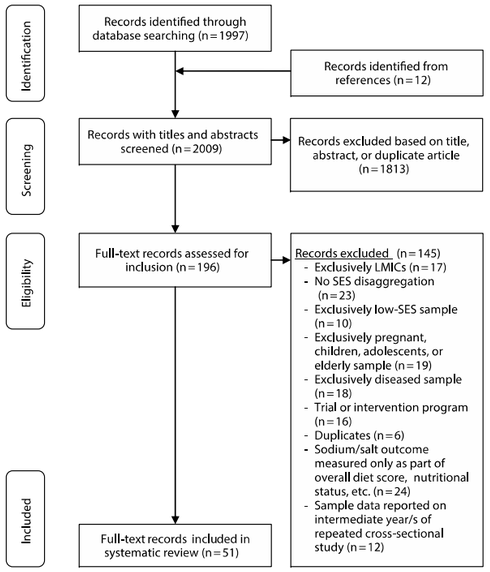
Criteria Set	Strengths	Limitations
Sample	Community- and population-based study design (+1)	Other study design
Sample	Representative sample (+1)	Nonrepresentative sample
Sample	More than 1 SES dimension (+1)	Only 1 SES dimension
Sample	Hierarchical, graded SES categories (+1)	Binary SES variables
Sample	SES–sodium intake association results adjusted for age, gender, BMI, energy (where applicable; +1)	No adjustment for age, gender, BMI, or energy in SES–sodium intake analysis (where applicable)
Presentation	SES–sodium intake association results presented in the form of mean ± SD, SE, confidence interval, and *P* value (+1)	Incomplete results presented (or data not shown) for SES–sodium intake analysis

Note. BMI = body mass index; SES = socioeconomic status. We assessed articles included in the review on their strengths and limitations according to 3 sets of criteria: sample, analysis, and presentation.

RESULTS

The selection procedure is summarized in Figure 1. The systematic search identified 2009 articles; after title and abstract screening, 196 remained for full-text inspection. Sixty-three articles complied with the inclusion criteria, but we excluded 12 for reporting intermediate years from repeated cross-sectional studies, leaving 51 articles for final inclusion.

Table 2 shows the characteristics of included articles. Sample sizes ranged from 87[39] to 91 900,[32] and most (44/51) included samples of greater than 1000. Nine articles were from East Asia (Japan, South Korea, Taiwan), 6 from Australia, 15 from North America, 20 from Europe, and 1 from Latin America (Chile), covering 19 HICs. Most articles included samples of both men and women, but 3 included samples composed of only women[44,76,80] and 1 predominantly of men.[78] Thirty-four articles attained higher-quality scores, with 3 scoring maximum points. Sixteen articles attained intermediate quality scores, and 1 attained a lower quality score (Table 2; detailed



Note. LMICs = low- to middle-income countries; SES = socioeconomic status.

FIGURE 1—Flowchart of Articles Included in Systematic Review

scoring is available as a supplement to this article at http://www.ajph.org as Table C).

Twenty-two articles used urine measurements to assess sodium intake: 15 used 24-hour urine collection, the gold standard assessment method; 1 used 12-hour urine collection[51]; 5 used the spot urine test; and 1 used the first morning void method.[57] Thirty articles reported sodium intake measured via dietary surveys, including 24-hour dietary recalls (16 articles), 72-hour dietary recall (1 article), 7-day dietary recall (1 article), food frequency questionnaires (7 articles), dietary records (3 articles), food diary (1 article), and dietary history questionnaire (1 article; Table 2).

Overall, 45 articles included education as the SES indicator, 20 income, 20 occupation, and 15 other SES indicators (Table 2).

The 22 articles reporting urine-based sodium intake assessed 54 associations with SES: 36 were negative (67%), 2 positive, and 16 nonsignificant (the overall pattern of associations is available as a supplement to this article at http://www.ajph.org in Figure A). Figure 2 displays the relative difference in sodium intake between low- and high-SES groups for each association assessed per article for which data were available; 9 articles reported the association without showing data results.[37,39,40,57,59,60,65,82,84] Associations between urine-based sodium intake and SES were predominantly negative, ranging from –19% in 4 different studies from Chile,[52] England,[55] Italy,[43] and South Korea,[54] to a nonstatistically significant –1% in a study from England.[56] Only 2 studies reported positive relative differences, although none was statistically significant.[36,51] Reported associations were adjusted differently per article, but most were adjusted for 1 or more potential confounders (energy, body mass index, age, gender); only 4 articles reported unadjusted associations. The corresponding absolute difference in sodium intake between low- and high-SES groups is available as a supplement to this article at http://www.ajph.org as Figure B (if data were available).

The 30 articles reporting diet-based sodium intake estimates assessed 117 associations with SES: 48 were negative (41%), 24 positive (21%), and 45 nonsignificant (38%; Figure A). As Figure 2 shows, there was no clear pattern in the association between diet-based sodium intake and SES, with relative differences ranging widely from –19% in 1 study in the United States[72] and –17% in 1 study in Ireland[76] to 14% in 1 study in South Korea[64] and 13% in 1 study in the United States.[66] Most associations were adjusted for potential confounders, but 6 articles reported only unadjusted associations (Figure 2; see corresponding absolute differences in Figure B).

Of the 22 articles that reported urine-based sodium association with SES, only 7[36,38,44,48–50,54] reported necessary and comparable data to be included in the meta-analysis. Six contacted authors provided additional data results.[45,46,52,53,55,56] Therefore, we included 12 study populations from 13 articles in the meta-analysis—2 articles analyzed the same study population but each used different SES indicators[48,50]—representing 42 255 combined participants from 9 countries. Figure 3 shows the Forest plot from the random-effects model, presenting the overall pooled effect size in relative difference in sodium intake between low-SES and high-SES groups and separately by the sodium intake measurement method. Overall, the SMD was –0.14 (95% confidence interval [CI] = –0.18, –0.09); among articles that relied on 24-hour urine collection to estimate sodium intake, the SMD was also –0.14 (95% CI = –0.21, –0.08); among articles that relied on spot urine to estimate sodium intake, the SMD was –0.13 (95% CI = –0.19, –0.07). The I^2 statistic indicated likely overall and subgroup heterogeneity ($I^2 > 50\%$; $P < .01$ for each).

The pooled relative difference translates to a global 503 milligrams per day (95% CI = 461, 545) of higher sodium intake among people of low SES, a difference ranging from 423 milligrams per day (95% CI = 352, 493) in Australia to 589 milligrams per day (95% CI = 491, 687) in the East Asian countries (South Korea and Japan).

In sensitivity analyses, the pooled effect size was slightly attenuated using fixed-effects models among studies that relied on urine spots to estimate sodium intake (SMD = –0.08; 95% CI = –0.10, –0.07; Figure C, available as a supplement to this article at http://www.ajph.org). Heterogeneity remained high even when fitting further random-effects models with different subgroups and exclusions (Figures D–F, available as supplements to this article at

TABLE 2—Characteristics and Quality Score of Included Articles

Reference	Country	Study Name or Sample	Age Range, Y	Sample Size, No. (% Women)	Sodium Intake Measurement Method	SES Dimension	Quality Score
Beard et al.[36]	Australia	Hobart Salt Study	18–70	194 (55)	24-h collection	Other: Index of Relative Socioeconomic Disadvantage	3 (intermediate)
Land et al.[37]	Australia	Lithgow adults	20–88	419 (55)	24-h collection	Education	2 (intermediate)
Nowson et al.[38]	Australia	Victoria Health Monitor Survey	18–75	1 040 (53)	24-h collection	Education, income, Index of Relative Socioeconomic Disadvantage	5 (higher)
Andersen et al.[39]	Denmark	Copenhagen adults	20–55	87 (58)	24-h collection	Education	1 (lower)
Hu et al.[40]	Finland	Finnish portion of Monitoring of Trends and Determinants in Cardiovascular Disease	25–64	1 935 (52)	24-h collection	Education	3 (intermediate)
Reinivuo et al.[41]	Finland	Finnish Study on Risk Factors on Chronic, Non-communicable Diseases	25–64	6 730 (55)	24-h collection	Education	3 (intermediate)
Cappuccio et al.[42]	Italy	MINISAL-GIRCSI and Meno Sale Più Salute studies	39–79	3 857 (49)	24-h collection	Education, occupation	5 (higher)
Leclercq and Ferro-Luzzi[43]	Italy	Households from 3 Italian regions	≥ 18	182 (50)	24-h collection	Other: SES (education, occupation)	2 (intermediate)
Murakami et al.[44]	Japan	Japanese women	18–22	1 105 (100)	24-h collection	Other: neighborhood socioeconomic disadvantage	3 (intermediate)
Polonia et al.[45]	Portugal	Portuguese Hypertension and Salt Study	18–90	3 720 (53)	24-h collection	Education	5 (higher)
Schoen et al.[46]	Switzerland	Swiss Salt Survey	≥ 15	1 547 (52)	24-h collection	Education	5 (higher)
Ji et al.[47]	United Kingdom	National Diet and Nutrition Survey	19–64	2 105 (55)	24-h collection, 7-d diet record	Education, occupation	4 (higher)
Angell and Eisenhower[48]	United States	Heart Follow-up Study	≥ 18	1 656 (58)	24-h collection	Poverty status	6 (higher)
Stamler et al.[49]	United States	International Study of Electrolyte Excretion and Blood Pressure	40–59	2 195 (50)	24-h collection	Education	4 (higher)
Yi et al.[50]	United States	Heart Follow-up Study	≥ 18	1 656 (58)	24-h collection	Education, poverty or income, neighborhood poverty	5 (higher)
Kho et al.[51]	South Korea	Healthy Twin Study	≥ 18	1 204 (54)	12-h collection	Education, income	5 (higher)
Caro[52]	Chile	National Health Survey (Chile)	≥ 15	5 434 (59)	Spot urine	Education, economic assistance	5 (higher)
Klenow et al.[53]	Germany	German Health Interview and Examination Survey for Adults	18–79	6 910 (52)	Spot urine	Other: SES (education, occupation, income)	5 (higher)
Hong et al.[54]	South Korea	Korean National Health and Nutrition Examination Survey	≥ 19	18 000 (55)	Spot urine	Education, income, occupation	6 (higher)
Millett et al.[55]	United Kingdom	Health Survey for England	≥ 16	6 384 (56)	Spot urine	Occupation	5 (higher)
Pfister et al.[56]	United Kingdom	Norfolk part of the European Prospective Investigation Into Cancer and Nutrition	39–79	25 639 (55)	Spot urine	Education, occupation	4 (higher)
Chien et al.[57]	Taiwan	Chin-Shan Community Cardiovascular Cohort Study	≥ 35	1 520 (52)	First morning void	Education, occupation	2 (intermediate)

Continued

TABLE 2—*Continued*

Reference	Country	Study Name or Sample	Age Range, Y	Sample Size, No. (% Women)	Sodium Intake Measurement Method	SES Dimension	Quality Score
McLaren et al.[58]	Canada	National Canada Survey, Canadian Community Health Survey	25–64	10 449 (56)	24-h dietary recall	Education, income	5 (higher)
Dubois and Girard[59]	Canada, United States	Quebec Nutrition Survey, National Health and Nutrition Examination Survey	18–74	2 103 (51)	24-h dietary recall	Education, income, occupation	4 (higher)
Buyck et al.[60]	France	Supplementation of Antioxidant Vitamins and Minerals Study	35–60	4 919 (58)	24-h dietary recall	Education	3 (intermediate)
van den Brandt et al.[61]	Netherlands	Netherlands Cohort Study	55–69	3 123 (51)	24-h dietary recall	Education	3 (intermediate)
Kim et al.[62]	South Korea	Korean National Health and Nutrition Examination Survey	≥ 20	20 777 (53)	24-h dietary recall	Education	4 (higher)
Lee et al.[63]	South Korea	Korean National Health and Nutrition Examination Survey	≥ 18	28 450 (50)	24-h dietary recall	Education, income	4 (higher)
Lee et al.[64]	South Korea	Korean National Health and Nutrition Examination Survey	≥ 20	14 539 (61)	24-h dietary recall	Education, income, occupation	5 (higher)
Beydoun and Wang[65]	United States	Continuing Food Survey on Intakes by Individuals, Diet and Health Knowledge Survey	≥ 18	4 356 (49)	24-h dietary recall	Other: perceived barrier to food price	3 (intermediate)
Cogswell et al.[66]	United States	National Health and Nutrition Examination Survey	≥ 20	12 581 (49)	24-h dietary recall	Education, income	5 (higher)
Crews et al.[67]	United States	Healthy Aging in Neighborhoods of Diversity Across the Life Span Study	30–64	2 058 (57)	24-h dietary recall	Income	3 (intermediate)
Greer et al.[68]	United States	National Health and Nutrition Examination Survey	≥ 20	8 779 (49)	24-h dietary recall	Other: modified retail food environment index	5 (higher)
Kachan et al.[69]	United States	National Health and Nutrition Examination Survey	≥ 18	8 987 (46)	24-h dietary recall	Occupation	6 (higher)
Meyer et al.[70]	United States	Minnesota Heart Study	25–74	10 863 (53)	24-h dietary recall	Education	4 (higher)
Popkin et al.[71]	United States	National Food Consumption Survey	≥ 18	32 406 (50)	24-h dietary recall	Other: SES (education, income)	4 (higher)
Welsh et al.[72]	United States	Shawnee County Survey	≥ 18	834 (52)	24-h dietary recall	Education, income	5 (higher)
Yang et al.[73]	United States	National Health and Nutrition Examination Survey	≥ 20	12 267 (52)	24-h dietary recall	Education	4 (higher)
Ji and Cappuccio[74]	United Kingdom	National Diet and Nutrition Survey	19–64	1 027 (56)	4-d food diary	Education, occupation	5 (higher)
Schröder et al.[75]	Spain	Gerona adults	25–74	1 577 (52)	72-h dietary recall	Education	4 (higher)
McCartney et al.[76]	Ireland	Young Dublin women	18–35	216 (100)	7-d dietary recall	Other: disadvantage status	3 (intermediate)
Meneton et al.[77]	France	French Food Safety Agency Survey	15–92	1 474 (54)	7-d food record	Income, occupation	5 (higher)
Miyaki et al.[78]	Japan	Japan Hospice and Palliative Care Evaluation Study	21–65	2 266 (11)	Dietary history questionnaire	Education, income	4 (higher)

Continued

TABLE 2—*Continued*

Reference	Country	Study Name or Sample	Age Range, Y	Sample Size, No. (% Women)	Sodium Intake Measurement Method	SES Dimension	Quality Score
Fukuda and Hiyoshi[79]	Japan	Comprehensive Survey of Living Conditions and the National Health and Nutrition Survey	18–74	22 712 (50)	Dietary records	Income	5 (higher)
Mishra et al.[80]	Australia	Australia Longitudinal Study on Women's Health	50–55	10 561 (100)	FFQ	Occupation	3 (intermediate)
Smith and Baghurst[81]	Australia	Australian adults	≥ 18	1 500 (50)	FFQ	Occupation, education, income	3 (intermediate)
Zhang et al.[82]	Australia	Melbourne Chinese Cohort Study	≥ 25	262 (48)	FFQ	Education, income, occupation	3 (intermediate)
Si Hassen et al.[32]	France	Determinants of Diet and Physical Activity Study	≥ 18	91 900 (78)	FFQ	Education, income, occupation	4 (higher)
Ilow et al.[83]	Poland	Polish–Norwegian Study	45–65	3 862 (67)	FFQ	Education	3 (intermediate)
Beer-Borst et al.[84]	Switzerland	Bus Santé	35–74	13 335 (50)	FFQ	Education, occupation	4 (higher)
Gerber et al.[85]	United States	Pitt County Study	25–50	1 784 (58)	FFQ	Other: SES (education, occupation)	5 (higher)

Note. FFQ = food frequency questionnaire; SES = socioeconomic status.

http://www.ajph.org), and the effect size remained largely unchanged after sequentially excluding each study population (Figure G, available as a supplement to this article at http://www.ajph.org). Meta-regressing the estimated sodium intake on the level of SES indicator showed a change of −126 milligrams per day per each increase in SES (P value = .03; Table D, available as a supplement to this article at http://www.ajph.org). No evidence of publication bias was found (Kendall $\tau = -0.11$; $P = .49$; Egger bias = −1.56; $P = .08$; Figure H, available as a supplement to this article at http://www.ajph.org).

Nineteen articles provided associations between the sodium to potassium ratio and a SES indicator. We calculated the ratio from 8 articles that reported both sodium and potassium intake disaggregated by SES.[36,46,66,67,70,76,80,85] Of 41 total associations, 30 were negative (73%), 2 positive (5%), and 9 nonsignificant (24%).

Among articles that reported urine-based sodium intake estimates, the pattern of association with SES was generally negative in all world regions, ranging from 50% of all associations that were negative in Australia, East Asia, and North America to 77% in Western Europe. However, no clear pattern emerged among articles that reported diet-based sodium intake estimates.

Only 7 articles reported associations between sodium intake and SES across time.[55,58,62,64,70,71,74] One article found that despite a nationwide decrease in sodium intake since the year 2000 in the United Kingdom, the relative difference in sodium intake between low and high SES remained unchanged after 10 years.[74] Another article from England found that the relative difference in sodium intake remained unchanged from 2004 to 2007.[55] One article from South Korea found that between 1998 and 2005 the relative difference in sodium intake increased from −5% to −9% among men and from −6% to −16% among women.[62] Another article found that the relative difference decreased for education but increased for income.[64] Finally, 1 article found that the relative difference tended to decrease from 1985 to 2009 in the United States.[70]

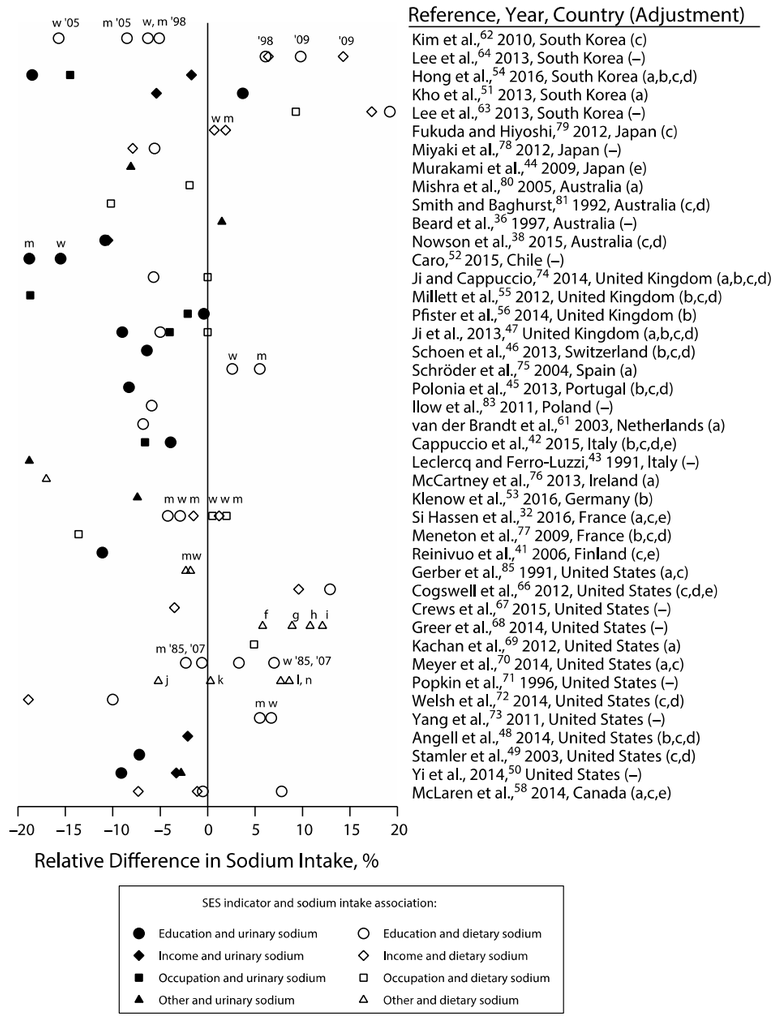
Only 12 articles reported sodium intake by SES separately by gender. In 7 of these articles, the direction of the association was the same between men and women.[48,56,62,70,73,75,85] One article found a positive association among women but none among men.[32] Two articles found a negative association among women but none among men.[41,58] Another article found negative associations among men for education and income but a positive association for occupation and no associations among women.[82] Finally, 1 article found a negative association among women but a positive association among men.[79]

DISCUSSION

To our knowledge, this is the first systematic review and meta-analysis summarizing the evidence for an association of SES with sodium intake in healthy adult populations of HICs. Most observed associations and the SMD from the meta-analysis point to higher sodium intake among low-SES groups than among high-SES groups. Our results are in line with previous reports of suboptimal dietary intake among low-SES populations[9–11] and confirm the existence of socioeconomic inequalities in diet in HICs.

Urine-Based Sodium Intake and Socioeconomic Status

The strongest evidence originated in reports that used urine-based sodium intake estimate. Most of the associations were negative, indicating that low-SES groups had higher sodium intake than did high-SES groups. In our meta-analysis we found that

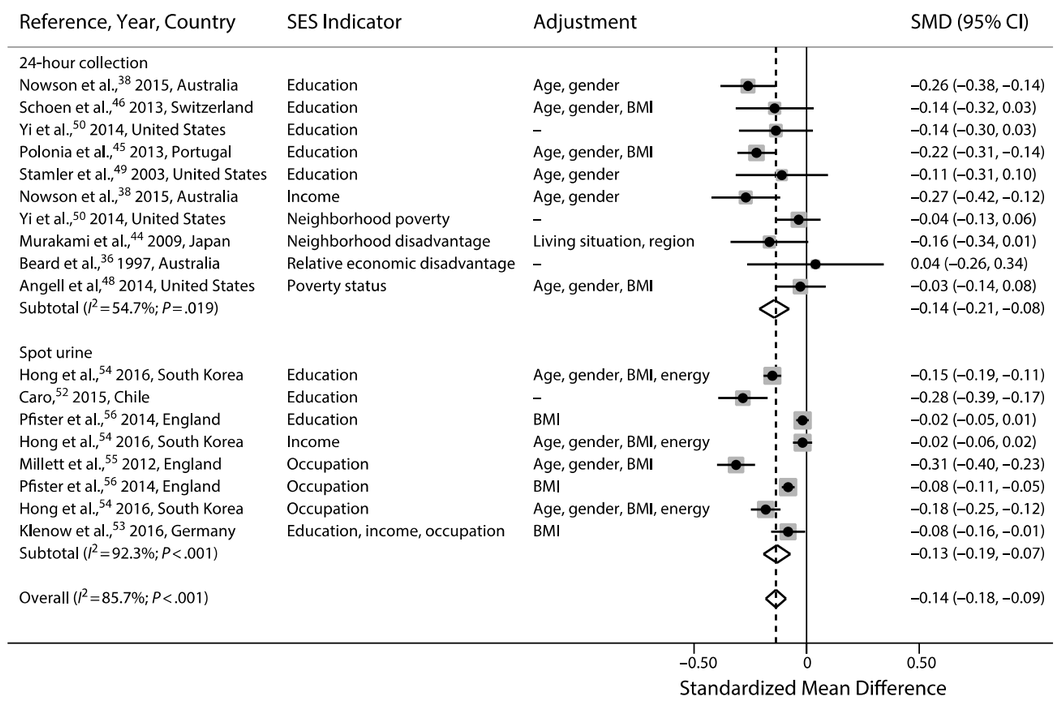


Note. m = men; SES = socioeconomic status; w = women. The formula for relative difference is ([value for high-SES group – value for low-SES group]/[value for high-SES group]) × 100. We adjusted the estimated sodium intake for (a) energy, (b) body mass index, (c) age, (d) gender, and (e) other. Sample description: a specific year is indicated with its last 2 digits (e.g., 1998 is indicated as '98); (f) Southern United States sample neighborhood poverty, (g) non-Southern United States sample neighborhood poverty, (h) Southern US sample poverty to income ratio, (i) non-Southern US sample poverty to income ratio, (j) 1977 African American sample, (k) 1989 African American sample, (l) 1989 Caucasian sample, and (m) 1977 Caucasian sample.

FIGURE 2—Forest Plot of Relative Difference in Daily Sodium Intake Between Low- and High-SES Groups

low-SES groups had 14% higher sodium intake than that of high-SES groups. Heterogeneity was present in the overall effect size, likely owing in part to different sample sizes across included studies (193–19 857), varying and disproportionate representation of SES groups (the low-SES to high-SES participants ratio ranged from 0.20 to 2.34), which contributed to widely different and nonoverlapping 95% CIs. Nevertheless, the overall effect size was similar between estimates of sodium intake from 24-hour urine collection and from urine spots. In sensitivity analyses, different subgroups by SES indicator, adjustment for confounding, and exclusions of each study sequentially failed to explain the heterogeneity observed. Importantly, the meta-regression confirmed the association between SES and sodium intake.

Because of the dose–response nature of sodium's effect on blood pressure,[2,3] our



Note. BMI = body mass index; CI = confidence interval; SES = socioeconomic status; SMD = standard mean difference. SMDs are presented separately by urine-based sodium measurement method.

FIGURE 3—Forest Plot From Random-Effects Model Meta-Analysis Showing the Standardized Mean Difference in Sodium Intake Between Low- and High-SES Groups

finding of 14% higher sodium intake by low-SES groups may translate into an increased risk of hypertension and cardiovascular disease. Extending previous projections of the effect of salt reduction on future cardiovascular disease to our findings, reducing the daily sodium intake of low-SES groups in the United States to the level of high-SES groups—a reduction of approximately 400 milligrams per day—could prevent annually 20 000 to 40 000 new cases of coronary heart disease, 11 000 to 23 000 new cases of stroke, and 15 000 to 32 000 deaths from any cause and save US $4.1 to US $7.0 billion in health care costs.[86]

Diet-Based Sodium Intake and Socioeconomic Status

Among reports of diet-based sodium intake estimates, the pattern of association with SES was less consistent. For example, 2 studies from South Korea reported opposite findings,[62,64] which may be because of SES categorization and adjustment for confounding factors: the categorization of education was considerably different and the study that found a positive association failed to adjust sodium intake estimates for any potential confounding factor.[64] The United States stood out as showing positive associations between SES and diet-based sodium intake, particularly in the National Health and Nutrition Examination Survey samples, regardless of adjustments for potential confounders. This may be because of strong recall and social desirability biases influencing participants' responses to the dietary instruments—a common limitation in dietary surveys. Interestingly, the only 2 studies assessing sodium intake from 24-hour urine collections in the United States found negative associations.[48,49]

The predominantly negative association observed with the sodium to potassium ratios supports previous findings of significantly lower potassium intake in low- versus high-SES groups.[9] Only a minority of articles reported the association between SES and sodium intake across different years, and no clear pattern could be observed; this highlights the need for improved measuring and reporting of data by SES to enable trends assessments.

Our findings also highlight the need for future research to report sodium intake in a disaggregated way using more than 1 measure of SES to better track changes in sodium intake in different population groups and to assess the impact of public health efforts to reduce socioeconomic inequalities in diet.

Public Health Implications

Although our findings indicate that low-SES populations have greater sodium

intake than do high-SES populations, it is important to note that sodium intake was above the World Health Organization recommended limit for all SES groups in all included articles. Interventions aimed at reducing sodium intake should, therefore, target the overall population but need to take into account the higher salt consumption in low-SES groups. This may contribute to the increased risk of hypertension and cardiovascular disease in low-SES populations.

Thus, in line with the United Nations Global Action Plan to reduce mean population sodium intake to 2 grams per day (5 g/day of salt), as part of the global target of 25% relative reduction in NCD mortality by 2025,[17] and the Global Action Plan on Social Determinants of Health to eliminate avoidable health inequalities,[19] appropriate public health interventions are urgently needed. Downstream interventions that focus on individual factors (e.g., education and media programs) tend to increase socioeconomic inequalities[87,88] and should be implemented with caution. In countries where cooking and table salt contributes significantly to sodium intake, inclusion of nutritional education in school curricula should be explored.[89]

Conversely, upstream interventions that focus on structural changes have the greatest potential to reduce socioeconomic inequalities in sodium intake.[87,89,90] One option is to restrict or eliminate advertisements of unhealthy fast food, particularly those aimed at children and adolescents, as attempted in the United Kingdom.[91] Another option, likely to have the most impact, is to legislatively mandate salt content reduction in processed food production, mirroring successful legislation to remove trans-fatty acids from processed foods in several HICs.[90]

Limitations

Our findings must be interpreted in light of several limitations. All the observed associations originated from cross-sectional analyses that used different sodium intake measurement methods. Only 15 studies used the gold standard method (24-hour urine collection), whereas the remaining studies estimated sodium intake using a variety of suboptimal methods. Estimates that derived from spot urine tests may have underestimated the relative difference in sodium intake between SES groups, because this method tends to underestimate sodium intake at high levels and to overestimate it at low levels.[92] Among studies that used dietary surveys, misreporting of sodium intake was likely common, because social desirability and reporting bias may contribute to underestimations; this is unlikely to have affected urine-based estimations, however. These widely different measurement methods likely contributed to differences in reported mean sodium intake between studies.[92,93] This heterogeneity is an important issue when estimating overall sodium intake or when comparing estimates between different populations. However, this is less of an issue in a study such as ours, which compared within-study differences in sodium intake between SES groups.

Studies also differed in the range of socioeconomic indicators included and in their categorization, making it difficult to compare relative and absolute SES differences between studies. We attempted to minimize this bias by taking only the 2 extreme groups, as previous systematic reviews have done.[10,24–26,29–31] Although most articles attained higher-quality scores, more than half included only 1 measure of SES, and almost half failed to adjust the reported sodium intake by energy intake, body mass index, age, or gender. In sensitivity analysis, the meta-regression showed that the higher the SES level, the lower the sodium intake. Although the Kendall τ and the Egger test showed no indication of publication bias, it cannot be ruled out with confidence.

Finally, our review focused only on HICs, but SES has been shown to influence diet quality in LMICs as well.[24] Future research should assess SES differences in sodium intake in LMICs and the impact of changes in sodium intake, particularly as these countries undergo rapid demographic, nutritional, and epidemiological transitions.

Conclusions

This systematic review and meta-analysis indicates that people of low SES likely consume more sodium than do people of high SES, which may influence the disproportionately higher burden of NCDs in socioeconomically disadvantaged groups. Our results strengthen the importance of existing global and regional targets to reduce sodium intake at the population level and should inform public health policies and interventions aimed at reducing socioeconomic disparities in diet quality and health, especially as countries work toward meeting the global target of 25% relative reduction in NCD mortality by 2025. AJPH

CONTRIBUTORS

C. de Mestral conducted the meta-analysis and sensitivity analyses, prepared tables and figures, and wrote the article. C. de Mestral, A.-L. Mayén, and D. Petrovic completed the literature search, selected articles, extracted data, and synthesized findings. C. de Mestral and S. Stringhini conceptualized the study. P. Marques-Vidal and M. Bochud provided statistical expertise. S. Stringhini had primary responsibility for final content. All authors revised the article, provided critical recommendations on structure and presentation, and approved the final article.

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HUMAN PARTICIPANT PROTECTION

Institutional review board approval was not needed for this systematic review and meta-analysis because data were obtained from secondary sources.

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Supplemental material

Table A. Literature search strategy and results by search engine

Search engine	Search terms	Results
Pubmed	(sodium[Title/Abstract] OR salt[Title/Abstract] OR NaCl[Title/Abstract]) AND (intake[Title/Abstract] OR diet[Title/Abstract] OR consumption[Title/Abstract] OR food[Title/Abstract] OR eating[Title/Abstract] OR ingestion[Title/Abstract]) AND (socioeconomic OR "socio-economic" OR "social class" OR "social status" OR "social position" OR education OR income OR occupation OR profession OR poor OR poverty OR disadvantaged) NOT (patients[Title/Abstract] OR pregnant[Title/Abstract] OR newborn*[Title/Abstract] OR infant*[Title/Abstract] OR children[Title/Abstract] OR student*[Title/Abstract] OR adolescent*[Title/Abstract] OR animal*[Title/Abstract] OR mice[Title/Abstract] OR mouse[Title/Abstract] OR rat[Title/Abstract] OR	1407
Embase	sodium OR salt OR NaCl AND (intake OR diet OR consumption OR food OR eating OR ingestion) AND (socioeconomic OR 'socio-economic' OR 'social class' OR 'social status' OR 'social position' OR education OR income OR occupation OR profession OR poverty OR poor OR disadvantaged) NOT (patient OR patients OR pregnant OR pregnancy OR newborn OR newborns OR infant OR infants OR children OR student OR students OR adolescent OR adolescents OR animal OR rat OR rats OR mouse OR mice) AND ([article]/lim OR [review]/lim) AND ([english]/lim OR [french]/lim OR [italian]/lim OR [portuguese]/lim OR [spanish]/lim) AND ([young adult]/lim OR [adult]/lim OR [middle aged]/lim) AND [embase]/lim	513
SciELO	(sodio OR sal OR NaCl) AND (socioeconomico OR inequidad OR desigualdad OR "diferencias sociales" OR ingreso OR sueldo OR salario OR educacion OR escolaridad OR ocupacion OR rango) AND (consumo OR ingesta OR nutricion OR alimento OR dieta)	77
	Total search results	1997

Table B. List of corresponding authors contacted to request data results

Corresponding author	Outcome
Pfister (1)	Responded, provided data results
Crews (2)	Responded, provided data results
Laverty (3)	Responded, provided data results
Schoen (4)	Responded, provided data results
Klenow (5)	Responded, provided data results
Caro (6)	Responded, provided data results
Polonia (7)	Responded, provided data results
van den Brandt (8)	Responded, unable to provide data results
Popkin (9)	Responded, unable to provide data results
Zhang (10)	Responded, unable to provide data results within time
Reinivuo (11)	Responded, unable to provide data results within time
Guessous (12)	Responded, unable to provided data results
Dubois (13)	No response
McCartney (14)	No response
Cappuccio (15)	No response
Kim (16)	No response
Yi (17)	No response
Stamler (18)	No response
Leclercq (19)	No response
Chien (20)	No response
Miyaki (21)	No response
Buyck (22)	No response
Cogswell (23)	No response
Land (24)	No response
Fukuda (25)	No response
Mishra (26)	Unreachable
Hu (27)	Unreachable
Schröder (28)	Unreachable

Table C. Criteria for quality score assessment

Author, year (reference #)	Community- or population-based study design? (+1)	Representative sample? (+1)	More than 1 SES dimension? (+1)	Hierarchical, graded SES categories? (+1)	SES-sodium association adjusted for any energy, BMI, age, sex (where	SES-sodium association results presented with mean values, SD,	Quality score
Beard, 1997	1	1	0	0	0	1	3
Land, 2014	1	0	0	1	0	0	2
Nowson,	1	1	1	1	0	1	5
Andersen,	1	0	0	0	0	0	1
Hu, 2005	1	1	0	0	1	0	3
Reinivuo,	1	1	0	0	1	0	3
Cappuccio,	1	1	1	1	1	0	5
Leclercq,	1	0	0	1	0	1	3
Murakami,	0	0	0	1	1	1	3
Polonia,	1	1	0	1	1	1	5
Schoen, 2013	1	1	0	1	1	1	5
Ji, 2013	1	1	1	1	1	0	5
Angell, 2014	1	1	1	1	1	1	6
Stamler,	1	1	0	1	1	0	4
Yi, 2014	1	1	1	1	0	1	5
Kho, 2013	1	1	1	0	1	1	5
Caro, 2015	1	1	1	1	0	1	5
Klenow,	1	1	0	1	1	1	5
Hong, 2016	1	1	1	1	1	1	6
Millett, 2012	1	1	0	1	1	1	5
Pfister, 2014	1	1	0	0	1	1	4
Chien, 2008	0	0	1	0	1	0	2
McLaren,	1	1	1	1	1	0	5
Dubois, 2001	1	1	1	0	1	0	4
Buyck, 2009	1	1	0	1	0	0	3
Brandt, 2003	1	0	0	1	1	0	3
Kim, 2010	1	1	0	1	1	0	4
Lee W, 2013	1	1	1	0	1	0	4
Lee H, 2015	1	1	1	1	0	1	5
Beydoun,	1	1	1	0	0	0	3
Cogswell,	1	1	1	1	0	1	5
Crews, 2015	1	1	0	0	1	0	3
Greer, 2014	1	1	1	1	0	1	5
Kachan,	1	1	1	1	1	1	6
Meyer, 2014	1	1	0	0	1	1	4
Popkin, 1996	1	1	0	1	0	1	4
Welsch,	1	1	1	0	1	1	5
Yang, 2011	1	1	0	1	0	1	4
Ji, 2014	1	1	1	1	1	0	5
Schröder,	1	1	0	1	1	0	4
McCartney,	1	0	0	0	1	1	3
Meneton,	1	1	0	1	1	1	5
Miyaki, 2013	0	0	1	1	1	1	4
Fukuda,	1	1	0	1	1	1	5
Mishra,	1	1	0	1	0	0	3
Smith, 1992	1	0	0	1	1	0	3
Zhang, 2002	1	1	1	0	0	0	3
Hassen, 2016	1	0	1	1	1	0	4
Ilow, 2011	1	0	0	1	0	1	3
Beer-Borst,	1	1	0	1	1	0	4
Gerber, 1991	1	1	0	1	1	1	5

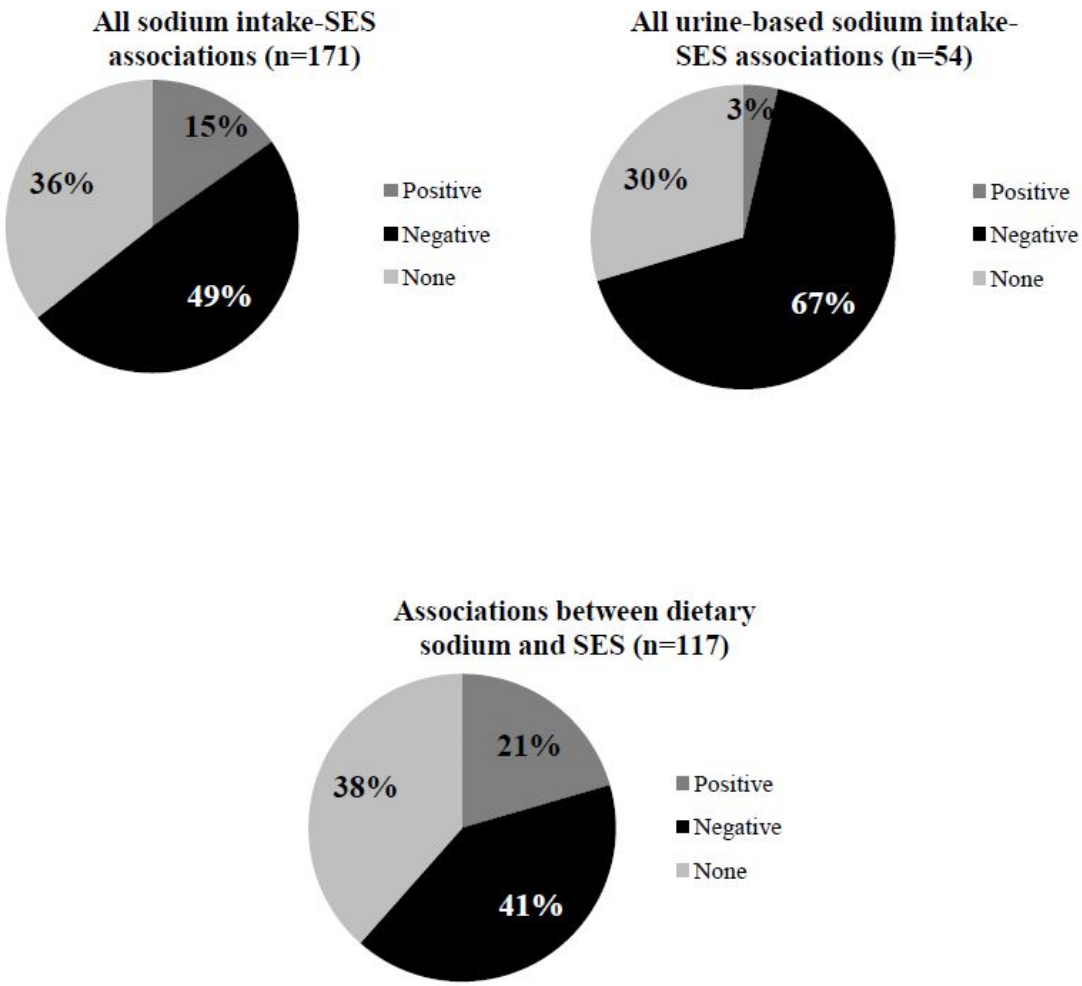
Adapted from previously published quality scoring criteria

Table D. Meta-regression sodium intake by levels of SES indicator

Explanatory	Coefficient	P-value	95% CI
Level of SES indicator[1]	-126	0.03	-240 , -12

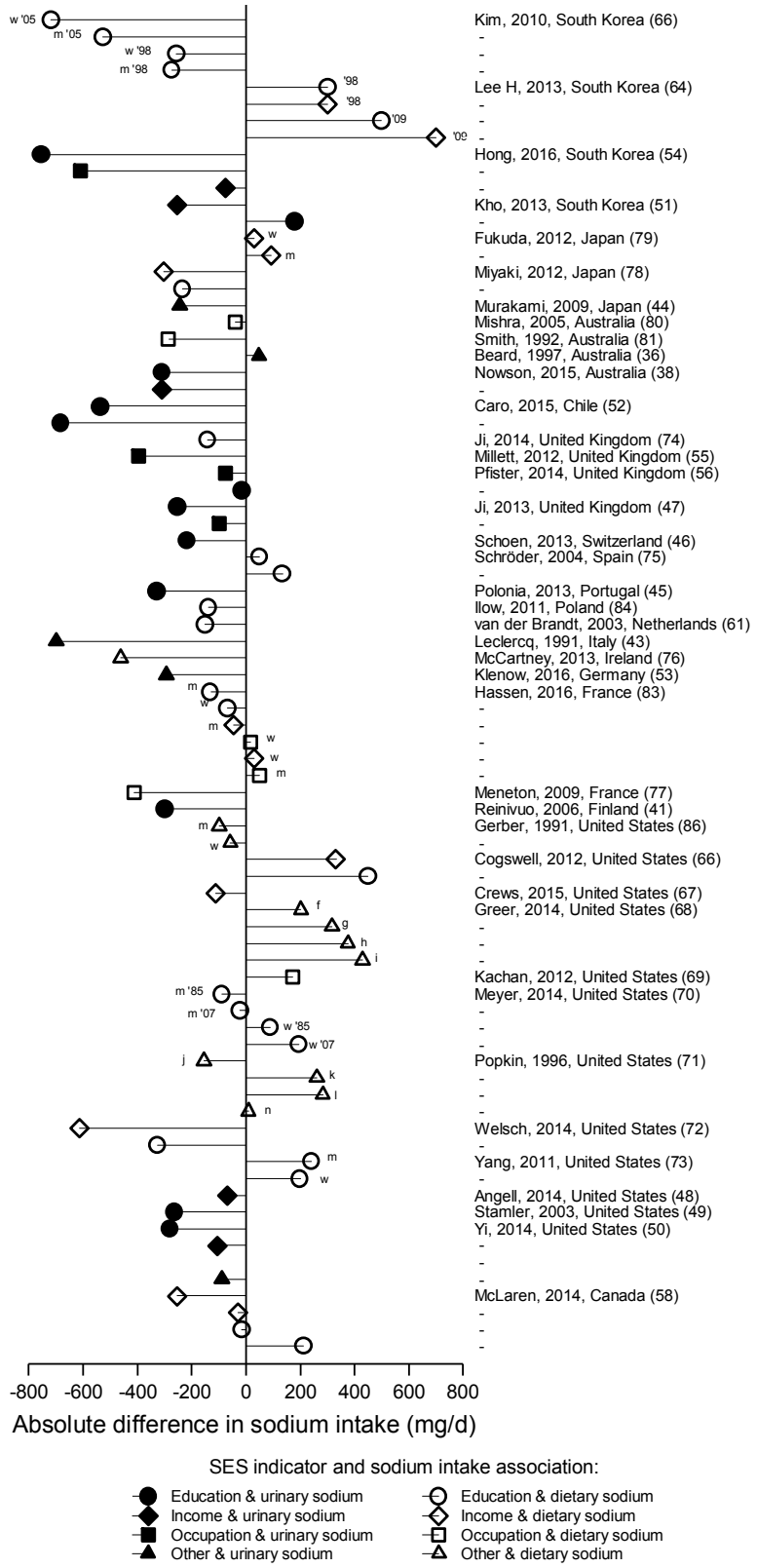
[1] Level of SES indicator: 1 (lowest SES group), 2, 3, 4, 5, 6.
Meta-regression model was conducted using the metareg command in Stata

Figure A. Overall pattern of direction in reported associations between SES and sodium intake from 51 papers included in systematic review



A positive association indicates that people of higher socioeconomic status consumed more sodium than people of lower socioeconomic status. A negative association indicates that people of lower socioeconomic status consumed more sodium than people of higher socioeconomic statuS

Figure B. Forest plot of absolute differences in sodium intake (mg/day) between high- and low-SES groups from papers for which data were shown



Absolute difference formula: Sodium intake in high-SES group – sodium intake in low-SES group; Sodium intake adjusted for: a) Energy, b) BMI, c) age, d) sex, e) other; Sample description: w) women, m) men; specific year indicated with last two digits (e.g., 1998 indicated as '98); f) Southern USA sample-neighborhood poverty, g) Non-Southern USA sample -neighborhood poverty, h) southern USA sample-poverty-income ratio, i) Non-Southern USA sample-poverty-income ratio, j) African-American sample-1977, k) African-American sample-1989, l) Caucasian sample-1989, n) Caucasian sample-1977.

Figure C. Fixed-effects meta-analysis results for the standardized mean difference between high- and low-SES groups, disaggregated by urine-based sodium intake method

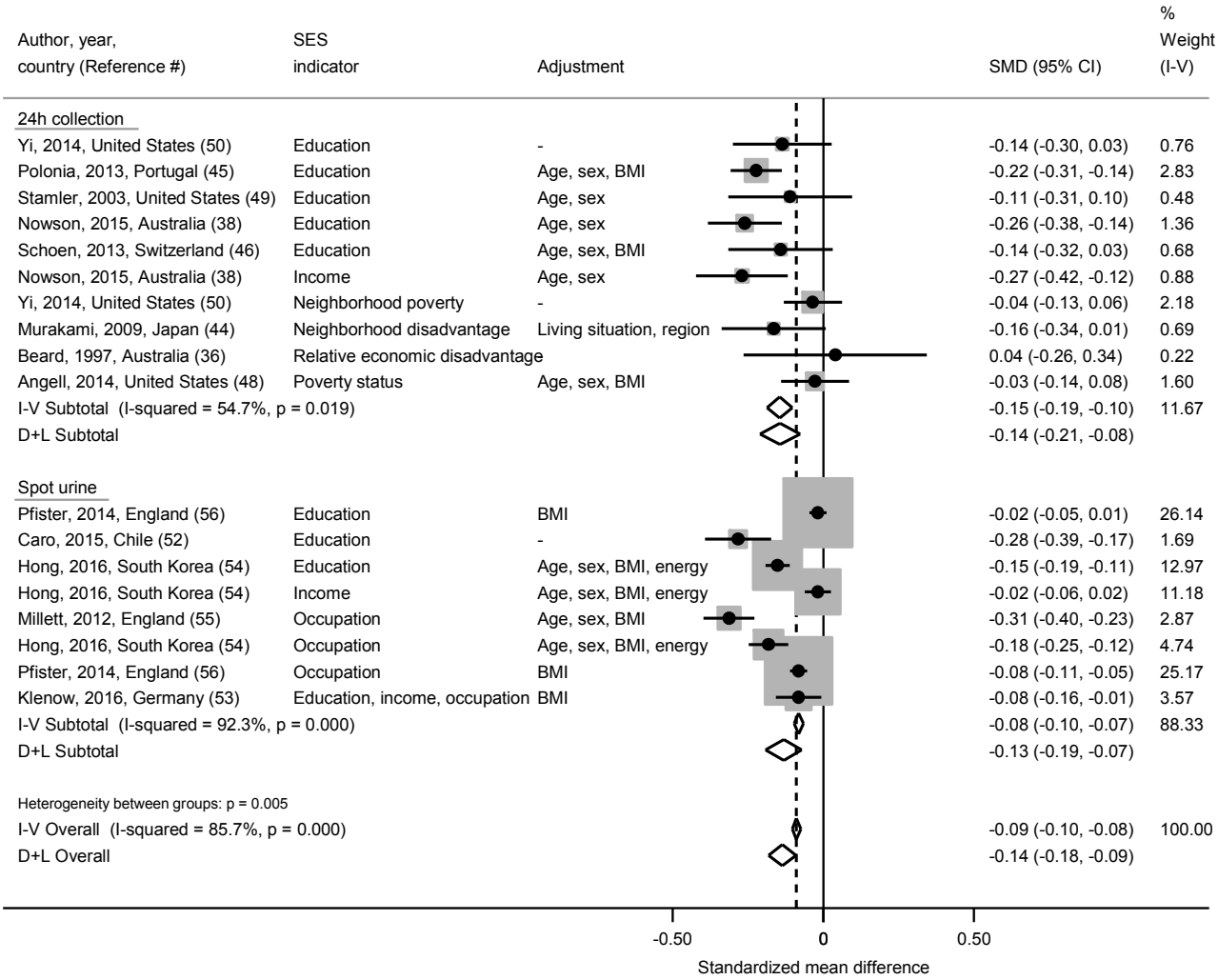


Figure D. Random-effects meta-analysis for the standardized mean difference between high- and low-SES groups, disaggregated by SES indicator

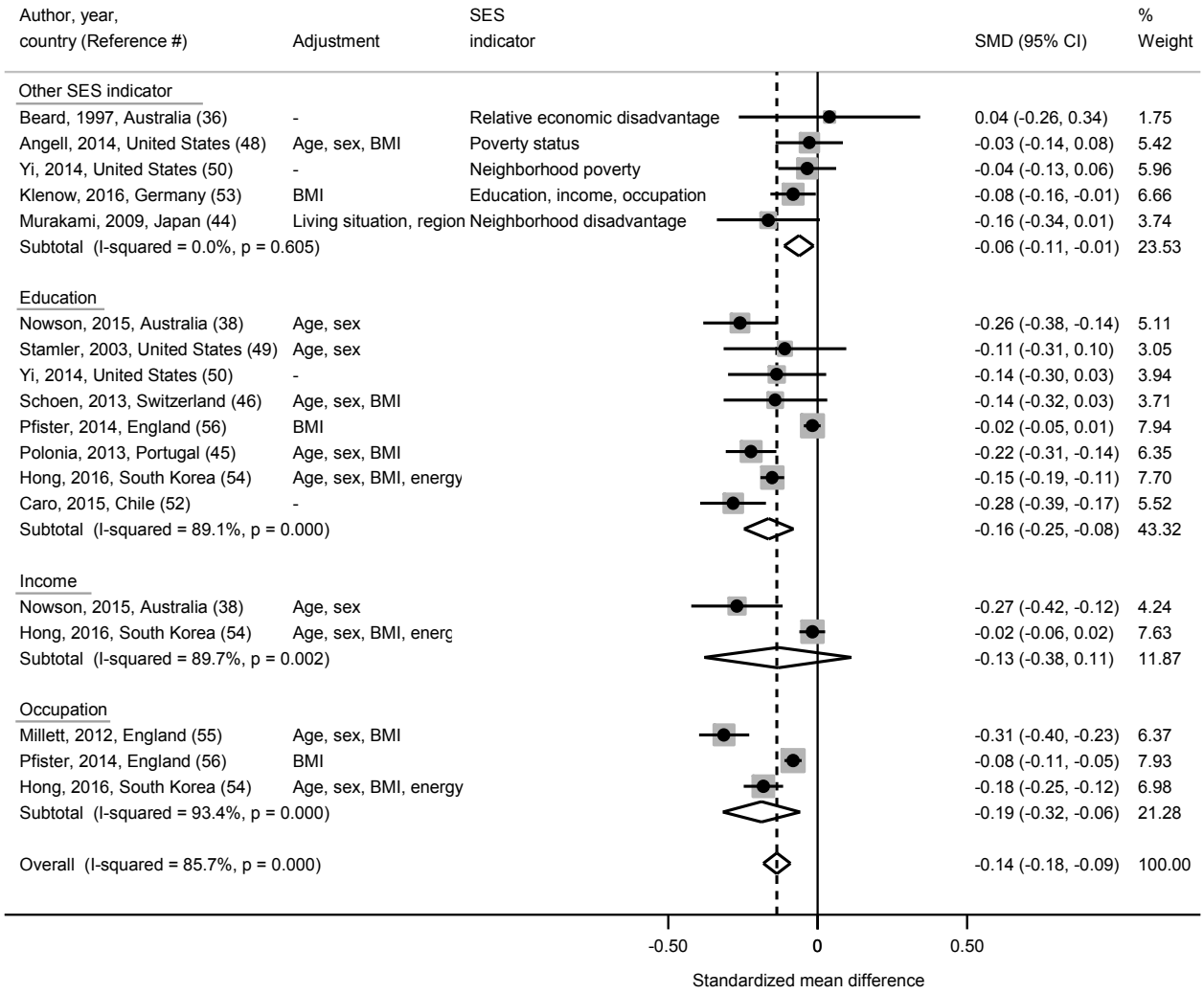


Figure E. Random-effects meta-analysis for the standardized mean difference between high- and low-SES groups, separately for adjusted vs non-adjusted models for sodium intake

Author, year, country (Reference #)	SES indicator	Adjustment	Sodium measurement method	SMD (95% CI)	% Weight
Unadjusted sodium estimates					
Beard, 1997, Australia (36)	Relative economic disadvantage	-	24h collection	0.04 (-0.26, 0.34)	1.75
Yi, 2014, United States (50)	Education	-	24h collection	-0.14 (-0.30, 0.03)	3.94
Yi, 2014, United States (50)	Neighborhood poverty	-	24h collection	-0.04 (-0.13, 0.06)	5.96
Caro, 2015, Chile (52)	Education	-	Spot urine	-0.28 (-0.39, -0.17)	5.52
Subtotal (I-squared = 75.6%, p = 0.006)				-0.12 (-0.27, 0.02)	17.16
Adjusted sodium estimates					
Nowson, 2015, Australia (38)	Education	Age, sex	24h collection	-0.26 (-0.38, -0.14)	5.11
Nowson, 2015, Australia (38)	Income	Age, sex	24h collection	-0.27 (-0.42, -0.12)	4.24
Stamler, 2003, United States (49)	Education	Age, sex	24h collection	-0.11 (-0.31, 0.10)	3.05
Angell, 2014, United States (48)	Poverty status	Age, sex, BMI	24h collection	-0.03 (-0.14, 0.08)	5.42
Millett, 2012, England (55)	Occupation	Age, sex, BMI	Spot urine	-0.31 (-0.40, -0.23)	6.37
Klenow, 2016, Germany (53)	Education, income, occupation	BMI	Spot urine	-0.08 (-0.16, -0.01)	6.66
Pfister, 2014, England (56)	Occupation	BMI	Spot urine	-0.08 (-0.11, -0.05)	7.93
Schoen, 2013, Switzerland (46)	Education	Age, sex, BMI	24h collection	-0.14 (-0.32, 0.03)	3.71
Pfister, 2014, England (56)	Education	BMI	Spot urine	-0.02 (-0.05, 0.01)	7.94
Polonia, 2013, Portugal (45)	Education	Age, sex, BMI	24h collection	-0.22 (-0.31, -0.14)	6.35
Murakami, 2009, Japan (44)	Neighborhood disadvantage	Living situation, region	24h collection	-0.16 (-0.34, 0.01)	3.74
Hong, 2016, South Korea (54)	Education	Age, sex, BMI, energy	Spot urine	-0.15 (-0.19, -0.11)	7.70
Hong, 2016, South Korea (54)	Income	Age, sex, BMI, energy	Spot urine	-0.02 (-0.06, 0.02)	7.63
Hong, 2016, South Korea (54)	Occupation	Age, sex, BMI, energy	Spot urine	-0.18 (-0.25, -0.12)	6.98
Subtotal (I-squared = 87.6%, p = 0.000)				-0.14 (-0.19, -0.09)	82.84
Overall (I-squared = 85.7%, p = 0.000)				-0.14 (-0.18, -0.09)	100.00

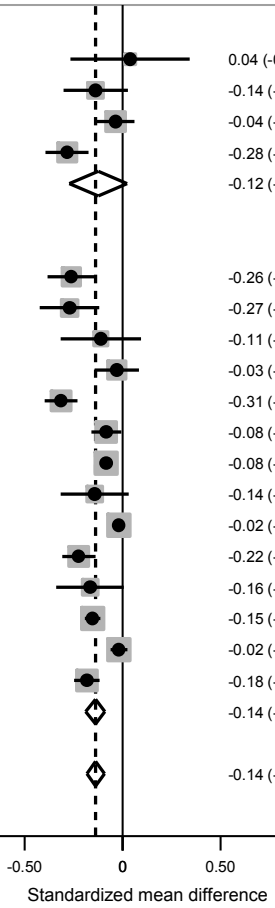


Figure F. Random-effects meta-analysis for the standardized mean difference between high- and low-SES groups, disaggregated by urine-based sodium intake method and excluding studies rated as lower or intermediate quality

Author, year, country (Reference #)	SES indicator	Adjustment	SMD (95% CI)	% Weight
24h collection				
Nowson, 2015, Australia (38)	Education	Age, sex	-0.26 (-0.38, -0.14)	5.42
Nowson, 2015, Australia (38)	Income	Age, sex	-0.27 (-0.42, -0.12)	4.51
Stamler, 2003, United States (49)	Education	Age, sex	-0.11 (-0.31, 0.10)	3.25
Angell, 2014, United States (48)	Poverty status	Age, sex, BMI	-0.03 (-0.14, 0.08)	5.75
Yi, 2014, United States (50)	Education	-	-0.14 (-0.30, 0.03)	4.19
Yi, 2014, United States (50)	Neighborhood poverty	-	-0.04 (-0.13, 0.06)	6.31
Schoen, 2013, Switzerland (46)	Education	Age, sex, BMI	-0.14 (-0.32, 0.03)	3.95
Polonia, 2013, Portugal (45)	Education	Age, sex, BMI	-0.22 (-0.31, -0.14)	6.72
Subtotal (I-squared = 61.9%, p = 0.010)			-0.15 (-0.22, -0.08)	40.09
Spot urine				
Millett, 2012, England (55)	Occupation	Age, sex, BMI	-0.31 (-0.40, -0.23)	6.74
Klenow, 2016, Germany (53)	Education, income, occupation	BMI	-0.08 (-0.16, -0.01)	7.04
Pfister, 2014, England (56)	Occupation	BMI	-0.08 (-0.11, -0.05)	8.36
Pfister, 2014, England (56)	Education	BMI	-0.02 (-0.05, 0.01)	8.37
Hong, 2016, South Korea (54)	Education	Age, sex, BMI, energy	-0.15 (-0.19, -0.11)	8.12
Hong, 2016, South Korea (54)	Income	Age, sex, BMI, energy	-0.02 (-0.06, 0.02)	8.05
Hong, 2016, South Korea (54)	Occupation	Age, sex, BMI, energy	-0.18 (-0.25, -0.12)	7.38
Caro, 2015, Chile (52)	Education	-	-0.28 (-0.39, -0.17)	5.85
Subtotal (I-squared = 92.3%, p = 0.000)			-0.13 (-0.19, -0.07)	59.91
Overall (I-squared = 87.2%, p = 0.000)			-0.14 (-0.19, -0.09)	100.00

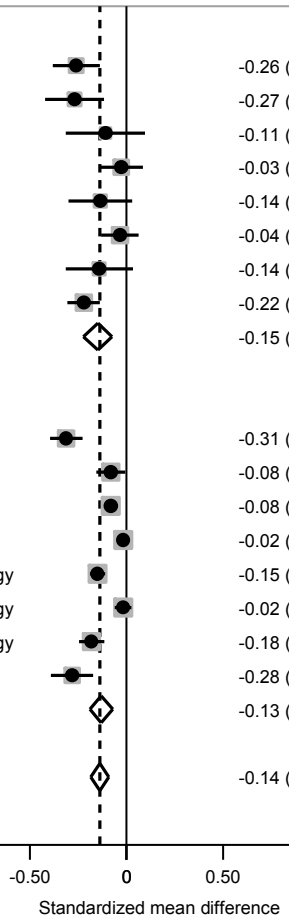


Figure G. Forest plot showing the results of each random-effects meta-analysis for the standardized mean difference between high- and low-SES groups after sequential removal of each study

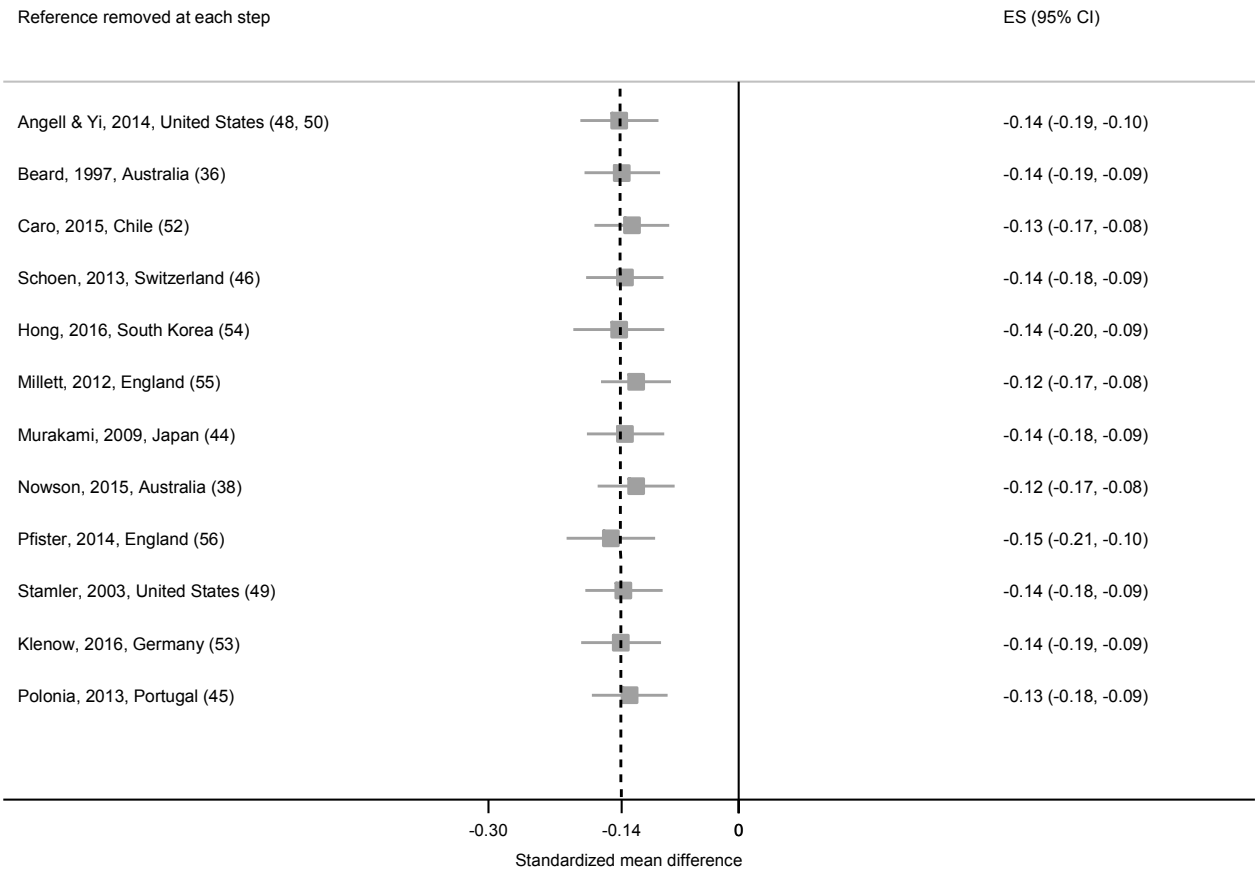
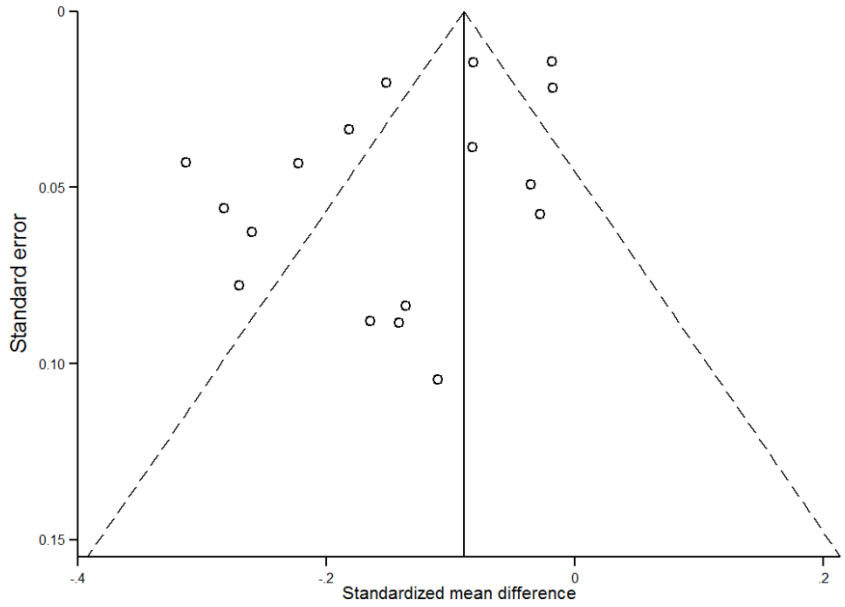


Figure H. Funnel plot for random-effects meta-analysis results for the standardized mean difference high- and low-SES groups to assess small-study publication bias



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Chapter 3 Barriers to healthy eating in Switzerland: a nationwide study

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Original article

Barriers to healthy eating in Switzerland: A nationwide study

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SUMMARY

Background & aims: Several barriers can hinder healthy eating in the population. We aimed to assess the prevalence of self-reported barriers to healthy eating in Switzerland and examine their socioeconomic and demographic determinants.

Methods: Using representative cross-sectional data from the Swiss Health Survey 2012, we assessed, separately by gender, the prevalence of ten barriers and their association with demographic and socioeconomic determinants; we used age- and multivariable-adjusted logistic regression and report the odds ratio for likelihood to identify each barrier according to each demographic and socioeconomic determinant.

Results: The most prevalent barriers were "price" (43.2% in women, 35.8% in men), "daily habits, constraints" (39.8%, 37.5%), "fondness of good food" (38.8%, 51.0%), "time constraint" (34.8%, 29.0%) and "lack of willpower" (22.0%, 21.2%). Prevalence of most barriers decreased with age, increased for "fondness of good food" and remained constant for "price." After multivariable adjustment, obese participants were more likely to report "fondness of good food" [Odds ratio (95% confidence interval) for obese vs. normal weight women and men, respectively: 1.63 (1.38–1.91), 2.02 (1.72–2.38)]. Participants with lower education were more likely to report "fondness of good food" [mandatory vs. tertiary women and men, respectively: 1.93 (1.62–2.39), 1.51 (1.26–1.81)], but less likely to report "lack of willpower" [0.45 (0.38–0.55), 0.40 (0.33–0.49)] and "time constraint" [0.61 (0.51–0.73), 0.78 (0.63–0.96)]. Participants with lower income were more likely to report "price" [lowest vs. highest quartile for women and men, respectively, 1.65 (1.43–1.90), 1.47 (1.26–1.71)] but less likely to report "lack of willpower" [0.71 (0.61–0.82), 0.40 (0.33–0.49)]. Smoking, living situation, nationality and living area showed little or no association.

Conclusion: Several barriers to healthy eating were highly prevalent regardless of gender; the most important determinants were age, obesity, education, and income, with different effects per barrier. This requires multifaceted interventions to tackle several barriers simultaneously.

1. Introduction

Healthy eating is associated with lower risk of developing many chronic noncommunicable diseases such as obesity, diabetes, hypertension, myocardial infarction, stroke and many forms of cancer [1,2], all of which disproportionately affect people of lower socioeconomic status (SES) [3,4]. Indeed, healthy eating—any diet high in fruits, vegetables, whole grains, nuts and seeds, and low in sugar, salt, red meat and processed foods—tends to be more common in women, older people, those with normal BMI and higher SES [5,6].

The demographic and socioeconomic inequalities in healthy eating are likely driven by the conditions in which people live and work, and by the distribution of and access to resources and money in their communities—the social determinants of health [7]. The evidence points to access barriers such as food price and availability of healthy foods in stores [8–12]; external barriers such as time and work constraints [8,9,13]; individual barriers such as food taste preference [8,11,12] and willpower [8]; and social barriers such as lack of social support [14]. Thus, despite widespread dietary

Abbreviations: CVD, cardiovascular disease; SES, socioeconomic status; SHS, Swiss Health Survey.

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guidelines in most high-income countries aiming to provide sufficient nutrition knowledge, people face several barriers that prevent compliance to healthy eating recommendations. In clinical nutrition, these barriers may hinder preventive measures and adversely affect outcomes.

In Switzerland, compliance to dietary guidelines is low, with men, obese people, and those with low education being less likely to comply [15]. The Swiss population enjoys a high quality of life, low unemployment and poverty, universal and mandatory healthcare, and one of the longest life expectancies worldwide [16]. Compared to bordering France or Germany, Switzerland has low cardiovascular disease (CVD) mortality and relatively low CVD risk factors [17]. A recent study in a Swiss city showed that people with high education, older age and living in couple were more likely to follow a healthy diet [18]. However, no study has investigated potential barriers to healthy eating in Switzerland. Thus, using a nationally representative sample of the Swiss adult population, we aimed to assess, separately by gender, the prevalence of barriers to healthy eating and their demographic and socioeconomic determinants.

2. Methods

2.1. Database and sampling

Data from the Swiss Health Survey (SHS) of 2012 was analyzed. The SHS is a cross-sectional, nationwide, population-based study conducted every five years since 1992 by the Swiss Federal Statistical Office under a mandate of the Swiss Government. The SHS is considered representative of the Swiss adult population, does not require consent from an Ethics Committee, and the data are anonymized before use.

Selection of participants is based on a stratified random sampling applied to a database of all private Swiss households with landline telephones (over 90% of the population). The first sampling stratum consists of the seven main administrative regions (Leman, Mittelland, Northwest, Zurich, Northeast, Central and South). The second stratum consists of the cantons, the number of households drawn being proportional to each cantonal population. In some cantons, oversampling of the households was made to obtain accurate cantonal estimates, and extra strata were used for the cantons of Zurich and Bern. Overall, 29 strata were used. The third stratum is the household. For each household, one member aged ≥15 years was randomly selected; an invitation letter to participate in the survey was sent, and phone contacts were made if no response to the letter was obtained. Participants aged <75 years were interviewed by phone using computer-assisted telephone interview software, while participants aged ≥75 years received face-to-face interviews at home. All participants were invited to fill out an additional written questionnaire sent by mail. The interviews were conducted in German, French or Italian—individuals unable to speak any were excluded, as were those with asylum-seeker status or with very poor health. The telephone survey and the written survey had participations rates of 53% and 45%, respectively. SHS 2012 details are available at http://www.bfs.admin.ch/bfs/portal/fr/index/infothek/erhebungen__quellen/blank/blank/ess/04.html.

2.2. Barriers to healthy eating

Barriers to healthy eating were assessed by the written questionnaire, completed by 85% of participants in the telephone survey. To the main question "Many people, maybe including yourself, place importance in following a healthy diet. Please identify which of the following obstacles prevent you from having a healthy diet," participants answered "yes" or "no" from a 10-item list (Supplementary Table 1). To facilitate the discussion from a social determinants of health perspective, the barriers were further categorized into four domains: a) access to healthy foods (items 2, 3 and 4); b) social support (items 5 and 6); c) external constraints (items 1 and 9) and d) individual factors (items 7, 8 and 10). The questions assessing barriers were set by a multidisciplinary group of experts before the first Swiss Health Survey took place in 1992, and no reference to any previously validated instrument could be found. However, the barriers assessed are similar to those in the pan-European survey and previous research that investigated barriers to healthy eating [8,10–12,19]. Hence, in the absence of a standard, validated instrument, the current questionnaire is the best and only option for the Swiss population.

2.3. Demographic and socioeconomic variables

All data was self-reported. Age was categorized into 18–35, 36–50, 51–65 and > 65 groups. Weight and height were collected; body mass index (BMI) was calculated and categorized as normal or underweight (BMI < 25 kg/m^2), overweight (25 ≤ BMI < 30 kg/m^2), and obese (BMI≥30 kg/m^2). Smoking status was categorized as never, former, or current. Living situation was categorized as alone (i.e., living alone or as single parent) or with someone (i.e., living with couple or adult family). Nationality was categorized as Swiss and non-Swiss. Living area was categorized as urban or rural. Education was categorized as mandatory, secondary, or tertiary. Income was categorized into quartiles: <2857; 2857–3999; 4000–5332 and ≥ 5333 CHF (1 CHF = 0.92 € or 1.01US$, as of 25.11.2015). Occupation was categorized as upper/middle management work, office/non-manual/small independent work, or manual work.

2.4. Statistical analysis

Statistical analyses were performed using Stata 13 (Stata Corp. College Station, TX, USA) and were stratified by gender. Results were expressed as number of participants (percentage) for qualitative data or as average ± standard deviation for quantitative data. Bivariate analyses were conducted using chi-square test for qualitative variables and student's t-test for quantitative variables. Multivariable analyses were conducted using logistic regression. Two models were applied: 1) adjusting for age only and 2) adjusting for all demographic and socioeconomic variables. As a large proportion (20%) of the sample could not be categorized regarding their occupation, occupation was used for sensitivity analyses only. A second sensitivity analysis included the same procedure but with weighted data. To reduce the likelihood of type I error due to the high number of tests performed, statistical significance was considered for two-sided tests with $p < 0.001$.

3. Results

3.1. Sample selection and characteristics

Of the initial 21,597 participants, 6803 (31.5%) were excluded because they were below age 18 or had missing information on demographic or socioeconomic determinants or on barriers to healthy eating (Supplementary Fig. 1). The characteristics of included and excluded participants are summarized in Supplementary Table 2. Excluded participants were less frequently aged 36 to 65, overweight or obese, never smokers or of Swiss nationality than included participants; excluded participants also had lower educational and income levels than included participants.

The characteristics of the included participants according to gender are summarized in Table 1. Men were more frequently overweight or obese, smokers, and living in couple, and had higher educational and income levels than women.

3.2. Prevalence of barriers to healthy eating

The overall prevalence of barriers to healthy eating and according to different demographic and socioeconomic determinants is summarized in Table 2 (women) and Table 3 (men). The top five barriers were similar in both genders, albeit with different prevalence, and were in the individual, external, and access domains. The most frequently reported barrier among women was "price," followed by "daily habits, constraints," "fondness of good food," "time constraint," and "lack of willpower." Conversely, the most frequently reported barrier among men was "fondness of good food," followed by "daily habits, constraints," "price," "time constraint" and "lack of willpower."

3.3. Demographic and socioeconomic determinants of barriers to healthy eating

In women, the prevalence of most barriers decreased gradually with age; "fondness of good food," however, increased with age, and "price" remained constant. Overweight and obese women were more likely to report "fondness of good food" and "lack of willpower." Smoking showed no association. Women living in couple were more likely to report "daily habits, constraints" and "lack of willpower" (Table 2). After adjusting for age (Supplementary Table 3) or all covariates (Table 4), obese women remained more likely to report the above barriers, but also "no social support," "daily habits, constraints" and "fondness of abundant food;" women living in couple were more likely to report "no social support" and "fondness of good food," but also less likely to report "price."

The socioeconomic determinants were associated with the most prevalent barriers. Women with lower income were more likely to report "price" and "fondness of good food;" those with higher income were more likely to report "time constraint," "daily habits, constraints" and "limited options in restaurants." Women with lower education were more likely to report "fondness of good food;" those with higher education were more likely to report "time constraints," "daily habits, constraints," "lack of willpower" and "limited options in restaurants" (Table 2). Most associations remained after adjustment, except between "daily habits, constraints" and education, and between "fondness of good food" and income (Supplementary Table 3, Table 4).

In men, age was associated with barriers the same way as in women. BMI category, however, showed slightly different associations (Table 3). After adjusting for age (Supplementary Table 4) or all covariates (Table 5), overweight and obese men were more likely to report "fondness of good food" and "fondness of abundant food." Smoking was associated with some barriers, though in no clear pattern. Neither living situation nor nationality showed any association with barriers after adjustment. The socioeconomic determinants were associated with the most prevalent barriers in the same way as in women, with the following additions after adjustment: men with higher education were more likely to report "daily habits, constrains," and men with the higher income were more likely to report "fondness of good food" (Table 5, Supplementary Table 4).

The associations indicated above did not change when occupation was included in the model (Supplementary Tables 5 and 6). In the sensitivity analysis with weighted data, the results were similar to the unweighted analysis (Supplementary Tables 7–10).

4. Discussion

This is one of the few studies assessing prevalence and determinants of multiple barriers to healthy eating, and the first

Table 1
Characteristics of included participants, total and by sex.

	Total	Men	Women	*p-value*
N	14,794	7083	7711	
Age (mean ± SD)	48.5 (17.1)	48.7 (17.3)	48.3 (17.0)	0.09
Age groups (N, %)				0.27
18-35	3715 (25.1)	1741 (24.6)	1974 (25.6)	
36-50	4567 (30.9)	2167 (30.6)	2400 (31.1)	
51–65	3744 (25.3)	1821 (25.7)	1923 (24.9)	
Above 65	2768 (18.7)	1354 (19.1)	1414 (18.3)	
BMI				<0.001
Under/normal weight	8516 (57.6)	3297 (46.6)	5219 (67.7)	
Overweight	4719 (31.9)	2955 (41.7)	1764 (22.9)	
Obese	1559 (10.5)	831 (11.7)	728 (9.4)	
Smoking				<0.001
Never smoked	7259 (49.1)	3005 (42.4)	4254 (55.2)	
Ex-smoker	3508 (23.7)	1941 (27.4)	1567 (20.3)	
Current smoker	4027 (27.2)	2137 (30.2)	1890 (24.5)	
Living alone	3319 (22.4)	1290 (18.2)	2029 (26.3)	<0.001
Swiss national	12,567 (85.0)	5883 (83.1)	6684 (86.7)	<0.001
Urban area	10,556 (71.4)	5040 (71.2)	5516 (71.5)	0.61
Education				<0.001
Mandatory	1744 (11.8)	727 (10.3)	1017 (13.2)	
Secondary	8396 (56.8)	3601 (50.8)	4795 (62.2)	
Tertiary	4654 (31.5)	2755 (38.9)	1899 (24.6)	
Income (quartiles)				<0.001
First (<2857 CHF)	3137 (21.2)	1341 (18.9)	1796 (23.3)	
Second (2857–3999 CHF)	3442 (23.3)	1538 (21.7)	1904 (24.7)	
Third (4000–5332 CHF)	3921 (26.5)	1863 (26.3)	2058 (26.7)	
Fourth (≥5333 CHF)	4294 (29.0)	2341 (33.1)	1953 (25.3)	

BMI, body mass index; CHF, Swiss Franc. Results are expressed as number of participants (percentage) for qualitative data or as average ± standard deviation for quantitative data. Bivariate analyses were conducted using chi-square test for qualitative variables and student's t-test for quantitative variables.

Table 2
Prevalence and socio-demographic determinants of barriers to healthy eating among women, Swiss Health survey 2012, unweighted data.

	Access			Social		External		Individual		
	Price	Limited options in restaurants	Limited options at market	No social support	Social group opposition	Time constraint	Daily habits, constraints	Fondness of good food	Fondness of abundant food	Lack of willpower
Overall	43.2 (42.1–44.3)	19.5 (18.6–20.4)	5.9 (5.4–6.5)	7.8 (7.2–8.4)	3.0 (2.6–3.4)	34.8 (33.7–35.9)	39.8 (38.7–40.9)	38.8 (37.7–39.8)	11.0 (10.3–11.8)	22.0 (21.1–22.9)
Age groups										
18-35	43.2 (41.0–45.4)	21.6 (19.8–23.5)	7.3 (6.2–8.5)	10.9 (9.6–12.3)	4.5 (3.6–5.5)	40.5 (38.3–42.7)	51.1 (48.9–53.3)	35.4 (33.3–37.6)	17.5 (15.8–19.2)	29.8 (27.8–31.9)
36-50	43.8 (41.8–45.8)	21.1 (19.5–22.8)	6.1 (5.2–7.2)	7.5 (6.4–8.6)	2.9 (2.2–3.6)	36.0 (34.1–38.0)	47.1 (45.1–49.1)	32.8 (31.0–34.8)	10.6 (9.4–11.9)	23.4 (21.7–25.2)
51-65	42.3 (40.1–44.6)	21.4 (19.6–23.3)	5.3 (4.3–6.3)	6.8 (5.7–8.0)	2.7 (2–3.5.0)	32.1 (30.1–34.3)	36.1 (33.9–38.3)	38.7 (36.5–40.9)	9.2 (7.9–10.6)	18.7 (17.0–20.5)
Above 65	43.5 (40.9–46.1)	11.4 (9.8–13.2)	4.6 (3.6–5.8)	5.2 (4.1–6.4)	1.6 (1.0–2.4)	28.4 (26.1–30.9)	16.5 (14.6–18.5)	53.5 (50.9–56.2)	5.3 (4.2–6.6)	13.0 (11.3–14.9)
p-value	*0.82*	***<0.001***	*<0.01*	***<0.001***	***<0.001***	***<0.001***	***<0.001***	***<0.001***	***<0.001***	***<0.001***
BMI category										
Under/ normal weight	43.4 (42.0–44.8)	20.7 (19.6–21.8)	6.3 (5.6–7.0)	7.5 (6.8–8.2)	3.1 (2.7–3.6)	36.0 (34.7–37.3)	41.1 (39.8–42.4)	34.5 (33.2–35.8)	10.7 (9.9–11.6)	21.7 (20.6–22.8)
Overweight	43.2 (40.9–45.5)	17.2 (15.4–19.0)	4.7 (3.8–5.8)	7.7 (6.5–9.0)	2.7 (2.0–3.5)	33.1 (30.9–35.4)	37.0 (34.7–39.3)	46.8 (44.5–49.2)	10.7 (9.3–12.3)	20.5 (18.7–22.5)
Obese	41.9 (38.3–45.6)	16.6 (14.0–19.5)	6.5 (4.8–8.5)	10.0 (7.9–12.4)	3.0 (1.9–4.5)	30.4 (27.0–33.8)	37.1 (33.6–40.7)	49.6 (45.9–53.3)	14.2 (11.7–16.9)	27.8 (24.5–31.2)
p-value	*0.75*	*0.001*	*0.05*	*0.05*	*0.62*	*<0.01*	*<0.01*	***<0.001***	*0.02*	***<0.001***
Smoking										
Never smoked	43.0 (41.5–44.5)	19.1 (18–20.3)	5.6 (5.0–6.4)	8.0 (7.2–8.9)	3.3 (2.8–3.8)	34.7 (33.2–36.1)	39.6 (38.1–41.1)	38.1 (36.6–39.5)	10.5 (9.6–11.5)	22.4 (21.2–23.7)
Ex-smoker	46.3 (43.8–48.8)	22.1 (20–24.2)	5.4 (4.4–6.7)	7.9 (6.6–9.3)	2.9 (2.1–3.8)	34.9 (32.5–37.3)	38.0 (35.6–40.5)	37.3 (34.9–39.8)	11.4 (9.9–13.1)	22.2 (20.2–24.3)
Current smoker	41.1 (38.8–43.3)	18.2 (16.5–20)	7.0 (5.9–8.2)	7.0 (5.9–8.3)	2.5 (1.9–3.4)	35.0 (32.8–37.2)	41.6 (39.4–43.8)	41.5 (39.2–43.7)	11.9 (10.5–13.5)	20.9 (19.0–22.7)
p-value	*<0.01*	*0.01*	*0.08*	*0.39*	*0.29*	*0.97*	*0.10*	*0.02*	*0.23*	*0.39*
Living situation										
Alone	45.9 (43.7–48.1)	19.6 (17.9–21.4)	6.1 (5.1–7.2)	5.4 (4.4–6.4)	2.7 (2.0–3.5)	35.1 (32.0–36.2)	34.8 (32.7–36.9)	39.6 (37.4–41.7)	9.8 (8.5–11.1)	18.0 (16.3–19.7)
In couple	42.2 (40.9–43.5)	19.5 (18.4–20.5)	5.9 (5.3–6.5)	8.6 (7.9–9.4)	3.1 (2.7–3.6)	34.1 (33.8–36.3)	41.6 (40.3–42.8)	38.5 (37.2–39.7)	11.5 (10.7–12.4)	23.4 (22.3–24.5)
p-value	*<0.01*	*0.88*	*0.68*	***<0.001***	*0.36*	*0.4*	***<0.001***	*0.37*	0.03	**<0.001**
Nationality										
Swiss	43.3 (42.1–44.5)	19.5 (18.6–20.5)	5.4 (4.9–6.0)	7.8 (7.1–8.4)	3.1 (2.7–3.5)	35.3 (34.1–36.5)	39.3 (38.5–40.9)	38.8 (37.7–40.0)	11.2 (10.4–11.9)	22.4 (21.4–23.4)
Non-Swiss	42.9 (39.9–46.0)	19.5 (17.1–22.0)	9.4 (7.6–11.3)	7.7 (6.1–9.5)	2.5 (1.7–3.7)	31.6 (28.7–34.5)	40.4 (37.4–43.5)	38.2 (35.2–41.2)	10.3 (8.5–12.3)	19.5 (17.1–22.0)
p-value	*0.85*	*0.98*	***<0.001***	*0.94*	*0.34*	*0.02*	*0.66*	*0.68*	0.43	0.04
Area										
Urban	44.0 (42.6–45.3)	19.8 (18.7–20.9)	6.1 (5.5–6.8)	7.5 (6.9–8.3)	3.0 (2.5–3.5)	35.0 (33.8–36.3)	39.3 (38.0–40.6)	38.4 (37.1–39.7)	11.1 (10.3–12.0)	20.9 (19.9–22.0)
Rural	41.3 (39.3–43.4)	18.8 (17.2–20.5)	5.5 (4.6–6.6)	8.3 (7.2–9.5)	3.1 (2.4–3.9)	34.2 (32.2–36.2)	40.9 (38.8–43.0)	39.7 (37.6–41.8)	10.8 (9.6–12.2)	24.6 (22.8–26.5)
p-value	*0.04*	*0.34*	*0.33*	*0.27*	*0.77*	*0.50*	*0.22*	*0.29*	*0.73*	***<0.001***
Education										
Mandatory	42.2 (39.1–45.3)	10.6 (8.8–12.7)	5.8 (4.4–7.4)	6.8 (5.3–8.5)	3.0 (2.0–4.2)	26.7 (24.0–29.5)	23.8 (21.2–26.5)	51.8 (48.7–54.9)	9.1 (7.4–11.1)	17.3 (15.0–19.8)
Secondary	43.5 (42.1–44.9)	18.8 (17.7–19.9)	5.5 (4.9–6.2)	8.0 (7.3–8.8)	3.0 (2.5–3.5)	33.7 (32.4–35.1)	38.7 (37.3–40.1)	39.8 (38.4–41.2)	10.9 (10.0–11.8)	22.5 (21.3–23.7)
Tertiary	43.1 (40.8–45.3)	26.1 (24.2–28.2)	7.1 (6.0–8.4)	7.6 (6.4–8.9)	3.2 (2.4–4.0)	41.9 (39.6–44.1)	51.1 (48.9–53.4)	29.2 (27.2–31.3)	12.5 (11.0–14.1)	23.2 (21.3–25.2)
p-value	*0.74*	***<0.001***	*0.04*	*0.38*	*0.91*	***<0.001***	***<0.001***	***<0.001***	*0.02*	***<0.001***
Income (quartiles)										
1st (<2857 CHF)	47.6 (45.2–49.9)	13.1 (11.6–14.7)	6.5 (5.4–7.8)	7.9 (6.7–9.3)	3.2 (2.5–4.2)	30.6 (28.5–32.8)	31.4 (29.2–33.5)	43.4 (41.1–45.8)	9.7 (8.4–11.2)	19.0 (17.3–20.9)
2nd (2857–3999 CHF)	45.4 (43.1–47.6)	17.7 (16.0–19.4)	5.8 (4.8–6.9)	7.6 (6.5–8.9)	2.9 (2.2–3.8)	33.0 (30.9–35.2)	38.5 (36.3–40.7)	40.3 (38.1–42.5)	10.9 (9.6–12.4)	22.5 (20.7–24.5)
3rd (4000–5332 CHF)	42.9 (40.7–45.0)	21.7 (20.0–23.6)	5.8 (4.8–6.9)	7.6 (6.5–8.9)	3.2 (2.4–4.0)	36.9 (34.8–39.0)	41.6 (39.5–43.8)	37.4 (35.3–39.5)	11.1 (9.8–12.5)	22.8 (21.0–24.7)
4th (≥5333 CHF)	37.5 (35.3–39.7)	24.9 (23.0–26.9)	5.7 (4.7–6.8)	7.9 (6.7–9.2)	2.7 (2–3.5.0)	38.2 (36.0–40.3)	46.8 (44.6–49.0)	34.4 (32.3–36.6)	12.3 (10.9–13.8)	23.3 (21.4–25.2)
p-value	***<0.001***	***<0.001***	*0.67*	*0.98*	*0.78*	***<0.001***	***<0.001***	***<0.001***	*0.10*	*<0.01*

Results are expressed as unweighted percentage (95% confidence interval). Bivariable statistical analyses performed using chi-square. Significant ($p < 0.001$) findings are indicated in bold.

Table 3
Prevalence and socio-demographic determinants of barriers to healthy eating among men, Swiss Health survey 2012, unweighted data.

	Access			Social		External		Individual		
	Price	Limited options in restaurants	Limited options at market	No social support	Social group opposition	Time constraint	Daily habits, constraints	Fondness of good food	Fondness of abundant food	Lack of willpower
Overall	35.8 (34.7–36.9)	17.1 (16.2–18.0)	6.1 (5.6–6.7)	6.1 (5.5–6.6)	1.8 (1.5–2.2)	29.0 (27.9–30.1)	37.5 (36.4–38.6)	51.0 (49.8–52.2)	16.4 (15.5–17.3)	21.2 (20.2–22.1)
Age groups										
18-35	37.6 (35.3–39.9)	16.1 (14.4–18.0)	6.9 (5.7–8.2)	7.5 (6.3–8.9)	2.9 (2.2–3.8)	38.5 (36.2–40.9)	44.1 (41.7–46.4)	45.0 (42.7–47.4)	24.2 (22.2–26.3)	26.3 (24.3–28.4)
36-50	36.8 (34.8–38.9)	20.8 (19.1–22.5)	7.4 (6.3–8.6)	6.4 (5.4–7.5)	1.8 (1.3–2.5)	29.7 (27.8–31.6)	46.5 (44.4–48.6)	44.8 (42.7–46.9)	16.8 (15.3–18.5)	21.1 (19.4–22.9)
51-65	33.7 (31.5–35.9)	17.2 (15.5–19.1)	5.4 (4.4–6.6)	5.9 (4.9–7.1)	1.2 (0.8–1.8)	23.9 (22.0–26.0)	34.1 (31.9–36.3)	54.0 (51.7–56.3)	13.0 (11.5–14.6)	20.9 (19.1–22.9)
Above 65	34.8 (32.2–37.4)	12.3 (10.6–14.2)	4.0 (3.0–5.2)	3.8 (2.8–4.9)	1.3 (0.8–2.1)	22.4 (20.2–24.7)	19.2 (17.1–21.4)	64.5 (61.9–67.0)	10.2 (8.6–11.9)	15.0 (13.1–17)
p-value	*0.06*	***<0.001***	***<0.001***	***<0.001***	***<0.001***	***0.001***	***<0.001***	***<0.001***	***<0.001***	***<0.001***
BMI category										
Under/ normal weight	37.3 (35.7–39.0)	18.1 (16.7–19.4)	6.8 (5.9–7.7)	6.3 (5.5–7.2)	1.9 (1.4–2.4)	31.2 (29.6–32.8)	40.2 (38.5–41.9)	43.6 (41.9–45.3)	15.7 (14.5–17.0)	22.2 (20.8–23.7)
Overweight	33.8 (32.1–35.6)	16.4 (15.1–17.8)	5.5 (4.7–6.3)	5.5 (4.7–6.4)	1.9 (1.4–2.4)	27.7 (26.1–29.4)	35.2 (33.5–36.9)	55.8 (54.0–57.6)	16.6 (15.2–17.9)	20.0 (18.6–21.5)
Obese	36.8 (33.5–40.2)	16.0 (13.6–18.7)	5.9 (4.4–7.7)	7.1 (5.4–9.1)	1.7 (0.9–2.8)	24.9 (22.0–28.0)	35.0 (31.8–38.4)	62.9 (59.6–66.2)	18.4 (15.8–21.2)	20.9 (18.2–23.9)
p-value	*<0.02*	*0.15*	*0.16*	*0.09*	*0.94*	***<0.001***	***<0.001***	***<0.001***	*0.16*	*0.10*
Smoking										
Never smoked	36.2 (34.5–38.0)	18.1 (16.7–19.5)	6.5 (5.7–7.5)	7.0 (6.1–7.9)	2.0 (1.5–2.6)	32.1 (30.4–33.8)	39.6 (37.9–41.4)	48.4 (46.6–50.2)	18.0 (16.6–19.4)	22.5 (21.0–24.1)
Ex-smoker	35.0 (32.9–37.2)	16.7 (15.1–18.5)	5.8 (4.8–7.0)	5.2 (4.3–6.3)	1.8 (1.2–2.4)	24.9 (23.0–26.9)	33.4 (31.3–35.6)	55.0 (52.7–57.2)	12.4 (11.0–14.0)	19.1 (17.3–20.9)
Current smoker	35.9 (33.9–38.0)	16.1 (14.5–17.7)	5.8 (4.8–6.9)	5.6 (4.6–6.6)	1.7 (1.2–2.3)	28.3 (26.4–30.2)	38.2 (36.1–40.3)	51.1 (48.9–53.2)	17.7 (16.1–19.4)	21.2 (19.4–22.9)
p-value	*0.69*	*0.14*	*0.02*	*0.47*	*0.68*	***<0.001***	***<0.001***	***<0.001***	***<0.001***	*0.02*
Living situation										
Alone	34.1 (31.5–36.8)	18.6 (16.5–20.8)	6.5 (5.2–8.0)	6.4(5.1–7.8)	1.8 (1.1–2.7)	28.1 (30.5–35.7)	39.1 (36.4–41.8)	48.5 (45.8–51.3)	16.1 (14.1–18.2)	21.6 (19.4–24.0)
In couple	36.2 (34.9–37.4)	16.8 (15.8–17.8)	6.0 (5.4–6.7)	6.0 (5.4–6.6)	1.9 (1.5–2.2)	33.0 (26.9–29.3)	37.2 (35.9–38.4)	51.5 (50.2–52.8)	16.5 (15.5–17.4)	21.1 (20.0–22.1)
p-value	*0.16*	*0.12*	*0.62*	*0.51*	*0.88*	***<0.001***	*0.20*	*0.05*	*0.72*	*0.65*
Nationality										
Swiss	35.2 (33.9–36.4)	17.2 (16.2–18.2)	5.8 (5.2–6.4)	6.0 (5.4–6.7)	1.7 (1.4–2.1)	29.1 (27.9–30.3)	37.7 (36.4–38.9)	51.7 (50.5–53.0)	16.8 (15.9–17.8)	22.1 (21.0–23.1)
Non-Swiss	38.9 (36.1–41.7)	16.8 (14.8–19.1)	7.6 (6.1–9.2)	6.2 (4.9–7.7)	2.5 (1.7–3.5)	28.5 (26.0–31.1)	37.0 (34.3–39.8)	47.3 (44.4–50.1)	14.2 (12.2–16.3)	16.8 (14.8–19.1)
p-value	*<0.02*	*0.78*	*0.86*	*0.02*	*0.06*	*0.39*	*0.70*	*<0.01*	*0.02*	***<0.001***
Area										
Urban	37.0 (35.7–38.4)	18.5 (17.4–19.6)	6.6 (5.9–7.3)	6.3(5.7–7.0)	1.9 (1.6–2.4)	29.3 (28.0–30.6)	37.7 (36.3–39)	50.4 (49.0–51.8)	16.2 (15.2–17.3)	20.5 (19.4–21.6)
Rural	32.8 (30.7–34.8)	13.8 (12.3–15.4)	4.9 (4.0–6.0)	5.4 (4.5–6.5)	1.6 (1.1–2.2)	28.2 (26.3–30.2)	37.1 (35–39.2)	52.4 (50.2–54.6)	16.8 (15.2–18.5)	22.8 (21.0–24.7)
p-value	***<0.001***	***<0.001***	*0.16*	*<0.01*	*0.28*	*0.38*	*0.66*	*0.14*	*0.55*	*0.03*
Education										
Mandatory	36.3 (32.8–39.9)	8.7 (6.7–11.0)	5.1 (3.6–6.9)	6.2 (4.6–8.2)	2.1 (1.2–3.4)	24.5 (21.4–27.8)	23.9 (20.9–27.2)	56.0 (52.3–59.6)	16.6 (14.0–19.6)	16.6 (14.0–19.6)
Secondary	36.9 (35.3–38.5)	15.2 (14.0–16.4)	5.7 (4.9–6.5)	6.1 (5.3–6.9)	1.7 (1.3–2.1)	29.1 (27.6–30.6)	32.6 (31.0–34.1)	53.4 (51.8–55.1)	15.5 (14.4–16.7)	20.5 (19.2–21.9)
Tertiary	34.3 (32.5–36.1)	21.9 (20.3–23.4)	7.0 (6.0–8.0)	6.0 (5.1–6.9)	2.0 (1.5–2.6)	30.1 (28.3–31.8)	47.5 (45.6–49.4)	46.5 (44.6–48.3)	17.4 (16.0–18.9)	23.2 (21.6–24.8)
p-value	*0.09*	***<0.001***	*0.96*	*<0.05*	*0.56*	*0.01*	***<0.001***	***<0.001***	*0.13*	***<0.001***
Income (quartiles)										
1st (<2857 CHF)	39.9 (37.3–42.6)	12.2 (10.5–14.1)	5.7 (4.6–7.1)	6.8 (5.5–8.3)	2.2 (1.5–3.1)	27.4 (25.0–29.8)	29.3 (26.9–31.8)	52.2 (49.5–54.9)	17.0 (15–19.1)	20.0 (17.9–22.2)
2nd (2857–3999 CHF)	37.6 (35.2–40.1)	14.2 (12.5–16.0)	5.3 (4.3–6.6)	5.8 (4.7–7.1)	1.6 (1.0–2.3)	27.0 (24.8–29.3)	34.7 (32.3–37.1)	50.8 (48.2–53.3)	15.1 (13.3–17)	20.0 (18.0–22.0)
3rd (4000–5332 CHF)	36.3 (34.1–38.5)	16.9 (15.2–18.7)	6.6 (5.5–7.8)	6.0 (5.0–7.2)	1.8 (1.2–2.5)	29.2 (27.1–31.3)	38.0 (35.8–40.3)	51.1 (48.8–53.4)	16.2 (14.5–17.9)	21.2 (19.3–23.1)
4th (≥5333 CHF)	31.9 (30.0–33.8)	22.0 (20.3–23.7)	6.5 (5.5–7.5)	5.9 (4.9–6.9)	1.9 (1.4–2.5)	31.1 (29.2–33.0)	43.7 (41.6–45.7)	50.3 (48.3–52.4)	17.0 (15.5–18.6)	22.6 (21.0–24.4)
p-value	***<0.001***	***<0.001***	*0.65*	*0.36*	*0.68*	*0.02*	***<0.001***	*0.74*	*0.38*	*0.14*

Results are expressed as unweighted percentage (95% confidence interval). Bivariable statistical analyses performed using chi-square. Significant ($p < 0.001$) findings are indicated in bold.

Table 4
Multivariable analysis of the associations between socio-demographic factors and barriers to healthy eating in women, Swiss Health survey 2012, unweighted data.

	Access			Social		External			Individual	
	Price	Limited options in restaurants	Limited options at markets	No social support	Social group opposition	Time constraint	Daily habits, constraints	Fondness of good food	Fondness of abundant food	Lack of willpower
BMI category										
Under/normal weight	1 (ref.)	1 (ref.)	1 (ref.)	1 (ref.)	1 (ref.)	1 (ref.)	1 (ref.)	1 (ref.)	1 (ref.)	1 (ref.)
Overweight	0.98 (0.88–1.10)	0.79 (0.61–1.02)	0.93 (0.80–1.07)	1.17 (0.95–1.45)	0.99 (0.71–1.39)	1.01 (0.90–1.13)	1.13 (0.98–1.30)	1.46 (1.30–1.64)	1.27 (1.06–1.53)	1.15 (1.02–1.30)
Obese	0.91 (0.77–1.06)	1.12 (0.81–1.55)	0.92 (0.74–1.14)	1.62 (1.24–2.13)	1.13 (0.71–1.79)	0.92 (0.78–1.09)	1.78 (1.48–2.13)	1.63 (1.38–1.91)	1.86 (1.47–2.36)	1.25 (1.05–1.48)
p-value for trend	*0.23*	*0.49*	*0.43*	***<0.001***	*0.62*	*0.35*	***<0.001***	***<0.001***	***<0.001***	*0.01*
Living situation										
In couple	1 (ref.)	1 (ref.)	1 (ref.)	1 (ref.)	1 (ref.)	1 (ref.)	1 (ref.)	1 (ref.)	1 (ref.)	1 (ref.)
Alone	1.15 (1.03–1.28)	1.07 (0.86–1.34)	1.2 (1.05–1.37)	0.68 (0.55–0.85)	1.03 (0.75–1.42)	1.05 (0.94–1.17)	0.88 (0.77–1.01)	0.87 (0.78–0.97)	1.02 (0.85–1.22)	1.01 (0.90–1.13)
Nationality										
Swiss	1 (ref.)	1 (ref.)	1 (ref.)	1 (ref.)	1 (ref.)	1 (ref.)	1 (ref.)	1 (ref.)	1 (ref.)	1 (ref.)
Non-Swiss	0.96 (0.84–1.11)	1.67 (1.31–2.13)	0.97 (0.81–1.15)	0.91 (0.70–1.17)	0.71 (0.47–1.09)	0.78 (0.67–0.90)	0.75 (0.63–0.89)	1.03 (0.90–1.19)	0.76 (0.61–0.95)	0.87 (0.75–1.00)
Area										
Urban	1 (ref.)	1 (ref.)	1 (ref.)	1 (ref.)	1 (ref.)	1 (ref.)	1 (ref.)	1 (ref.)	1 (ref.)	1 (ref.)
Rural	0.87 (0.79–0.96)	0.95 (0.76–1.18)	1.01 (0.88–1.15)	1.03 (0.85–1.24)	0.97 (0.72–1.30)	0.98 (0.88–1.10)	1.16 (1.03–1.31)	1.03 (0.92–1.14)	0.93 (0.79–1.09)	1.06 (0.95–1.18)
Education										
Tertiary	1 (ref.)	1 (ref.)	1 (ref.)	1 (ref.)	1 (ref.)	1 (ref.)	1 (ref.)	1 (ref.)	1 (ref.)	1 (ref.)
Secondary	0.94 (0.84–1.05)	0.80 (0.63–1.00)	0.77 (0.68–0.88)	1.08 (0.87–1.33)	0.96 (0.69–1.33)	0.75 (0.67–0.84)	1.02 (0.89–1.17)	1.37 (1.22–1.55)	0.93 (0.78–1.11)	0.72 (0.64–0.81)
Mandatory	0.83 (0.70–0.98)	0.77 (0.54–1.09)	0.49 (0.39–0.62)	0.96 (0.69–1.33)	1.06 (0.65–1.73)	0.61 (0.51–0.73)	0.88 (0.71–1.09)	1.93 (1.62–2.29)	0.91 (0.69–1.20)	0.45 (0.38–0.55)
p-value for trend	*0.03*	*0.14*	***<0.001***	*0.79*	*0.81*	***<0.001***	*0.24*	***<0.001***	*0.51*	***<0.001***
Income (CHF)										
Highest	1 (ref.)	1 (ref.)	1 (ref.)	1 (ref.)	1 (ref.)	1 (ref.)	1 (ref.)	1 (ref.)	1 (ref.)	1 (ref.)
3rd quartile	1.29 (1.13–1.46)	1.09 (0.83–1.44)	0.93 (0.80–1.08)	0.99 (0.78–1.25)	1.22 (0.84–1.77)	1.02 (0.90–1.16)	0.99 (0.85–1.15)	0.99 (0.87–1.14)	0.92 (0.76–1.12)	0.92 (0.80–1.05)
2nd quartile	1.47 (1.29–1.68)	1.12 (0.84–1.48)	0.76 (0.65–0.90)	0.96 (0.75–1.22)	1.13 (0.76–1.69)	0.89 (0.78–1.03)	0.95 (0.81–1.11)	1.05 (0.91–1.21)	0.90 (0.73–1.11)	0.83 (0.72–0.95)
Lowest quartile	1.65 (1.43–1.90)	1.30 (0.97–1.75)	0.60 (0.50–0.72)	1.07 (0.82–1.38)	1.33 (0.88–2.00)	0.86 (0.74–1.00)	0.82 (0.69–0.98)	1.04 (0.90–1.20)	0.84 (0.67–1.06)	0.71 (0.61–0.82)
p-value for trend	***<0.001***	*0.09*	***<0.001***	*0.69*	*0.24*	*0.16*	*0.02*	*0.47*	*0.15*	***<0.001***

BMI, body mass index; CHF; Swiss Franc. Statistical analysis by logistic regression adjusting for all variables in the table, plus age. Results are expressed as odds ratio and (95% confidence interval). Significant ($p < 0.001$) findings are indicated in bold.

conducted in Switzerland. Our results show that the most frequent barriers, regardless of gender, relate to access ("price"), external factors ("time constraint" and "daily habits, constraints") and the individual ("fondness of good food" and "lack of willpower").

4.1. Prevalence of barriers to healthy eating

The most frequently reported barriers differed slightly by gender. While 51% of men reported "fondness of good food," only 39% of women did so; and while 43% of women reported "price," only 36% of men did so. The pan-EU study yielded similar findings [8]. This difference is possibly due to women's higher likelihood to take charge of food shopping [20], rendering them more aware of price differences between healthy and unhealthy foods. Interestingly, the prevalence of "price" as a barrier irrespective of gender was considerably higher in Switzerland than in France (19%), Austria (19%), Germany (9%) and Italy (7%) [8], although the Swiss actually dedicate a similar portion of their budget (9%) to foods compared to Austrians (10%) and Germans (11%), and less than the French and Italians (14%) [21]. People in Switzerland may identify healthy eating differently than their European counterparts, namely regarding the consumption of organic products; Switzerland has the world's highest per capita organic products consumption, well above its neighboring countries [22]. The much higher costs of organic products may account for this higher perception of "price" as a barrier to healthy eating.

Additionally, women seemed to be more affected by "time constraint" than men (35% vs 29%), probably due to difficulties in balancing household duties with professional life, as previously reported [13]. Conversely, both genders reported similar prevalence for "daily habits, constraints" and "lack of willpower," the latter being similar to the prevalence reported in Austria (24%) and France (21%), but higher than in Germany and Italy (10%) [8].

4.2. Demographic and socioeconomic determinants of barriers to healthy eating

In both genders, the prevalence of most barriers followed an age gradient; "price," however, remained a constant access barrier in all age groups. As an individual barrier, "fondness of good food" solely increased with age, as previously reported [23,24]. The decreasing prevalence of external barriers may be due to seniority or better life and work time management as one ages, and to more available time in retirement. It could also indicate a cohort effect: older people may belong to a generation more used to preparing their own meals and less reliant on ready-to-eat foods. Future studies should explore whether these barriers are age- or cohort-dependant. Obese women were more likely to report "daily

Table 5
Multivariable analysis of the associations between socio-demographic factors and barriers to healthy eating in men, Swiss Health survey 2012, unweighted data.

	Access			Social		External		Individual		
	Price	Limited options in restaurants	Limited options at markets	No social support	Social group opposition	Time constraint	Daily habits, constraints	Fondness of good food	Fondness of abundant food	Lack of willpower
BMI category										
Under/ normal weight	1 (ref.)	1 (ref.)	1 (ref.)	1 (ref.)	1 (ref.)	1 (ref.)	1 (ref.)	1 (ref.)	1 (ref.)	1 (ref.)
Overweight	0.87 (0.79–0.97)	0.85 (0.68–1.05)	0.92 (0.80–1.05)	0.95 (0.76–1.18)	1.21 (0.83–1.78)	0.98 (0.88–1.10)	0.96 (0.85–1.09)	1.55 (1.40–1.72)	1.31 (1.14–1.51)	0.91 (0.81–1.01)
Obese	1.00 (0.85–1.17)	0.95 (0.69–1.32)	0.94 (0.76–1.17)	1.29 (0.94–1.75)	1.17 (0.64–2.13)	0.90 (0.75–1.08)	1.06 (0.88–1.29)	2.02 (1.72–2.38)	1.64 (1.33–2.02)	1.00 (0.84–1.18)
p-value for trend	*0.95*	*0.77*	*0.59*	*0.11*	*0.62*	*0.27*	*0.52*	***<0.001***	***<0.001***	*0.97*
Living situation										
In couple	1 (ref.)	1 (ref.)	1 (ref.)	1 (ref.)	1 (ref.)	1 (ref.)	1 (ref.)	1 (ref.)	1 (ref.)	1 (ref.)
Alone	0.90 (0.79–1.02)	1.05 (0.82–1.35)	1.12 (0.96–1.32)	1.04 (0.81–1.34)	0.92 (0.58–1.46)	1.23 (1.08–1.40)	1.04 (0.89–1.21)	0.89 (0.78–1.00)	0.95 (0.80–1.12)	1.11 (0.97–1.26)
Nationality										
Swiss	1 (ref.)	1 (ref.)	1 (ref.)	1 (ref.)	1 (ref.)	1 (ref.)	1 (ref.)	1 (ref.)	1 (ref.)	1 (ref.)
Non-Swiss	1.12 (0.98–1.28)	1.24 (0.97–1.59)	0.99 (0.83–1.18)	0.94 (0.72–1.22)	1.32 (0.86–2.03)	0.94 (0.82–1.09)	0.71 (0.60–0.84)	0.88 (0.77–1.00)	0.73 (0.60–0.87)	0.93 (0.81–1.07)
Area										
Urban	1 (ref.)	1 (ref.)	1 (ref.)	1 (ref.)	1 (ref.)	1 (ref.)	1 (ref.)	1 (ref.)	1 (ref.)	1 (ref.)
Rural	0.80 (0.72–0.89)	0.76 (0.60–0.96)	0.75 (0.65–0.87)	0.81 (0.65–1.02)	0.81 (0.54–1.22)	0.96 (0.85–1.08)	1.12 (0.99–1.27)	1.05 (0.95–1.17)	0.99 (0.86–1.14)	1.02 (0.91–1.14)
Education										
Tertiary	1 (ref.)	1 (ref.)	1 (ref.)	1 (ref.)	1 (ref.)	1 (ref.)	1 (ref.)	1 (ref.)	1 (ref.)	1 (ref.)
Secondary	1.07 (0.95–1.19)	0.85 (0.69–1.06)	0.75 (0.65–0.86)	1.03 (0.83–1.29)	0.82 (0.55–1.21)	0.98 (0.87–1.10)	0.84 (0.74–0.96)	1.29 (1.16–1.44)	0.84 (0.73–0.97)	0.57 (0.51–0.64)
Mandatory	0.93 (0.77–1.12)	0.73 (0.49–1.08)	0.44 (0.33–0.59)	1.00 (0.69–1.45)	0.87 (0.46–1.63)	0.78 (0.63–0.96)	0.69 (0.55–0.87)	1.51 (1.26–1.81)	0.94 (0.74–1.19)	0.40 (0.33–0.49)
p-value for trend	*0.46*	*0.11*	***<0.001***	*0.99*	*0.65*	*0.02*	*<0.01*	***<0.001***	*0.60*	***<0.001***
Income (CHF)										
Highest	1 (ref.)	1 (ref.)	1 (ref.)	1 (ref.)	1 (ref.)	1 (ref.)	1 (ref.)	1 (ref.)	1 (ref.)	1 (ref.)
3rd quartile	1.24 (1.08–1.41)	1.14 (0.88–1.46)	0.83 (0.71–0.98)	1.07 (0.82–1.40)	1.01 (0.63–1.61)	0.95 (0.83–1.09)	0.98 (0.84–1.14)	0.90 (0.79–1.02)	0.99 (0.83–1.17)	0.97 (0.85–1.11)
2nd quartile	1.30 (1.13–1.50)	0.91 (0.68–1.22)	0.71 (0.59–0.85)	1.03 (0.77–1.37)	0.87 (0.51–1.46)	0.87 (0.75–1.01)	0.93 (0.79–1.10)	0.86 (0.75–0.99)	0.89 (0.74–1.07)	0.86 (0.74–0.99)
Lowest quartile	1.47 (1.26–1.71)	1.07 (0.79–1.46)	0.68 (0.56–0.84)	1.31 (0.97–1.76)	1.28 (0.76–2.16)	0.94 (0.80–1.11)	1.04 (0.87–1.24)	0.82 (0.71–0.96)	1.14 (0.94–1.39)	0.82 (0.70–0.96)
p-value for trend	***<0.001***	*0.99*	***<0.001***	*0.11*	*0.48*	*0.31*	*0.85*	*<0.01*	*0.37*	*<0.01*

BMI, body mass index; CHF; Swiss Franc. Statistical analysis by logistic regression adjusting for all variables in the table, plus age. Results are expressed as odds ratio and (95% confidence interval). Significant ($p < 0.001$) findings are indicated in bold.

habits, constraints" and "no social support" than normal weight women, indicating that obese women may not find the stimulating and supportive environment needed to improve their diet, as suggested before [14].

Income was associated with access, external and individual barriers: "price" and "fondness of good food" decreased with higher income, while "daily habits, constraints," "limited options in restaurants" and "lack of willpower" increased. These findings reflect those in several countries [9,10,25], which found that access barriers were more prevalent in lower income groups. For "fondness of good food," however, the literature remains inconclusive [12,24]. The higher prevalence of external barriers among people with higher income may due to busy work schedules—future studies should explore this hypothesis.

Education was associated with mostly external and individual barriers. For instance, the prevalence of "fondness of good food" decreased with increasing education, possibly due to incorrect beliefs among people with lower education that healthy foods taste poorly [25]. Conversely, the prevalence of "time constraint," "daily habits, constraints" and "lack of willpower" increased with increasing education. People with higher education may experience these external barriers more often because of busy work schedules and high work stress. The higher prevalence of "lack of willpower," however, may be due to greater nutrition knowledge and more stringent self-imposed healthy eating standards among highly educated people, particularly women—future studies should explore this link.

4.3. Implications of findings

The high prevalence of barriers to healthy eating in the population represents a major challenge both in public health and clinical nutrition. In the general population, these barriers hinder the adherence to existing dietary guidelines for chronic disease prevention [2,26]; among people diagnosed with chronic diseases and undergoing treatment, critically, these barriers can adversely affect health outcomes. For instance, adherence to a low-protein diet is critical among people with chronic kidney disease to reduce renal death risk [27]; among overweight and obese people with high blood pressure, adherence to the DASH diet results in significant improvements in cardiometabolic markers [28]. Multifaceted interventions at the population and clinical levels are needed to tackle several barriers simultaneously; Table 6 proposes measures to tackle the most prevalent barriers. At the population level, interventions must challenge beliefs that healthy foods taste poorly, as appears to be common among people with lower

Table 6
Proposed measures to eliminate barriers to healthy eating in the population.

Barrier to healthy eating	Proposed intervention	Stakeholders	Ways to intervene
Price	1) Increase subsidies on healthy foods, and reduce or eliminate subsidies on unhealthy foods, promoting shift from meat and dairy production to fruit and vegetable production [30]; 2) Introduce or increase taxes on unhealthy foods (e.g., on sugary, salty, and fat rich products); 3) Introduce health insurance coverage of nutrition therapy to treat chronic diseases.	Government Food industry Farmers Health professionals (dieticians, nutritionists, doctors, social workers etc.) Health insurance providers	Reform price and tax legislation/ subsidies; Diversify agricultural production; Provide healthier products and cheaper alternatives with similar nutritional value; Cover medical nutrition therapy as part of treatment and prevention.
Daily habits, constraints/Time constraints	1) Favor and promote flexible work schedules, and part-time work; 2) Teach how to quickly and efficiently prepare healthy foods in school curricula and elsewhere; 3) Promote and increase availability of ready-to-eat healthy meals; 4) Promote time spent preparing healthy meals as important component of healthy lifestyle.	Government Employers Food industry Health professionals	Reform work policies to introduce part-time, flexible timetables; Introduce nutrition education in school curricula; Provide healthy ready-to-eat meals; Promote time spent preparing meals; Create time slots for cooking and eating, especially for patients.
Fondness of good food	1) Promote and advertise healthy food as tasty food; 2) Ban advertisement of unhealthy foods; 3) Promote diversification of healthy food products	Restaurants, food carts, cafeterias Health promotion agencies Media Health professionals	Increase number of healthy and tasty meal options; Promote healthy foods as tasty foods; Promote cooking methods to improve taste.
Lack of willpower	1) Promote environments conducive to healthy eating in schools, at work, public spaces, and at home 2) Promote healthy eating as part of healthy and enjoyable lifestyle; 3) Challenge views of stringent diets as only way to healthy eating; 4) Promote healthy eating as easily attainable with many different foods, recipes, and flavors, and adaptable to personal preferences 5) With patients, establish collaboration between medical, nutrition, and social workers to design best course of action towards healthy eating	Government Food industry Media Health professionals	Provide counsel and advice on methods of behavior change at schools, work, and healthcare facilities; Advertise and promote different options of healthy foods and ways to eat them; Promote behavior change as part of healthier, more enjoyable lifestyle; Work closely with patients to increase self-confidence and empower them to eat healthier foods

education; simultaneously, they must challenge ideas that healthy eating is only attainable under stringent conditions, as appears to be more common among people with higher education and income. At the clinical level, given the demographic and socioeconomic patterned presence of barriers to healthy eating, multidisciplinary teams of medical, nutrition and social workers must collaborate closely to enable patients to achieve and maintain healthy eating habits.

4.4. Strengths and limitations

This study benefits from a large population-based representative sample and extends the findings from the pan-EU study conducted almost 20 years ago [8]. The questionnaire applied covers a wide range of barriers and could easily be applied in other countries for comparison, and to assess the effectiveness of healthy eating promotion campaigns. We also conducted our analysis separately for men and women, and used a p-value of <0.001 for statistical significance to reduce the likelihood of type I error due to multiple testing. However, our results are limited by the use of cross-sectional data, and the self-reported nature of all the information obtained, susceptible to recall and social desirability bias. The way participants understood the concept of healthy eating was not assessed. However, a previous study in a Swiss city found that participants had a high general level of nutrition and health knowledge [29]. The questions assessing barriers were set by a multidisciplinary group of experts before the first Swiss Health Survey took place in 1992, and no reference to any previously validated instrument could be found. However, the barriers assessed are similar to those in the pan-European survey and previous research that investigated barriers to healthy eating [8,10–12,19]. Hence, in the absence of a standard, validated instrument, the current questionnaire is the best and only option for the Swiss population. The dichotomous nature of the answers prevented us from assessing how variations in the degree of each barrier may affect people in general and according to socioeconomic and demographic indicators. Many participants were excluded from the main analysis, and they differed significantly for those excluded in some demographic factors. This exclusion was necessary, however, as these participants had no information on barriers to healthy eating. Finally, no option was given to identify other barriers besides the ten already provided in the question; it is possible that other barriers may also affect healthy eating and be associated with socioeconomic and demographic determinants.

5. Conclusion

In Switzerland, several barriers to healthy eating have high prevalence in the population, relate to access (“price”), external (“time constraint” and “daily habits, constraints”), and individual

factors ("fondness of good food" and "lack of willpower"), and are associated with age, obesity, income and education; this requires multifaceted interventions to tackle several barriers simultaneously.

Authors' contributions

CdM and PMV conceived the paper; CdM analyzed data and wrote paper. PMV supervised the analysis, and had primary responsibility for final content. PMV and SS reviewed the manuscript and provided critical recommendations. All authors approved the final manuscript.

Conflict of interest

None.

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Appendix A. Supplementary data

Supplementary data related to this article can be found at http://dx.doi.org/10.1016/j.clnu.2016.04.004.

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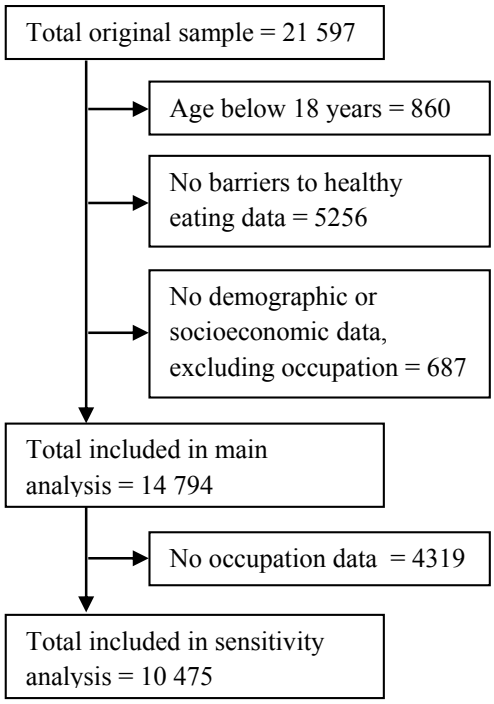
Supplemental material

Supplementary table 1. Barriers to healthy eating, Swiss health survey 2012

Item[1]	Original statement in Swiss Health Survey 2012[2]			English translation	Abridged statement	Domain
	German	French	Italian			
1	Hofer Zeitaufwand für Einkaufen und Zubereitung.	Les achats et la préparation prennent beaucoup de temps.	Troppo tempo per gli acquisti e la preparazione dei pasti.	Shopping and preparation takes too much time.	"Time constraint"	External
2	Zu wenig Angebote in den Geschäften.	L'offre dans les magasins est trop restreinte.	L'offerta nei negozi è troppo scarsa.	Options are too limited at the store.	"Limited options at market"	Access
3	Zu wenig Angebote in Restaurants, Kantinen, usw.	L'offre dans les restaurants, cantines, etc. est trop restreinte.	L'offerta nei ristoranti, mense, ecc. è troppo scarsa.	Options are too limited in restaurants, cafeterias, etc.	"Limited options in restaurants"	Access
4	Gesundes Essen ist relativ teuer.	Une alimentation saine est relativement chère.	Il costo dell'alimentazione sana è relativamente alto.	Healthy eating is expensive.	"Price"	Access
5	Zu wenig Unterstützung durch Mitmenschen.	Le manque de soutien de la part de mon entourage.	Poco aiuto dalle persone circonstanti.	Lack of support from my social group.	"Lack of social support"	Social
6	Mitmenschen halten davon ab.	Mon entourage fait opposition.	Ostacoli da parte delle persone circonstanti.	Social group opposition.	"Social group opposition"	Social
7	Grosse Vorliebe für gutes Essen.	J'aime bien manger.	Grande preferenza per il mangiare bene.	Fondness of good food.	"Fondness of good food"	Individual
8	Grosse Vorliebe für reichliches Essen.	J'aime beaucoup manger.	Grande preferenza per il mangiare molto.	Fondness of abundant food.	"Fondness of abundant food"	Individual
9	Gewohnheiten und Zwänge des Alltags.	Les habitudes et contraintes de la vie quotidienne.	Le abitudini e le esigenze della vitaquotidiana lo impediscono.	Habits and constraints of daily life.	"Daily habits, constraints"	External
10	Fehlender Wille, fehlender Glaube an Erfolg.	Le manque de volonté, pas convaincu de l'efficacité.	Poca volontà e scarsa fiducia in un risultato positivo.	Lack of willpower.	"Lack of willpower"	Individual

[1] item position in the original written questionnaire. [2] Questionnaire was given in German, French, and Italian, Switzerland's three national languages**.** For simplicity, abridged statements are used throughout the text. Link to Swiss Health Survey 2012 questionnaires in German, French and Italian: http://www.bfs.admin.ch/bfs/portal/fr/index/infothek/erhebungen__quellen/blank/blank/ess/03.html

Supplementary figure 1. Flowchart for inclusion of participants



Supplementary table 2. Socio-demographic characteristics of included and excluded participants, Swiss Health Survey 2012.

	Included	Excluded	p-value
N	14,794	6,803	
Women	7,711 (52.1)	3,603 (53.0)	0.25
Age (mean ± SD)	48.5 ± 17.1	47.5 ± 17.0	<0.001
Age groups (n, %)			<0.001
18-35	3,715 (25.1)	1,345 (22.6)	
36-50	4,567 (30.9)	1,479 (24.9)	
51-65	3,744 (25.3)	1,423 (23.9)	
Above 65	2,768 (18.7)	1,696 (28.5)	
BMI category			<0.001
Under/normal weight	8,516 (57.6)	4,120 (62.5)	
Overweight	4,719 (31.9)	1,846 (28.0)	
Obese	1,559 (10.5)	622 (9.4)	
Smoking status			<0.001
Never smoked	7,259 (49.1)	3,583 (52.7)	
Ex-smoker	3,508 (23.7)	1,290 (19.0)	
Current smoker	4,027 (27.2)	1,924 (28.3)	
Living alone	3,319 (22.4)	1,603 (23.6)	0.07
Swiss national	12,567 (85.0)	5,369 (78.9)	<0.001
Urban area	10,556 (71.4)	4,860 (71.4)	0.90
Education			<0.001
Mandatory	1,744 (11.8)	2,124 (31.7)	
Secondary	8,396 (56.8)	3,172 (47.4)	
Tertiary	4,654 (31.5)	1,398 (20.9)	
Income (quartiles)			<0.001
First (<2857 CHF)	3,137 (21.2)	1,673 (30.3)	
Second (2857-3999 CHF)	3,442 (23.3)	1,264 (22.9)	
Third (4000-5332 CHF)	3,921 (26.5)	1,304 (23.6)	
Fourth (≥5333 CHF)	4,294 (29)	1,284 (23.2)	

BMI, body mass index; CHF, Swiss Francs. Results are expressed as number of participants (percentage) for qualitative data or as average ± standard deviation for quantitative data. Bivariate analyses were conducted using chi-square test for qualitative variables and student's t-test for quantitative variables.

Supplementary table 3. Age adjusted logistic regression analysis of the associations between socio-demographic factors and barriers to healthy eating in women, Swiss Health survey 2012, unweighted data

	Access			Social		External		Individual		
	Price	Limited options in	Limited options at	No social support	Social group opposition	Time constraint	Daily habits, constraints	Fondness of good food	Fondness of abundant food	Lack of willpower
BMI category										
Under/normal	1 (ref.)	1 (ref.)	1 (ref.)	1 (ref.)	1 (ref.)	1 (ref.)	1 (ref.)	1 (ref.)	1 (ref.)	1 (ref.)
Overweight	0.99 (0.89-1.11)	0.80 (0.62-1.03)	0.86 (0.75-0.99)	1.18 (0.96-1.46)	0.99 (0.71-1.39)	0.96 (0.85-1.08)	1.11 (0.97-1.28)	1.53 (1.37-1.71)	1.24 (1.04-1.49)	1.07 (0.95-1.20)
Obese	0.94 (0.80-1.11)	1.13 (0.82-1.56)	0.83 (0.67-1.02)	1.64 (1.25-2.14)	1.16 (0.73-1.84)	0.85 (0.72-1.01)	1.73 (1.44-2.07)	1.71 (1.46-2.00)	1.79 (1.42-2.26)	1.11 (0.94-1.31)
p-value for trend	*0.47*	*0.45*	*0.07*	***<0.001***	*0.53*	*0.07*	***<0.001***	***<0.001***	***<0.001***	*0.23*
Living situation										
In couple	1 (ref.)	1 (ref.)	1 (ref.)	1 (ref.)	1 (ref.)	1 (ref.)	1 (ref.)	1 (ref.)	1 (ref.)	1 (ref.)
Alone	1.17 (1.06-1.30)	1.15 (0.92-1.43)	1.16 (1.02-1.32)	0.67 (0.54-0.83)	1.02 (0.74-1.39)	1.05 (0.94-1.18)	0.85 (0.74-0.97)	0.88 (0.79-0.98)	1.02 (0.86-1.21)	1.00 (0.90-1.12)
Nationality										
Swiss	1 (ref.)	1 (ref.)	1 (ref.)	1 (ref.)	1 (ref.)	1 (ref.)	1 (ref.)	1 (ref.)	1 (ref.)	1 (ref.)
Non-Swiss	0.98 (0.86-1.12)	1.71 (1.35-2.17)	0.94 (0.79-1.11)	0.90 (0.7-1.15)	0.73 (0.48-1.10)	0.78 (0.68-0.90)	0.73 (0.62-0.86)	1.08 (0.94-1.24)	0.79 (0.63-0.98)	0.84 (0.73-0.97)
Area										
Urban	1 (ref.)	1 (ref.)	1 (ref.)	1 (ref.)	1 (ref.)	1 (ref.)	1 (ref.)	1 (ref.)	1 (ref.)	1 (ref.)
Rural	0.90 (0.81-0.99)	0.89 (0.71-1.10)	0.91 (0.80-1.04)	1.09 (0.91-1.31)	1.02 (0.76-1.36)	0.95 (0.85-1.05)	1.20 (1.07-1.35)	1.10 (0.99-1.22)	0.94 (0.8-1.10)	1.00 (0.90-1.11)
Education										
Tertiary	1 (ref.)	1 (ref.)	1 (ref.)	1 (ref.)	1 (ref.)	1 (ref.)	1 (ref.)	1 (ref.)	1 (ref.)	1 (ref.)
Secondary	1.02 (0.91-1.13)	0.79 (0.64-0.99)	0.69 (0.61-0.79)	1.14 (0.93-1.40)	1.02 (0.75-1.39)	0.74 (0.66-0.82)	1.06 (0.93-1.21)	1.47 (1.31-1.65)	0.95 (0.81-1.12)	0.70 (0.63-0.78)
Mandatory	0.97 (0.82-1.13)	0.89 (0.64-1.22)	0.38 (0.30-0.48)	1.03 (0.76-1.39)	1.12 (0.71-1.76)	0.55 (0.46-0.65)	0.85 (0.70-1.04)	2.18 (1.85-2.56)	0.88 (0.68-1.14)	0.40 (0.34-0.48)
p-value for trend	*0.67*	*0.46*	***<0.001***	*0.87*	*0.62*	***<0.001***	*0.12*	***<0.001***	*0.34*	***<0.001***
Income (quartiles,										
Fourth (≥5333)	1 (ref.)	1 (ref.)	1 (ref.)	1 (ref.)	1 (ref.)	1 (ref.)	1 (ref.)	1 (ref.)	1 (ref.)	1 (ref.)
Third (4000-5332)	1.25 (1.10-1.42)	1.04 (0.79-1.35)	0.87 (0.75-1.00)	0.99 (0.79-1.25)	1.21 (0.84-1.76)	0.96 (0.85-1.09)	1.00 (0.87-1.17)	1.09 (0.96-1.25)	0.93 (0.76-1.13)	0.86 (0.75-0.98)
Second (2857-3999)	1.39 (1.22-1.58)	1.03 (0.78-1.35)	0.67 (0.58-0.79)	0.99 (0.78-1.25)	1.13 (0.77-1.65)	0.80 (0.70-0.92)	0.98 (0.84-1.14)	1.24 (1.09-1.42)	0.91 (0.74-1.11)	0.74 (0.65-0.84)
First (<2857)	1.52 (1.33-1.74)	1.21 (0.92-1.58)	0.50 (0.42-0.59)	1.07 (0.84-1.37)	1.32 (0.90-1.93)	0.74 (0.65-0.85)	0.84 (0.72-0.99)	1.32 (1.15-1.51)	0.85 (0.69-1.05)	0.59 (0.52-0.68)
p-value for trend	***<0.001***	*0.20*	***<0.001***	*0.60*	*0.22*	***<0.001***	*0.03*	***<0.001***	*0.14*	***<0.001***

BMI, body mass index; CHF; Swiss Franc. Statistical analysis by logistic regression adjusting for all variables in the table, plus age. Results are expressed as odds ratio and (95% confidence interval). Significant (p<0.001) findings are indicated in bold.

Supplementary table 4. Age adjusted logistic regression analysis of the associations between socio-demographic factors and barriers to healthy eating in men, Swiss Health survey 2012, unweighted data

	Access			Social		External		Individual		
	Price	Limited options in	Limited options at	No social support	Social group opposition	Time constraint	Daily habits, constraints	Fondness of good food	Fondness of abundant food	Lack of willpower
BMI category										
Under/normal	1 (ref.)	1 (ref.)	1 (ref.)	1 (ref.)	1 (ref.)	1 (ref.)	1 (ref.)	1 (ref.)	1 (ref.)	1 (ref.)
Overweight	0.88 (0.79-0.98)	0.83 (0.67-1.03)	0.88 (0.77-1.01)	0.93 (0.75-1.15)	1.20 (0.82-1.75)	0.96 (0.86-1.07)	0.95 (0.84-1.08)	1.56 (1.41-1.73)	1.28 (1.11-1.47)	0.89 (0.80-0.99)
Obese	1.01 (0.86-1.19)	0.93 (0.67-1.28)	0.87 (0.70-1.07)	1.26 (0.93-1.71)	1.16 (0.64-2.11)	0.87 (0.73-1.04)	1.03 (0.85-1.25)	2.04 (1.74-2.40)	1.56 (1.27-1.92)	0.93 (0.79-1.09)
p-value for trend	*0.90*	*0.65*	*0.18*	*0.14*	*0.63*	*0.13*	*0.75*	***<0.001***	***<0.001***	*0.38*
Living situation										
In couple	1 (ref.)	1 (ref.)	1 (ref.)	1 (ref.)	1 (ref.)	1 (ref.)	1 (ref.)	1 (ref.)	1 (ref.)	1 (ref.)
Alone	0.91 (0.80-1.03)	1.08 (0.85-1.39)	1.15 (0.98-1.34)	1.05 (0.82-1.35)	0.93 (0.59-1.47)	1.23 (1.08-1.41)	1.01 (0.87-1.18)	0.89 (0.79-1.01)	0.94 (0.79-1.11)	1.08 (0.95-1.22)
Nationality										
Swiss	1 (ref.)	1 (ref.)	1 (ref.)	1 (ref.)	1 (ref.)	1 (ref.)	1 (ref.)	1 (ref.)	1 (ref.)	1 (ref.)
Non-Swiss	1.16 (1.02-1.31)	1.25 (0.98-1.59)	0.93 (0.79-1.10)	0.97 (0.75-1.26)	1.39 (0.92-2.10)	0.91 (0.79-1.04)	0.68 (0.58-0.80)	0.91 (0.80-1.03)	0.75 (0.62-0.89)	0.86 (0.75-0.98)
Area										
Urban	1 (ref.)	1 (ref.)	1 (ref.)	1 (ref.)	1 (ref.)	1 (ref.)	1 (ref.)	1 (ref.)	1 (ref.)	1 (ref.)
Rural	0.83 (0.74-0.92)	0.73 (0.58-0.92)	0.70 (0.60-0.81)	0.84 (0.67-1.05)	0.80 (0.53-1.19)	0.94 (0.84-1.05)	1.13 (1.00-1.28)	1.10 (0.99-1.23)	1.03 (0.89-1.18)	0.95 (0.85-1.06)
Education										
Tertiary	1 (ref.)	1 (ref.)	1 (ref.)	1 (ref.)	1 (ref.)	1 (ref.)	1 (ref.)	1 (ref.)	1 (ref.)	1 (ref.)
Secondary	1.13 (1.01-1.25)	0.83 (0.67-1.02)	0.67 (0.59-0.76)	1.05 (0.85-1.29)	0.81 (0.56-1.18)	0.94 (0.85-1.06)	0.85 (0.75-0.96)	1.28 (1.15-1.41)	0.86 (0.75-0.99)	0.55 (0.5-0.61)
Mandatory	1.10 (0.93-1.31)	0.75 (0.52-1.09)	0.36 (0.28-0.48)	1.07 (0.76-1.50)	0.97 (0.54-1.74)	0.73 (0.60-0.88)	0.65 (0.52-0.81)	1.39 (1.18-1.65)	0.92 (0.73-1.15)	0.37 (0.3-0.44)
p-value for trend	*0.28*	*0.13*	***<0.001***	*0.71*	*0.92*	*<0.01*	***<0.001***	***<0.001***	*0.45*	***<0.001***
Income (quartiles,										
Fourth (≥5333)	1 (ref.)	1 (ref.)	1 (ref.)	1 (ref.)	1 (ref.)	1 (ref.)	1 (ref.)	1 (ref.)	1 (ref.)	1 (ref.)
Third (4000-5332)	1.22 (1.07-1.39)	1.05 (0.82-1.35)	0.74 (0.63-0.86)	1.06 (0.82-1.37)	0.95 (0.60-1.50)	0.92 (0.81-1.05)	0.94 (0.81-1.09)	0.99 (0.88-1.12)	0.96 (0.81-1.13)	0.83 (0.73-0.94)
Second (2857-3999)	1.28 (1.12-1.47)	0.82 (0.62-1.08)	0.59 (0.49-0.70)	1.01 (0.77-1.33)	0.82 (0.50-1.36)	0.81 (0.71-0.94)	0.87 (0.74-1.02)	1.00 (0.88-1.14)	0.87 (0.73-1.04)	0.69 (0.60-0.79)
First (<2857)	1.43 (1.24-1.65)	0.95 (0.71-1.26)	0.52 (0.43-0.63)	1.28 (0.97-1.69)	1.19 (0.74-1.92)	0.87 (0.75-1.01)	0.92 (0.77-1.08)	0.97 (0.85-1.12)	1.07 (0.89-1.29)	0.60 (0.52-0.70)
p-value for trend	***<0.001***	*0.37*	***<0.001***	*0.13*	*0.63*	*0.03*	*0.21*	*0.72*	*0.69*	***<0.001***

BMI, body mass index; CHF; Swiss Franc. Statistical analysis by logistic regression adjusting for all variables in the table, plus age. Results are expressed as odds ratio and (95% confidence interval). Significant (p<0.001) findings are indicated in bold.

Supplementary table 5. Multivariable adjusted sensitivity analysis of the associations between socio-demographic factors and barriers to healthy eating in women, Swiss Health survey 2012, unweighted data

	Access			Social		External		Individual		
	Price	Limited options in	Limited options at	No social support	Social group opposition	Time constraint	Daily habits, constraints	Fondness of good food	Fondness of abundant food	Lack of willpower
BMI category										
Under/normal	1 (ref.)	1 (ref.)	1 (ref.)	1 (ref.)	1 (ref.)	1 (ref.)	1 (ref.)	1 (ref.)	1 (ref.)	1 (ref.)
Overweight	0.94 (0.81-1.08)	0.74 (0.53-1.03)	0.94 (0.79-1.12)	1.08 (0.84-1.40)	1.01 (0.66-1.53)	1.03 (0.89-1.20)	1.10 (0.93-1.30)	1.53 (1.32-1.77)	1.1 (0.88-1.37)	1.14 (0.99-1.32)
Obese	0.95 (0.77-1.18)	1.02 (0.65-1.58)	1.00 (0.77-1.30)	1.37 (0.96-1.97)	1.21 (0.68-2.14)	0.99 (0.79-1.24)	1.68 (1.33-2.12)	1.83 (1.48-2.27)	1.84 (1.38-2.45)	1.45 (1.17-1.80)
p-value for trend	*0.67*	*0.88*	*0.99*	*0.08*	*0.52*	*0.91*	***<0.001***	***<0.001***	***<0.001***	***<0.001***
Living situation										
In couple	1 (ref.)	1 (ref.)	1 (ref.)	1 (ref.)	1 (ref.)	1 (ref.)	1 (ref.)	1 (ref.)	1 (ref.)	1 (ref.)
Alone	1.06 (0.93-1.22)	1.06 (0.80-1.40)	1.25 (1.07-1.47)	0.71 (0.54-0.93)	1.14 (0.78-1.66)	1.08 (0.94-1.24)	0.89 (0.75-1.04)	0.83 (0.72-0.96)	1.00 (0.81-1.23)	1.00 (0.87-1.15)
Nationality										
Swiss	1 (ref.)	1 (ref.)	1 (ref.)	1 (ref.)	1 (ref.)	1 (ref.)	1 (ref.)	1 (ref.)	1 (ref.)	1 (ref.)
Non-Swiss	1.03 (0.87-1.21)	1.73 (1.29-2.32)	1.02 (0.84-1.25)	0.99 (0.74-1.33)	0.77 (0.47-1.25)	0.79 (0.67-0.94)	0.80 (0.66-0.98)	1.14 (0.96-1.36)	0.75 (0.58-0.97)	0.92 (0.78-1.08)
Area										
Urban	1 (ref.)	1 (ref.)	1 (ref.)	1 (ref.)	1 (ref.)	1 (ref.)	1 (ref.)	1 (ref.)	1 (ref.)	1 (ref.)
Rural	0.94 (0.83-1.06)	0.91 (0.69-1.19)	1.02 (0.87-1.18)	0.96 (0.77-1.20)	1.12 (0.80-1.58)	0.96 (0.84-1.09)	1.14 (0.99-1.32)	1.09 (0.96-1.24)	0.92 (0.76-1.11)	1.04 (0.92-1.18)
Education										
Tertiary	1 (ref.)	1 (ref.)	1 (ref.)	1 (ref.)	1 (ref.)	1 (ref.)	1 (ref.)	1 (ref.)	1 (ref.)	1 (ref.)
Secondary	1.02 (0.89-1.17)	0.84 (0.63-1.10)	0.81 (0.69-0.95)	0.98 (0.76-1.25)	0.87 (0.60-1.28)	0.81 (0.71-0.93)	1.05 (0.89-1.22)	1.38 (1.20-1.60)	0.91 (0.74-1.11)	0.73 (0.64-0.83)
Mandatory	0.80 (0.64-1.01)	0.90 (0.56-1.43)	0.51 (0.37-0.70)	0.85 (0.56-1.29)	0.97 (0.51-1.84)	0.57 (0.44-0.73)	0.84 (0.64-1.10)	1.97 (1.55-2.49)	0.78 (0.55-1.12)	0.46 (0.36-0.58)
p-value for trend	*0.06*	*0.62*	***<0.001***	*0.44*	*0.93*	***<0.001***	*0.21*	***<0.001***	*0.18*	***<0.001***
Income (quartiles,										
Fourth (≥5333)	1 (ref.)	1 (ref.)	1 (ref.)	1 (ref.)	1 (ref.)	1 (ref.)	1 (ref.)	1 (ref.)	1 (ref.)	1 (ref.)
Third (4000-5332)	1.29 (1.11-1.49)	0.94 (0.69-1.29)	0.91 (0.77-1.08)	0.99 (0.75-1.29)	1.25 (0.83-1.89)	1.04 (0.89-1.21)	0.98 (0.83-1.16)	0.91 (0.78-1.07)	0.89 (0.72-1.12)	0.96 (0.83-1.11)
Second (2857-3999)	1.38 (1.17-1.62)	0.94 (0.66-1.32)	0.75 (0.62-0.91)	0.95 (0.71-1.27)	0.94 (0.59-1.52)	0.91 (0.77-1.07)	1.00 (0.83-1.20)	0.93 (0.79-1.10)	0.95 (0.75-1.20)	0.94 (0.80-1.01)
First (<2857)	1.66 (1.39-2.00)	1.32 (0.92-1.90)	0.6 (0.48-0.76)	1.08 (0.78-1.50)	1.29 (0.78-2.14)	0.97 (0.81-1.18)	0.90 (0.72-1.11)	0.86 (0.71-1.04)	0.95 (0.72-1.25)	0.83 (0.69-0.99)
p-value for trend	***<0.001***	*0.67*	***<0.001***	*0.71*	*0.56*	*0.49*	*0.36*	*0.15*	*0.84*	*0.05*
Occupation										
Upper	1 (ref.)	1 (ref.)	1 (ref.)	1 (ref.)	1 (ref.)	1 (ref.)	1 (ref.)	1 (ref.)	1 (ref.)	1 (ref.)
Middle	0.84 (0.74-0.96)	0.99 (0.75-1.29)	1.05 (0.9-1.22)	1.33 (1.05-1.68)	0.80 (0.55-1.15)	0.93 (0.82-1.06)	1.02 (0.88-1.18)	1.10 (0.97-1.26)	0.87 (0.72-1.06)	0.87 (0.77-0.99)
Low	0.85 (0.70-1.02)	0.83 (0.55-1.24)	0.86 (0.68-1.09)	1.34 (0.97-1.87)	1.07 (0.65-1.75)	0.77 (0.63-0.94)	1.04 (0.84-1.29)	1.14 (0.94-1.38)	1.18 (0.90-1.54)	0.74 (0.61-0.90)
p-value for trend	*0.08*	*0.41*	*0.22*	*0.08*	*0.79*	*<0.01*	*0.71*	*0.17*	*0.24*	*<0.01*

BMI, body mass index; CHF; Swiss Franc. Occupation: upper, upper and middle managerial work; middle, office/non manual/small independent work; low, manual work. Statistical analysis by logistic regression adjusting for all variables in the table, plus age. Results are expressed as odds ratio and (95% confidence interval). Significant ($p<0.001$) findings are indicated in bold.

Supplementary table 6. Multivariable adjusted sensitivity analysis of the associations between socio-demographic factors and barriers to healthy eating in men, Swiss Health survey 2012, unweighted data

	Access			Social		External		Individual		
	Price	Limited options in	Limited options at	No social support	Social group opposition	Time constraint	Daily habits, constraints	Fondness of good food	Fondness of abundant food	Lack of willpower
BMI category										
Under/normal	1 (ref.)	1 (ref.)	1 (ref.)	1 (ref.)	1 (ref.)	1 (ref.)	1 (ref.)	1 (ref.)	1 (ref.)	1 (ref.)
Overweight	0.86 (0.76-0.98)	0.90 (0.71-1.14)	0.96 (0.83-1.12)	0.85 (0.66-1.08)	1.12 (0.73-1.72)	1.03 (0.90-1.17)	0.96 (0.83-1.11)	1.61 (1.43-1.81)	1.35 (1.15-1.58)	0.91 (0.80-1.03)
Obese	1.02 (0.84-1.24)	0.95 (0.64-1.39)	0.98 (0.77-1.26)	1.28 (0.90-1.82)	1.08 (0.54-2.19)	0.89 (0.72-1.11)	1.18 (0.95-1.47)	2.03 (1.68-2.46)	1.83 (1.45-2.32)	1.09 (0.90-1.33)
p-value for trend	*0.85*	*0.78*	*0.89*	*0.18*	*0.82*	*0.31*	*0.14*	***<0.001***	***<0.001***	*0.37*
Living situation										
In couple	1 (ref.)	1 (ref.)	1 (ref.)	1 (ref.)	1 (ref.)	1 (ref.)	1 (ref.)	1 (ref.)	1 (ref.)	1 (ref.)
Alone	0.84 (0.72-0.98)	0.99 (0.74-1.33)	1.18 (0.98-1.41)	0.97 (0.72-1.3)	0.62 (0.33-1.14)	1.22 (1.04-1.42)	0.95 (0.80-1.13)	0.90 (0.78-1.05)	1.00 (0.83-1.21)	1.12 (0.96-1.30)
Nationality										
Swiss	1 (ref.)	1 (ref.)	1 (ref.)	1 (ref.)	1 (ref.)	1 (ref.)	1 (ref.)	1 (ref.)	1 (ref.)	1 (ref.)
Non-Swiss	1.14 (0.98-1.33)	1.43 (1.09-1.87)	1.03 (0.86-1.25)	0.91 (0.67-1.24)	1.17 (0.71-1.93)	0.90 (0.77-1.06)	0.70 (0.58-0.85)	0.82 (0.70-0.95)	0.74 (0.60-0.90)	0.97 (0.83-1.13)
Area										
Urban	1 (ref.)	1 (ref.)	1 (ref.)	1 (ref.)	1 (ref.)	1 (ref.)	1 (ref.)	1 (ref.)	1 (ref.)	1 (ref.)
Rural	0.77 (0.68-0.87)	0.76 (0.59-0.99)	0.78 (0.67-0.92)	0.90 (0.70-1.15)	0.89 (0.57-1.39)	0.97 (0.85-1.10)	1.11 (0.96-1.28)	1.04 (0.93-1.18)	1.06 (0.91-1.24)	1.05 (0.92-1.18)
Education										
Tertiary	1 (ref.)	1 (ref.)	1 (ref.)	1 (ref.)	1 (ref.)	1 (ref.)	1 (ref.)	1 (ref.)	1 (ref.)	1 (ref.)
Secondary	1.07 (0.94-1.23)	0.91 (0.70-1.17)	0.79 (0.67-0.93)	1.07 (0.82-1.39)	0.85 (0.53-1.37)	1.03 (0.89-1.18)	0.84 (0.72-0.98)	1.25 (1.10-1.42)	0.84 (0.71-0.99)	0.66 (0.58-0.75)
Mandatory	0.94 (0.74-1.20)	0.62 (0.37-1.05)	0.52 (0.36-0.75)	0.83 (0.50-1.38)	1.06 (0.49-2.28)	0.87 (0.67-1.13)	0.73 (0.55-0.98)	1.41 (1.11-1.78)	0.94 (0.70-1.27)	0.45 (0.35-0.58)
p-value for trend	*0.61*	*0.07*	***<0.001***	*0.48*	*0.89*	*0.28*	*0.04*	*<0.01*	*0.71*	***<0.001***
Income (quartiles,										
Fourth (≥5333)	1 (ref.)	1 (ref.)	1 (ref.)	1 (ref.)	1 (ref.)	1 (ref.)	1 (ref.)	1 (ref.)	1 (ref.)	1 (ref.)
Third (4000-5332)	1.29 (1.11-1.50)	1.12 (0.85-1.48)	0.85 (0.71-1.02)	1.07 (0.8-1.43)	0.83 (0.48-1.42)	0.93 (0.80-1.09)	0.98 (0.83-1.16)	0.88 (0.77-1.02)	0.95 (0.79-1.15)	1.04 (0.90-1.20)
Second (2857-3999)	1.29 (1.09-1.51)	0.93 (0.68-1.29)	0.78 (0.64-0.96)	0.98 (0.71-1.36)	0.91 (0.52-1.60)	0.82 (0.69-0.97)	0.95 (0.79-1.15)	0.88 (0.76-1.03)	0.89 (0.72-1.10)	0.99 (0.84-1.16)
First (<2857)	1.36 (1.13-1.64)	1.21 (0.85-1.73)	0.66 (0.51-0.85)	1.19 (0.83-1.71)	1.27 (0.69-2.32)	0.86 (0.71-1.05)	1.04 (0.84-1.29)	0.80 (0.67-0.96)	1.21 (0.96-1.53)	0.94 (0.78-1.13)
p-value for trend	*<0.01*	*0.51*	*<0.01*	*0.47*	*0.42*	*0.08*	*0.81*	*0.02*	*0.18*	*0.43*
Occupation										
Upper	1 (ref.)	1 (ref.)	1 (ref.)	1 (ref.)	1 (ref.)	1 (ref.)	1 (ref.)	1 (ref.)	1 (ref.)	1 (ref.)
Middle	0.85 (0.73-1.00)	1.10 (0.83-1.46)	0.82 (0.68-0.98)	0.84 (0.62-1.15)	0.95 (0.55-1.63)	0.93 (0.79-1.09)	0.98 (0.82-1.17)	1.16 (1.01-1.35)	0.96 (0.79-1.16)	0.74 (0.64-0.86)
Low	0.89 (0.76-1.04)	0.76 (0.56-1.04)	0.80 (0.66-0.97)	1.00 (0.74-1.34)	1.07 (0.63-1.82)	0.89 (0.75-1.04)	0.96 (0.80-1.14)	1.18 (1.02-1.37)	1.01 (0.83-1.22)	0.66 (0.57-0.77)
p-value for trend	*0.13*	*0.09*	*0.03*	*0.98*	*0.81*	*0.14*	*0.63*	*0.03*	*0.94*	***<0.001***

BMI, body mass index; CHF; Swiss Franc. Occupation: upper, upper and middle managerial work; middle, office/non manual/small independent work; low, manual work. Statistical analysis by logistic regression adjusting for all variables in the table, plus age. Results are expressed as odds ratio and (95% confidence interval). Significant ($p<0.001$) findings are indicated in bold.

Supplementary table 7. Weighted prevalence and socio-demographic determinants of barriers to healthy eating among women, Swiss Health survey 2012

	Access			Social		External		Individual		
	Price	Limited options in restaurants	Limited options at market	No social support	Social group opposition	Time constraint	Daily habits, constraints	Fondness of good food	Fondness of abundant food	Lack of willpower
Overall	43.7	18.4	5.7	8.0	3.1	34.6	39.1	39.1	11.1	21.7
Age groups										
18-35	43.4	22.1	7.1	12.0	4.3	39.6	48.9	35.6	17.2	30.4
36-50	43.9	18.9	5.7	7.5	2.9	35.4	46.7	34.3	10.3	22.4
51-65	42.2	20.0	5.7	6.7	3.0	31.0	35.6	40.0	8.8	17.3
Above 65	45.3	9.9	3.8	4.2	1.7	29.6	15.7	51.5	5.2	12.1
p-value	*0.60*	***<0.001***	*0.01*	***<0.001***	*<0.01*	***<0.001***	***<0.001***	***<0.001***	***<0.001***	***<0.001***
BMI category										
Under/normal weight	44.3	19.9	6.0	7.8	3.3	35.8	40.4	34.8	11.0	21.2
Overweight	43.3	15.4	4.9	8.1	2.8	32.9	36.4	46.2	10.1	19.9
Obese	40.2	14.7	5.9	9.3	2.7	30.0	36.8	51.9	13.9	26.4
p-value	*0.28*	***<0.001***	*0.36*	*0.56*	*0.61*	*0.03*	*0.04*	***<0.001***	*0.11*	***<0.001***
Smoking										
Never smoked	44.0	18.2	5.7	8.2	3.4	34.6	37.7	39.2	10.8	21.4
Ex-smoker	46.1	19.8	4.7	8.3	3.3	33.7	40.0	36.4	11.5	23.7
Current smoker	41.1	17.6	6.6	7.4	2.4	35.2	41.4	41.1	11.4	20.8
p-value	*0.07*	*0.39*	*0.13*	*0.64*	*0.33*	*0.78*	*0.09*	*0.10*	*0.77*	*0.26*
Living situation										
Alone	47.8	17.7	5.4	4.8	2.9	34.5	31.9	39.8	9.6	17.3
In couple	42.3	18.6	5.9	9.1	3.2	34.6	41.5	38.9	11.6	23.2
p-value	*<0.01*	*0.50*	*0.53*	***<0.001***	*0.53*	*0.97*	***<0.001***	*0.63*	*0.07*	***<0.001***
Nationality										
Swiss	44.0	18.6	5.1	7.7	3.2	36.0	39.1	38.4	11.3	22.5
Non-Swiss	42.7	17.5	8.1	9.1	3.0	29.7	39.2	41.8	10.3	19.1
p-value	*0.55*	*0.51*	***<0.001***	*0.27*	*0.81*	***<0.001***	*0.94*	*0.11*	*0.45*	*0.07*
Area										
Urban	44.5	18.5	5.9	7.9	3.0	34.7	38.6	39.3	11.5	20.6
Rural	41.5	17.9	5.3	8.4	3.4	34.5	40.7	38.6	9.9	24.8
p-value	*0.09*	*0.64*	*0.36*	*0.60*	*0.55*	*0.91*	*0.20*	*0.69*	*0.11*	***<0.001***
Education										
Mandatory	43.1	8.9	5.5	6.6	3.0	24.2	23.1	54.0	7.8	16.4
Secondary	43.8	17.9	5.3	8.1	3.0	34.0	37.9	39.3	11.0	21.9
Tertiary	43.8	25.9	7.1	8.7	3.7	43.0	52.8	29.1	13.3	23.1
p-value	*0.95*	***<0.001***	*0.08*	*0.28*	*0.53*	***<0.001***	***<0.001***	***<0.001***	*<0.01*	***<0.001***
Income (quartiles)										
1st (<2857 CHF)	48.2	11.6	6.0	6.9	3.4	29.7	30.6	44.2	8.7	18.9
2nd (2857-3999 CHF)	46.0	17.2	5.8	8.3	3.0	33.6	37.6	39.6	10.6	22.2
3rd (4000-5332 CHF)	41.4	20.7	5.2	7.9	3.0	36.5	42.8	37.6	12.6	24.1
4th (≥5333 CHF)	38.6	24.5	6.0	9.2	3.2	39.0	46.2	34.8	12.5	21.7
p-value	***<0.001***	***<0.001***	*0.79*	*0.28*	*0.96*	***<0.001***	***<0.001***	***<0.001***	*0.01*	*0.03*

Results are expressed as row percentage. Bivariable statistical analyses performed using chi-square. Significant (p<0.001) findings are indicated in bold.

Supplementary table 8. Weighted prevalence and socio-demographic determinants of barriers to healthy eating among men, Swiss Health survey 2012

	Access			Social		External		Individual		
	Price	Limited options in restaurants	Limited options at market	No social support	Social group opposition	Time constraint	Daily habits, constraints	Fondness of good food	Fondness of abundant food	Lack of willpower
Overall	35.9	16.5	6.2	6.3	2.1	29.4	37.6	49.7	17.1	21.1
Age groups										
18-35	37.1	16.1	6.8	7.8	3.5	37.1	43.7	44.9	24.4	25.9
36-50	35.7	19.9	7.6	6.4	1.5	29.6	43.6	45.2	16.5	19.5
51-65	34.9	15.5	5.1	6.1	1.4	23.2	33.2	53.5	13.2	21.4
Above 65	35.9	12.2	4.1	3.7	1.4	23.4	20.6	62.2	10.0	14.4
p-value	*0.74*	***<0.001***	***<0.001***	***<0.001***	***<0.001***	***<0.001***	***<0.001***	***<0.001***	***<0.001***	***<0.001***
BMI category										
Under/normal weight	37.9	17.2	6.7	6.7	2.1	31.3	40.4	43.6	16.8	22.2
Overweight	33.7	15.7	5.5	5.7	2.1	28.2	35.5	53.9	17.5	20.0
Obese	35.7	16.5	6.5	6.9	1.9	26.0	33.2	61.1	17.4	20.1
p-value	*0.04*	*0.44*	*0.29*	*0.41*	*0.97*	***<0.001***	***<0.001***	***<0.001***	*0.84*	*0.21*
Smoking										
Never smoked	36.0	18.5	6.6	7.8	2.3	32.4	38.8	48.1	19.2	22.4
Ex-smoker	35.8	15.3	6.0	4.9	1.8	25.1	35.2	51.0	12.2	18.5
Current smoker	36.2	14.9	6.0	5.5	2.0	28.9	37.9	50.8	18.2	21.4
p-value	*0.98*	*0.01*	*0.75*	*0.001*	*0.58*	***<0.001***	*0.15*	*0.22*	***<0.001***	*0.04*
Living situation										
Alone	33.8	18.0	5.9	6.3	1.8	28.6	38.9	49.3	19.3	21.8
In couple	36.4	16.2	6.3	6.3	2.1	34.1	37.4	49.8	16.7	21.0
p-value	*0.21*	*0.26*	*0.69*	*0.99*	*0.61*	***<0.001***	*0.47*	*0.83*	*0.11*	*0.72*
Nationality										
Swiss	34.9	16.9	5.7	6.3	1.9	29.8	38.2	51.1	18.0	22.5
Non-Swiss	38.9	15.4	7.6	6.3	2.5	28.4	35.9	46.0	14.8	17.2
p-value	*0.04*	*0.29*	*0.04*	*0.95*	*0.27*	*0.47*	*0.25*	*0.02*	*0.04*	***<0.001***
Area										
Urban	37.4	18.1	6.9	6.3	2.1	29.7	37.7	49.3	16.6	20.5
Rural	32.0	12.2	4.5	6.3	2.1	28.6	37.5	50.8	18.4	22.8
p-value	*<0.01*	***<0.001***	*<0.01*	*0.97*	*0.97*	*0.46*	*0.92*	*0.38*	*0.18*	*0.10*
Education										
Mandatory	37.7	6.9	4.4	4.2	2.0	23.2	23.8	56.4	14.9	16.3
Secondary	37.1	14.9	6.0	7.0	2.1	30.2	32.8	51.9	16.8	20.9
Tertiary	34.0	21.6	7.1	6.0	2.0	30.3	48.3	44.8	18.2	22.9
p-value	*0.12*	***<0.001***	*0.07*	*0.03*	*0.97*	*<0.01*	***<0.001***	***<0.001***	*0.23*	***<0.001***
Income (quartiles)										
1st (<2857 CHF)	39.3	10.9	5.8	6.3	2.2	27.5	30.5	52.2	16.8	18.9
2nd (2857-3999 CHF)	38.2	14.2	5.8	6.3	2.2	27.9	34.4	48.4	15.8	20.9
3rd (4000-5332 CHF)	35.9	16.6	6.4	6.6	1.9	29.0	39.7	49.3	17.9	21.4
4th (≥5333 CHF)	32.2	21.9	6.7	6.2	2.0	32.3	43.0	49.4	17.6	22.5
p-value	***<0.001***	***<0.001***	*0.77*	*0.98*	*0.94*	*0.07*	***<0.001***	*0.43*	*0.61*	*0.27*

Results are expressed as row percentage. Bivariable statistical analyses performed using chi-square. Significant (p<0.001) findings are indicated in bold.

Supplementary table 9. Weighted, multivariable analysis of the associations between socio-demographic factors and barriers to healthy eating in women, Swiss Health survey 2012

	Access			Social		External		Individual		
	Price	Limited options in restaurants	Limited options at markets	No social support	Social group opposition	Time constraint	Daily habits, constraints	Fondness of good food	Fondness of abundant food	Lack of willpower
BMI category										
Under/normal	1 (ref.)	1 (ref.)	1 (ref.)	1 (ref.)	1 (ref.)	1 (ref.)	1 (ref.)	1 (ref.)	1 (ref.)	1 (ref.)
Overweight	0.94 (0.81-1.09)	0.88 (0.66-1.19)	0.91 (0.76-1.09)	1.29 (0.99-1.58)	0.99 (0.65-1.52)	1.03 (0.89-1.21)	1.21 (1.04-1.42)	1.38 (1.19-1.61)	1.23 (0.98-1.54)	1.12 (0.94-1.34)
Obese	0.81 (0.66-0.96)	1.09 (0.72-1.65)	0.89 (0.68-1.18)	1.56 (1.11-2.18)	0.93 (0.53-1.63)	0.95 (0.75-1.19)	1.43 (1.06-1.66)	1.7 (1.38-2.11)	1.87 (1.35-2.57)	1.61 (1.27-2.06)
p-value for trend	*0.01*	*0.67*	*0.42*	*0.001*	*0.81*	*0.21*	***<0.001***	***<0.001***	***<0.001***	***<0.001***
Living situation										
In couple	1 (ref.)	1 (ref.)	1 (ref.)	1 (ref.)	1 (ref.)	1 (ref.)	1 (ref.)	1 (ref.)	1 (ref.)	1 (ref.)
Alone	1.21 (1.05-1.39)	1.03 (0.78-1.36)	1.23 (1.02-1.49)	0.65 (0.49-0.85)	1.09 (0.70-1.69)	1.11 (0.96-1.29)	0.96 (0.82-1.13)	0.83 (0.72-0.97)	1.08 (0.86-1.35)	0.91 (0.76-1.09)
Nationality										
Swiss	1 (ref.)	1 (ref.)	1 (ref.)	1 (ref.)	1 (ref.)	1 (ref.)	1 (ref.)	1 (ref.)	1 (ref.)	1 (ref.)
Non-Swiss	0.95 (0.80-1.13)	1.54 (1.14-2.09)	0.92 (0.74-1.15)	1.03 (0.74-1.42)	0.82 (0.49-1.38)	0.72 (0.60-0.87)	0.83 (0.70-0.99)	1.17 (0.98-1.4)	0.74 (0.57-0.97)	0.71 (0.57-0.88)
Area										
Urban	1 (ref.)	1 (ref.)	1 (ref.)	1 (ref.)	1 (ref.)	1 (ref.)	1 (ref.)	1 (ref.)	1 (ref.)	1 (ref.)
Rural	0.86 (0.74-0.99)	0.93 (0.71-1.23)	1.02 (0.85-1.21)	1.02 (0.80-1.30)	1.07 (0.71-1.62)	1.00 (0.87-1.16)	1.09 (0.95-1.26)	0.95 (0.82-1.10)	0.81 (0.66-0.99)	1.18 (1.01-1.38)
Education										
Tertiary	1 (ref.)	1 (ref.)	1 (ref.)	1 (ref.)	1 (ref.)	1 (ref.)	1 (ref.)	1 (ref.)	1 (ref.)	1 (ref.)
Secondary	0.92 (0.80-1.07)	0.78 (0.59-1.03)	0.76 (0.64-0.89)	1.04 (0.80-1.36)	0.85 (0.57-1.26)	0.71 (0.61-0.82)	0.64 (0.55-0.74)	1.40 (1.2-1.64)	0.91 (0.73-1.14)	0.85 (0.70-0.98)
Mandatory	0.83 (0.66-1.05)	0.71 (0.47-1.08)	0.43 (0.31-0.60)	0.93 (0.61-1.42)	0.94 (0.51-1.76)	0.52 (0.40-0.66)	0.40 (0.31-0.52)	2.15 (1.7-2.73)	0.78 (0.54-1.13)	0.56 (0.41-0.72)
p-value for trend	*0.13*	*0.11*	***<0.001***	*0.72*	*0.85*	***<0.001***	***<0.001***	***<0.001***	*0.19*	***<0.001***
Income (quartiles,										
Fourth (≥5333)	1 (ref.)	1 (ref.)	1 (ref.)	1 (ref.)	1 (ref.)	1 (ref.)	1 (ref.)	1 (ref.)	1 (ref.)	1 (ref.)
Third (4000-5332)	1.16 (1.00-1.36)	0.93 (0.67-1.31)	0.9 (0.74-1.09)	0.88 (0.65-1.20)	1.01 (0.62-1.64)	0.98 (0.83-1.16)	1.02 (0.86-1.20)	0.99 (0.83-1.18)	1.06 (0.82-1.37)	1.02 (0.90-1.33)
Second (2857-3999)	1.44 (1.22-1.71)	1.09 (0.77-1.55)	0.77 (0.62-0.95)	0.91 (0.66-1.24)	1.01 (0.61-1.7)	0.9 (0.75-1.07)	0.84 (0.70-1.00)	1.00 (0.84-1.20)	0.89 (0.69-1.15)	0.89 (0.70-1.05)
First (<2857)	1.61 (1.33-1.92)	1.17 (0.81-1.68)	0.55 (0.44-0.70)	0.81 (0.58-1.13)	1.23 (0.73-2.07)	0.82 (0.68-0.99)	0.74 (0.61-0.90)	1.04 (0.86-1.26)	0.78 (0.59-1.02)	0.69 (0.53-0.86)
p-value for trend	***<0.001***	*0.29*	***<0.001***	*0.26*	*0.45*	*0.02*	***<0.001***	*0.65*	*0.04*	*<0.01*

BMI, body mass index; CHF; Swiss Franc. Statistical analysis by logistic regression adjusting for all variables in the table, plus age. Results are expressed as odds ratio and (95% confidence interval). Significant (p<0.001) findings are indicated in bold.

Supplementary table 10. Weighted, multivariable analysis of the associations between socio-demographic factors and barriers to healthy eating in men, Swiss Health survey 2012

	Access			Social		External		Individual		
	Price	Limited options in restaurants	Limited options at markets	No social support	Social group opposition	Time constraint	Daily habits, constraints	Fondness of good food	Fondness of abundant food	Lack of willpower
BMI category										
Under/normal	1 (ref.)	1 (ref.)	1 (ref.)	1 (ref.)	1 (ref.)	1 (ref.)	1 (ref.)	1 (ref.)	1 (ref.)	1 (ref.)
Overweight	0.84 (0.73-0.97)	0.86 (0.65-1.14)	0.93 (0.78-1.11)	0.93 (0.71-1.22)	1.2 (0.75-1.9)	0.99 (0.85-1.15)	0.88 (0.76-1.02)	1.47 (1.28-1.68)	1.29 (1.07-1.55)	0.95 (0.8-1.12)
Obese	0.9 (0.72-1.12)	1.05 (0.69-1.59)	1.07 (0.8-1.42)	1.17 (0.79-1.74)	1.22 (0.53-2.79)	0.94 (0.74-1.19)	0.89 (0.71-1.1)	1.93 (1.55-2.39)	1.58 (1.19-1.96)	1.02 (0.8-1.31)
p-value for trend	*0.34*	*0.83*	*0.65*	*0.43*	*0.64*	*0.59*	*0.28*	***<0.001***	***<0.001***	*0.85*
Living situation										
In couple	1 (ref.)	1 (ref.)	1 (ref.)	1 (ref.)	1 (ref.)	1 (ref.)	1 (ref.)	1 (ref.)	1 (ref.)	1 (ref.)
Alone	0.88 (0.73-1.05)	0.91 (0.66-1.26)	1.11 (0.89-1.38)	0.98 (0.71-1.35)	0.84 (0.45-1.59)	1.26 (1.05-1.51)	1.1 (0.92-1.31)	0.96 (0.81-1.14)	1.19 (0.95-1.48)	1.06 (0.86-1.29)
Nationality										
Swiss	1 (ref.)	1 (ref.)	1 (ref.)	1 (ref.)	1 (ref.)	1 (ref.)	1 (ref.)	1 (ref.)	1 (ref.)	1 (ref.)
Non-Swiss	1.13 (0.95-1.35)	1.28 (0.95-1.73)	0.93 (0.75-1.16)	0.99 (0.71-1.37)	1.24 (0.73-2.09)	0.9 (0.75-1.09)	0.86 (0.72-1.03)	0.84 (0.7-0.99)	0.71 (0.56-0.9)	0.7 (0.57-0.87)
Area										
Urban	1 (ref.)	1 (ref.)	1 (ref.)	1 (ref.)	1 (ref.)	1 (ref.)	1 (ref.)	1 (ref.)	1 (ref.)	1 (ref.)
Rural	0.77 (0.66-0.9)	0.66 (0.49-0.88)	0.66 (0.55-0.8)	0.95 (0.72-1.25)	0.97 (0.6-1.57)	0.94 (0.81-1.1)	1.02 (0.88-1.19)	1.03 (0.9-1.19)	1.06 (0.89-1.28)	1.1 (0.93-1.31)
Education										
Tertiary	1 (ref.)	1 (ref.)	1 (ref.)	1 (ref.)	1 (ref.)	1 (ref.)	1 (ref.)	1 (ref.)	1 (ref.)	1 (ref.)
Secondary	1.09 (0.94-1.26)	0.87 (0.66-1.15)	0.75 (0.63-0.89)	1.18 (0.91-1.54)	0.95 (0.62-1.46)	1.01 (0.87-1.17)	0.53 (0.46-0.61)	1.33 (1.15-1.52)	0.84 (0.7-1.01)	0.78 (0.63-0.91)
Mandatory	1 (0.78-1.29)	0.59 (0.37-0.97)	0.36 (0.25-0.52)	0.69 (0.44-1.07)	0.83 (0.4-1.74)	0.76 (0.58-0.99)	0.37 (0.28-0.48)	1.69 (1.33-2.16)	0.81 (0.59-1.1)	0.59 (0.45-0.72)
p-value for trend	*0.97*	*0.04*	***<0.001***	*0.09*	*0.62*	*0.04*	***<0.001***	***<0.001***	*0.17*	***<0.001***
Income (quartiles,										
Fourth (≥5333)	1 (ref.)	1 (ref.)	1 (ref.)	1 (ref.)	1 (ref.)	1 (ref.)	1 (ref.)	1 (ref.)	1 (ref.)	1 (ref.)
Third (4000-5332)	1.19 (1.01-1.42)	1.04 (0.76-1.43)	0.82 (0.67-1.00)	1.11 (0.81-1.53)	0.93 (0.54-1.60)	0.89 (0.74-1.06)	1.07 (0.90-1.27)	0.88 (0.74-1.04)	1.09 (0.87-1.36)	1.01 (0.83-1.23)
Second (2857-3999)	1.30 (1.08-1.57)	0.95 (0.65-1.37)	0.72 (0.57-0.90)	1.06 (0.75-1.52)	1.05 (0.56-1.97)	0.85 (0.70-1.03)	0.88 (0.73-1.05)	0.83 (0.70-1.00)	0.94 (0.74-1.19)	1.01 (0.82-1.25)
First (<2857)	1.36 (1.10-1.68)	1.03 (0.70-1.52)	0.62 (0.48-0.80)	1.16 (0.81-1.66)	1.16 (0.64-2.11)	0.89 (0.72-1.11)	0.91 (0.73-1.13)	0.88 (0.72-1.08)	1.13 (0.88-1.45)	0.98 (0.78-1.24)
p-value for trend	***<0.001***	*0.99*	***<0.001***	*0.51*	*0.56*	*0.28*	*0.16*	*0.18*	*0.58*	*0.86*

BMI, body mass index; CHF; Swiss Franc. Statistical analysis by logistic regression adjusting for all variables in the table, plus age. Results are expressed as odds ratio and (95% confidence interval). Significant (p<0.001) findings are indicated in bold

Chapter 4 Fifteen-year trends in the prevalence of barriers to healthy eating in a high-income country

Fifteen-year trends in the prevalence of barriers to healthy eating in a high-income country[1–3]

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ABSTRACT

Background: Despite increasing levels of education and income in the Swiss population over time and greater food diversity due to globalization, adherence to dietary guidelines has remained persistently low. This may be because of barriers to healthy eating hampering adherence, but whether these barriers have evolved in prevalence over time has never been assessed, to our knowledge.

Objective: We assessed 15-y trends in the prevalence of self-reported barriers to healthy eating in Switzerland overall and according to sex, age, education, and income.

Design: We used data from 4 national Swiss Health Surveys conducted between 1997 and 2012 (52,238 participants aged ≥18 y, 55% women), applying multivariable-adjusted logistic regression models to assess trends in prevalence of 6 barriers to healthy eating (taste, price, daily habits, time, lack of willpower, and limited options).

Results: The prevalence of 3 barriers exhibited an increasing trend until 2007, followed by a decrease in 2012 (from 44% in 1997 to 50% in 2007 and then to 44% in 2012 for taste, from 40% to 52% and then to 39% for price, and from 29% to 34% and then to 32% for time; quadratic P-trend < 0.0001). Limited options decreased slightly until 2007 (35–33%) and then sharply by 2012 (18%) (linear P-trend < 0.0001). Daily habits remained relatively stable across time from 42% in 1997 to 38% in 2012 (linear P-trend < 0.0001). Conversely, lack of willpower decreased steadily over time from 26% in 1997 to 21% in 2012 (linear P-trend < 0.0001). Trends were similar for all barriers irrespective of sex, age, education, and income.

Conclusion: Between 1997 and 2012, barriers to healthy eating remained highly prevalent (≥20%) in the Swiss population and evolved similarly irrespective of age, sex, education, and income. *Am J Clin Nutr* 2017;105:660–8.

Keywords: trends, barriers to healthy eating, adult population, Switzerland, socioeconomic and demographic factors

INTRODUCTION

Healthy eating can lower the risk of developing chronic diseases, such as obesity, diabetes, hypertension, myocardial infarction, stroke, and many forms of cancer (1, 2). Although different diet types can facilitate healthy eating, all are generally characterized by high intakes of fruits, vegetables, whole grains, nuts, and seeds and low intakes of sugar, red meat, and processed foods (2, 3). Women, older people, and those with normal BMI and higher socioeconomic status (SES)[6] are more likely to follow healthy diets (4, 5). Among the factors influencing healthy eating, evidence points to food price (e.g., healthy foods are too expensive) (6–8), food taste (e.g., healthy foods lack taste) (6, 9), time constraints (e.g., lack of time to prepare and cook healthy foods) (6, 7, 10), and lack of willpower (6)—all self-perceived barriers that people identify as impediments to achieve and maintain healthy eating. Hence, despite widespread dietary guidelines and improved nutrition knowledge in the population (11), people face many barriers preventing them from healthy eating.

The Swiss population enjoys a high quality of life, low unemployment and poverty, universal health care, and one of the longest life expectancies worldwide (12). In comparison with bordering France or Germany, Switzerland has low cardiovascular disease risk factors and mortality (13). However, compliance to the Swiss dietary guidelines has remained low in the population (14), showing no improvements over time (15). A previous nationwide study showed that barriers to healthy eating were highly prevalent (≥20%) and demographically and socioeconomically patterned in the Swiss population (16). Still, whether the prevalence of barriers to healthy eating remains constant or evolves over time has never been assessed. Such analysis is important given the persistently low compliance to the dietary guidelines, particularly

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[3] Supplemental Figures 1–3 and Supplemental Tables 1–5 are available from the "Online Supplemental Material" link in the online posting of the article and from the same link in the online table of contents at http://ajcn.nutrition.org.

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[6] Abbreviations used: CHF, Swiss franc; SES, socioeconomic status; SHS, Swiss Health Survey.

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against a backdrop of increasing education and income levels in the Swiss population, as well as increasing globalization that has introduced greater food diversity and decreasing food prices (17). Thus, we used data from the national Swiss Health Surveys (SHSs) conducted between 1997 and 2012 to assess the trends in prevalence of barriers to healthy eating in the adult population according to different demographic and socioeconomic indicators.

METHODS

Database and sampling

Data from 4 consecutive SHSs conducted between 1997 and 2012 were used. The SHS is a cross-sectional, nationwide, population-based study conducted every 5 y by the Swiss Federal Statistical Office. The SHSs do not require consent from an Ethics Committee because they are part of the Swiss Federal Government mandate, and the data were anonymized before use.

Selection of participants was based on a stratified random sampling applied to a database of all private Swiss households with a registered landline or portable telephone (>90% of households between 1997 and 2012), which was further expanded by the use of the official population registries available at each Swiss village or city. The first stratum consisted of the 7 administrative regions of Switzerland (Leman, Mittelland, Northwest, Zurich, Northeast, Central, and South), and the second stratum consisted of the 26 Swiss cantons (equivalent to American states). The primary sampling unit was the household, and the secondary sampling unit was the individual aged ≥15 y. For each sampled subject, an invitation letter to participate in the survey was sent, and phone contacts were made if no response to the letter was obtained. Participants were interviewed by phone by using computer-assisted telephone interview software, and those aged ≥75 y could opt for a face-to-face interview at home (to accommodate participants with disabilities that may interfere with a phone interview; <5% of total participants chose this between 1997 and 2012). Subsequently, all participants were invited to fill out an additional written questionnaire sent by mail. The interviews were conducted in German, French, or Italian—individuals unable to speak any were excluded, as were those with asylum-seeker status or with very poor health. The participation rate was 85% in 1997, 64% in 2002, 66% in 2007, and 53% in 2012. SHS details (in French and German) are available at: http://www.bfs.admin.ch/bfs/portal/fr/index/infothek/erhebungen__quellen/blank/blank/ess/04.html.

Barriers to healthy eating

Barriers to healthy eating were assessed by the question "Many people, maybe including yourself, place importance in following a healthy diet. Please identify which of the following obstacles prevent you from having a healthy diet," which had 10 different possible items, and the responder chose "yes" or "no" for each of them. The different versions of the items are provided in **Supplemental Table 1** and can be summarized as follows: *1*) time, *2*) limited options in markets, *3*) limited options in restaurants, *4*) price, *5*) no social support, *6*) social group opposition, *7*) taste, *8*) fondness of abundant food, *9*) daily habits, and *10*) lack of willpower. The questions assessing barriers were set by a multidisciplinary group of experts, but no reference to any previously validated instrument could be found. However, the barriers assessed were similar to those used in other studies (6, 8, 9, 18, 19), none of which had been validated either. Hence, in the absence of a standard, validated instrument, the current questionnaire was the only option for the Swiss population.

Demographic and socioeconomic variables

Data were self-reported. Age was categorized into 4 groups (18–35, 36–50, 51–65, and >65 y) for the descriptive and multivariable analyses; for the age-period-cohort analysis, age was categorized into twelve 5-y groups (from 18–22 to 73–77 y). Weight and height were collected, and the resulting BMI (in kg/m^2) was categorized as normal or underweight (<25), overweight (25 to <30), and obese (≥30). Smoking status was categorized as current smoker (yes or no), nationality as Swiss or non-Swiss, and living area as urban or rural. Civil status was categorized as married, single, divorced or separated, and widowed. Education was categorized as mandatory, secondary, or tertiary. Mandatory education in Switzerland corresponds to 9 y. Income (net household income after taxes) was categorized into tertiles for each SHS sample [values expressed in Swiss francs (CHF); 1 CHF = 1.04 US$ or 0.92 €]: lower: <2778 CHF, middle: 2778–4000 CHF, and higher: >4000 CHF for 1997; lower: <3000 CHF, middle: 3000–4500 CHF, and higher: >4500 CHF for 2002; lower: <3044 CHF, middle: 3044–4667 CHF, and higher: >4667 CHF for 2007; and lower: <3333 CHF, middle: 3333–4900 CHF, and higher: >4900 CHF for 2012. Occupation was categorized into 6 groups: upper or middle management work; office, nonmanual, or small independent work; manual work; retired; unemployed; and other (student, stay-at-home).

Exclusion criteria

Participants were excluded if they were <18 y old or if they lacked data for barriers to healthy eating or for the demographic and socioeconomic variables.

Statistical analysis

Statistical analyses were performed by using Stata 14 (Stata Corp.). To test for differences in demographic and socioeconomic characteristics of the sample across survey years, we conducted bivariate analyses by using the chi-square test for categorical variables and Student's *t* test for continuous variables. To assess trends in prevalence of barriers to healthy eating, we conducted multivariable analyses using logistic regression adjusting for all demographic and socioeconomic indicators previously mentioned. Linear and quadratic trends were assessed by using orthogonal polynomial contrasts. Potential age-period-cohort effects were assessed by using the median polish analysis (20, 21). To reduce the likelihood of type I error due to the high number of tests performed, we considered statistical significance for 2-sided tests at $P < 0.0001$. We present the results only for

barriers with prevalence ≥20%, which we arbitrarily set as the cutoff for high prevalence.

RESULTS

Sample selection and characteristics

Of the initial 73,067 participants, 52,238 (71.5%) were included in the analysis. In total, 17,966 participants were excluded because they lacked information on barriers to healthy eating (**Supplemental Figure 1**). Excluded participants were more likely to be aged >65, non-Swiss, and single and to have lower education and income and were slightly less likely to be overweight (**Supplemental Table 2**). **Table 1** summarizes the demographic and socioeconomic characteristics of the included participants by sex and survey year. Between 1997 and 2012, the proportion of participants who were older, were overweight and obese, and had tertiary education increased; among women, the proportion of participants with higher income also increased (Table 1).

Overall trends

Between 1997 and 2012, participants consistently identified taste, price, daily habits, time, lack of willpower, and limited options as barriers to healthy eating with prevalence ≥20% (**Figure 1**; for the remaining 4 barriers, see **Supplemental Figure 2**). Three barriers (taste, price, and time) increased in prevalence between 1997 and 2007 and decreased afterward; the prevalence of daily habits remained relatively stable until 2007 and decreased slightly afterward. Conversely, the prevalence of limited options decreased slightly until 2007, and sharply so by 2012, whereas that of lack of willpower decreased steadily over time.

Trends by sex and age

Figure 2 shows the trends in prevalence of self-reported barriers to healthy eating by sex and age groups. Although the prevalence differed between men and women, the trends evolved similarly. Between 1997 and 2007, the prevalence of price, daily habits, and time increased but decreased afterward—markedly so for price. Differently, lack of willpower steadily decreased across the 15-y period (Figure 2). In 2012, men and women were less likely to report daily habits, lack of willpower, and limited options as barriers, but they were more likely to report time than they were in 1997 (**Table 2**; see **Supplemental Table 3** for prevalence values).

The prevalence and trends for barriers to healthy eating tended to differ across age groups—only the trends for taste and price

TABLE 1
Characteristics of 52,238 included participants by sex and survey year, Swiss Health Survey, 1997–2012[1]

	1997		2002		2007		2012		
	Women	Men	Women	Men	Women	Men	Women	Men	*P*
Participants	5798 (55.7)	4595 (44.2)	7656 (55.5)	6139 (44.5)	7098 (56.0)	5573 (44.0)	8109 (52.7)	7270 (47.3)	
Age group, y									<0.001
18–35	1907 (32.9)	1666 (36.3)	1864 (24.4)	1524 (24.8)	1579 (22.3)	1183 (21.2)	2045 (25.2)	1800 (24.8)	
36–50	1540 (26.6)	1313 (28.6)	2238 (29.2)	2018 (32.9)	2114 (29.8)	1802 (32.3)	2458 (30.3)	2189 (30.1)	
51–65	1285 (22.2)	965 (21.0)	2045 (26.7)	1533 (25.0)	1822 (25.7)	1497 (26.9)	2006 (24.7)	1856 (25.5)	
>65	1066 (18.4)	651 (14.2)	1509 (19.7)	1064 (17.3)	1583 (22.3)	1091 (19.6)	1600 (19.7)	1425 (19.6)	
BMI, kg/m^2									<0.001
<25	4178 (72.1)	2664 (58.0)	5322 (69.5)	3157 (51.4)	4897 (69.0)	2801 (50.3)	5471 (67.5)	3396 (46.7)	
25–29.9	1218 (21.0)	1637 (35.6)	1743 (22.8)	2424 (39.5)	1601 (22.6)	2269 (40.7)	1869 (23.1)	3024 (41.6)	
≥30	402 (6.9)	294 (6.4)	591 (7.7)	558 (9.1)	600 (8.5)	503 (9.0)	769 (9.5)	850 (11.7)	
Smokers	1639 (28.3)	1757 (38.2)	2028 (26.5)	2129 (34.7)	1671 (23.5)	1701 (30.5)	1969 (24.3)	2195 (30.2)	<0.001
Civil status									<0.001
Single	1440 (24.8)	1388 (30.2)	1742 (22.8)	1608 (26.2)	1717 (24.1)	1468 (26.3)	2079 (25.6)	2132 (29.3)	
Married	2982 (51.4)	2687 (58.5)	4054 (53.0)	3743 (61.0)	3539 (49.9)	3240 (58.1)	4425 (54.6)	4402 (60.6)	
Divorced or separated	623 (10.8)	350 (7.6)	924 (12.0)	558 (9.1)	922 (13.0)	618 (11.1)	966 (11.9)	559 (7.7)	
Widowed	753 (13.0)	170 (3.7)	936 (12.2)	230 (3.7)	920 (13.0)	247 (4.5)	639 (7.9)	177 (2.4)	
Swiss national	5041 (86.9)	3925 (85.4)	6933 (90.6)	5451 (88.8)	6451 (90.9)	4906 (88.0)	7025 (86.6)	6035 (83.0)	<0.001
Urban area	4028 (69.5)	3076 (66.9)	5593 (73.1)	4390 (71.5)	4944 (69.7)	3764 (67.5)	5817 (71.7)	5185 (71.3)	<0.01
Education									<0.001
Mandatory	1426 (24.6)	599 (13.0)	1591 (20.8)	627 (10.2)	1001 (14.1)	366 (6.6)	1115 (13.8)	761 (10.5)	
Secondary	3804 (65.6)	2670 (58.1)	5233 (68.4)	3821 (62.3)	4171 (58.8)	2936 (52.7)	4013 (49.6)	3163 (43.6)	
Tertiary	568 (9.8)	1326 (28.9)	829 (10.8)	1687 (27.5)	1926 (27.1)	2271 (40.8)	2964 (36.6)	3338 (46.0)	
Income									<0.0001
Lower	2017 (37.6)	1182 (26.8)	2737 (37.9)	1702 (28.6)	2294 (33.6)	1394 (25.6)	2624 (34.0)	1991 (28.1)	
Middle	1854 (34.5)	1396 (31.6)	2427 (33.6)	1911 (32.1)	2487 (36.4)	1768 (32.5)	2677 (34.7)	2298 (32.4)	
Higher	1498 (27.9)	1839 (41.6)	2053 (28.5)	2343 (39.3)	2053 (30.0)	2285 (42.0)	2419 (31.3)	2800 (39.5)	

[1] Values are *n* (%). Comparisons were made by using chi-square tests. The *P* value was for overall difference across survey years with statistical significance at $P < 0.0001$. Mandatory education was 9 y. Income was categorized as the following (values expressed in CHF; 1 CHF = 1.04 US$ or 0.92 €)—lower: <2778 CHF, middle: 2778–4000 CHF, and higher: >4000 CHF for 1997; lower: <3000 CHF, middle: 3000–4500 CHF, and higher: >4500 CHF for 2002; lower: <3044 CHF, middle: 3044–4667 CHF, and higher: >4667 CHF for 2007; and lower: <3333 CHF, middle: 3333–4900 CHF, and higher: >4900 CHF for 2012. CHF, Swiss franc.

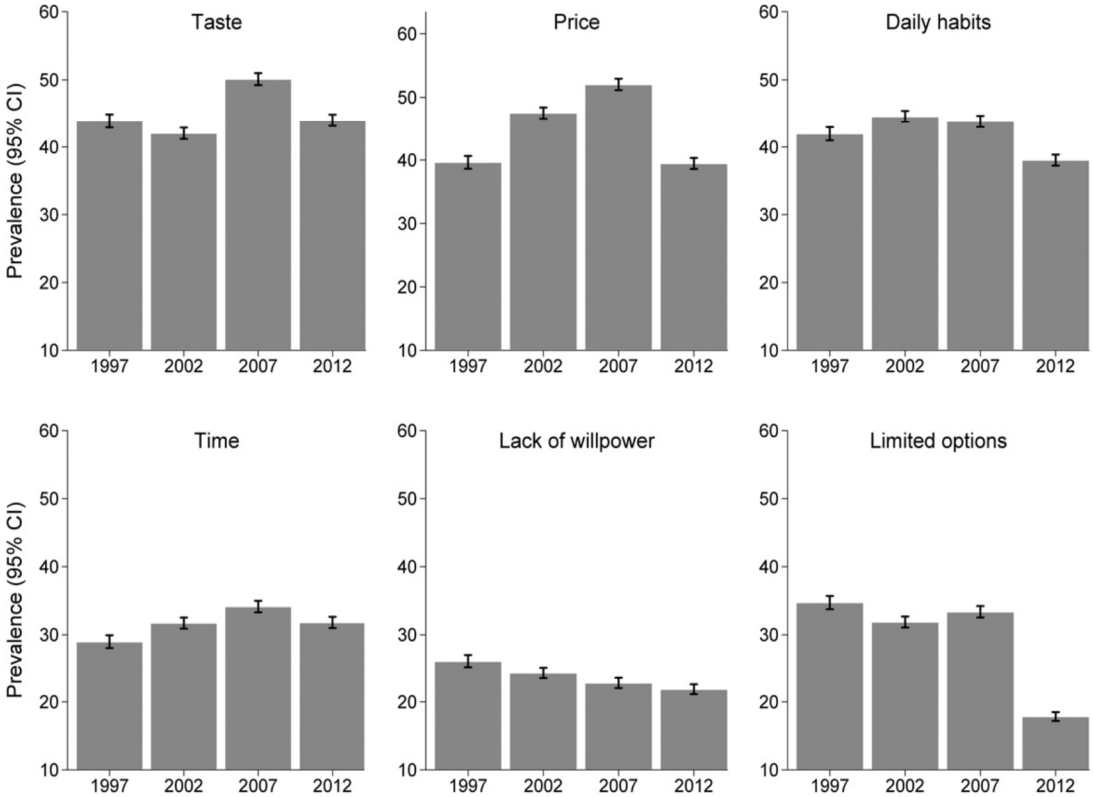

FIGURE 1 Overall adjusted prevalence (means and 95% CIs) of self-reported barriers to healthy eating by survey year from the Swiss Health Surveys conducted between 1997 and 2012. Results obtained from logistic regression models were adjusted for age, BMI, smoking, nationality, civil status, living area, education, income, and occupation. Only barriers with a prevalence ≥20% are shown; for the remaining 4 barriers, see Supplemental Figure 2. The number of included participants was 10,393 for 1997, 13,795 for 2002, 12,671 for 2007, and 15,379 for 2012.

were similar, increasing in all groups between 1997 and 2007 and decreasing afterward. Over 15 y, the prevalence of time increased in the 2 younger age groups, remained stable in the 51- to 65-y age group, and decreased in the oldest age group. The prevalence of daily habits increased slightly between 1997 and 2002 but decreased afterward in the 3 younger age groups. The prevalence of lack of willpower decreased in the 3 younger age groups, and that of limited options decreased in all age groups (Figure 2). As shown in Table 2, in 2012 only the youngest age group was more likely to report price as a barrier than in 1997. The 2 younger age groups were more likely to report time and less likely to report daily habits. All age groups were less likely to report lack of willpower (except the oldest group) and limited options in 2012 than in 1997 (Table 2; see Supplemental Table 3 for prevalence values). The median polish analysis indicated no evidence of a birth cohort effect for any of the barriers to healthy eating (**Supplemental Table 4**).

Trends by education and income

As shown in **Figure 3**, the trends in barriers to healthy eating evolved similarly across education and income groups and mirrored the overall trends. In 2012, irrespective of education and income, all participants were less likely to report daily habits, lack of willpower, and limited options as barriers than in 1997 (**Table 3**). Participants in the higher 2 levels of education and income were more likely to report time as barriers than in 1997; conversely, those with mandatory education were less likely to report time and price (Table 3; see **Supplemental Table 5** for prevalence values).

DISCUSSION

To our knowledge, this is the first study to examine trends in prevalence of self-reported barriers to healthy eating in a population. Our results show that, over a 15-y period, several barriers remained highly prevalent in the Swiss population, and their trends evolved similarly irrespective of sex, age, education, or income.

Overall trends

Between 1997 and 2012, price and taste remained the 2 most prevalent barriers to healthy eating. The prevalence of taste in 1997 (44%) was higher than in the pan-European survey (31%) (6), and it remained high (48%) in 2012. This finding agrees with previous studies showing that taste is one of the most important factors influencing eating behavior, particularly among men (6, 9, 18). This barrier persisted over time, which may be because of the aggressive marketing of fast foods and misleading opinions that healthy eating lacks flavor and enjoyment, exacerbated by the decreasing rate of cooking knowledge and skills in the population (22, 23).

The prevalence of price in 1997 (40%) was much higher than those reported the same year in bordering France (19%), Austria (19%), Germany (9%), and Italy (7%) (6). The increase in prevalence of this barrier between 1997 and 2007 and its

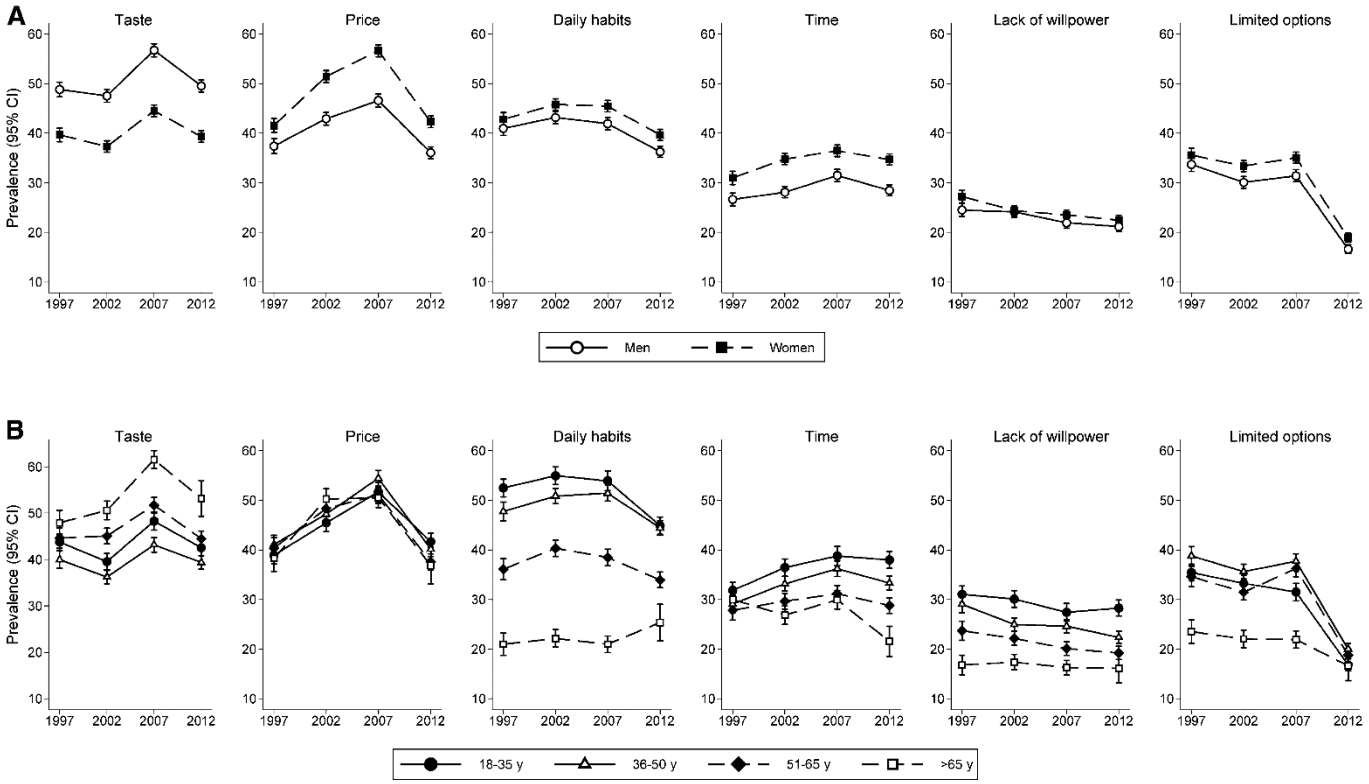

FIGURE 2 Adjusted prevalence (means and 95% CIs) of self-reported barriers to healthy eating in Switzerland by sex (A) and age (B) from the Swiss Health Surveys conducted between 1997 and 2012. Results obtained from logistic regression models adjusted for sex (when stratifying on age), age (when stratifying on sex), BMI, smoking, nationality, civil status, living area, education, income, and occupation. The numbers of participants per survey years 1997, 2002, 2007, and 2012, respectively, were 4595, 6139, 5573, and 7270 for men; 5798, 7656, 7098, and 8109 for women; 3573, 3388, 2762, and 3845 for the age group 18–35 y; 2853, 4256, 3916, and 4647 for the age group 36–50 y; 2250, 3578, 3319, and 3862 for the age group 51–65 y; and 1717, 2573, 2674, and 3025 for the age group >65 y.

subsequent decrease closely resemble the trend in the Swiss consumer price index for the healthier food groups (fresh fruits, vegetables, and fish); meanwhile, the price of less-healthy food groups (bread and flour products, dairy products, ready-made foods) remained relatively stable or decreased over the study period (**Supplemental Figure 3**). This indicates that the perception of price as a barrier in the population indeed reflects the changing prices of healthy foods.

The prevalence of daily habits and lack of willpower tended to decrease over time for all sociodemographic groups. In 1997, the overall prevalence of lack of willpower in Switzerland (26%) resembled that found in bordering countries (6). The overall decrease in these barriers may indicate increasing awareness of the important role of healthy eating as part of a healthy lifestyle, particularly for long-term chronic disease prevention, as has been observed in other European countries (24, 25). Another factor may be the growing view of healthy eating as a socially desirable lifestyle practice (26). These factors may have contributed to increasing willpower to achieve and maintain healthy eating behaviors in an increasingly obesogenic environment.

Conversely, the prevalence of lack of time (for food shopping and preparation) increased slightly over time; in 1997, its prevalence (29%) was higher than in bordering Germany (12%) and France (23%) but lower than in Austria (31%) and Italy (36%) (6). The upward trend observed in Switzerland is in line with the increasingly widespread feeling of time scarcity reported in the United States (10, 27) and among younger adults in bordering Italy (28) and France (29), because people are devoting more time to work and leisure but less time to preparing foods. Among women, the upward trend is likely due to their increased participation in the labor market in the past decades (30).

The prevalence of limited options (in restaurants and cafeterias) as a barrier nearly halved between 1997 and 2012 across all sociodemographic groups. This is likely due to diversification in menus and an increase in the number of foods and meals offered in restaurants and cafeterias in Switzerland, in turn likely driven by both globalization and increasing consumer demand for healthier options (31). However, as reported trends in the United States have indicated, diversification of menu offerings does not necessarily translate to more healthy options (32, 33). Thus, as the share of the population consuming out-of-home meals continues to increase (34), it is important that diversification and greater offerings in restaurant and cafeteria menus actually introduce more healthy options to customers.

Trends by sociodemographic group

Trends were similar for all barriers irrespective of sex, age, education, and income. Nevertheless, given the persistent inequalities in prevalence of several barriers across demographic

TABLE 2
Multivariable analysis of trends in prevalence of barriers to healthy eating, stratified by sex and age groups, Swiss Health Survey, 1997–2012[1]

	Taste	Price	Daily habits	Time	Lack of willpower	Limited options
Men						
1997	1 (ref)	1 (ref)	1 (ref)	1 (ref)	1 (ref)	1 (ref)
2002	0.95 (0.87, 1.03)	1.27 (1.17, 1.38)	1.11 (1.01, 1.21)	1.09 (1.01, 1.19)	0.97 (0.89, 1.07)	0.82 (0.76, 0.90)
2007	1.37 (1.26, 1.49)	1.50 (1.38, 1.63)	1.04 (0.95, 1.13)	1.30 (1.19, 1.42)	0.85 (0.78, 0.94)	0.88 (0.80, 0.96)
2012	1.02 (0.94, 1.11)	0.96 (0.88, 1.05)	0.80 (0.74, 0.88)	1.12 (1.02, 1.23)	0.81 (0.74, 0.89)	0.38 (0.34, 0.41)
P^2	0.001	0.70	<0.0001	0.0005	<0.0001	<0.0001
P^3	<0.0001	<0.0001	<0.0001	0.0002	0.73	<0.0001
Women						
1997	1 (ref)	1 (ref)	1 (ref)	1 (ref)	1 (ref)	1 (ref)
2002	0.91 (0.84, 0.98)	1.49 (1.38, 1.60)	1.15 (1.07, 1.25)	1.17 (1.08, 1.27)	0.87 (0.80, 0.94)	0.92 (0.85, 0.99)
2007	1.26 (1.16, 1.36)	1.82 (1.69, 1.96)	1.14 (1.05, 1.24)	1.24 (1.15, 1.34)	0.83 (0.76, 0.91)	0.99 (0.92, 1.08)
2012	1.01 (0.93, 1.10)	1.01 (0.93, 1.09)	0.88 (0.80, 0.95)	1.14 (1.05, 1.24)	0.79 (0.72, 0.87)	0.41 (0.38, 0.45)
P^2	0.007	0.09	0.002	0.0008	<0.0001	<0.0001
P^3	0.03	<0.0001	<0.0001	<0.0001	0.14	<0.0001
Age group, y						
18–35						
1997	1 (ref)	1 (ref)	1 (ref)	1 (ref)	1 (ref)	1 (ref)
2002	0.84 (0.76, 0.93)	1.33 (1.20, 1.47)	1.10 (1.01, 1.22)	1.24 (1.12, 1.37)	0.96 (0.86, 1.07)	0.90 (0.80, 0.99)
2007	1.19 (1.07, 1.32)	1.69 (1.52, 1.88)	1.05 (0.95, 1.17)	1.37 (1.23, 1.53)	0.85 (0.76, 0.95)	0.83 (0.74, 0.93)
2012	0.93 (0.84, 1.03)	1.11 (1.01, 1.22)	0.71 (0.64, 0.79)	1.32 (1.19, 1.47)	0.89 (0.79, 0.99)	0.35 (0.31, 0.39)
P^2	0.45	0.003	<0.0001	<0.0001	0.009	<0.0001
P^3	0.37	<0.0001	<0.0001	0.0008	0.27	<0.0001
36–50						
1997	1 (ref)	1 (ref)	1 (ref)	1 (ref)	1 (ref)	1 (ref)
2002	0.86 (0.77, 0.95)	1.28 (1.16, 1.42)	1.14 (1.03, 1.25)	1.22 (1.09, 1.35)	0.81 (0.72, 0.90)	0.87 (0.79, 0.96)
2007	1.17 (1.05, 1.30)	1.75 (1.58, 1.93)	1.17 (1.05, 1.29)	1.38 (1.24, 1.54)	0.80 (0.71, 0.89)	0.96 (0.86, 1.06)
2012	1.00 (0.90, 1.11)	0.97 (0.88, 1.08)	0.88 (0.79, 0.97)	1.21 (1.09, 1.35)	0.71 (0.63, 0.79)	0.38 (0.34, 0.43)
P^2	0.07	0.17	0.03	<0.0001	<0.0001	<0.0001
P^3	0.94	<0.0001	<0.0001	<0.0001	0.23	<0.0001
51–65						
1997	1 (ref)	1 (ref)	1 (ref)	1 (ref)	1 (ref)	1 (ref)
2002	1.02 (0.91, 1.14)	1.40 (1.25, 1.57)	1.20 (1.07, 1.35)	1.09 (0.96, 1.23)	0.91 (0.80, 1.04)	0.87 (0.77, 0.98)
2007	1.35 (1.20, 1.51)	1.56 (1.39, 1.76)	1.10 (0.98, 1.24)	1.16 (1.02, 1.32)	0.79 (0.69, 0.91)	1.07 (0.95, 1.21)
2012	0.98 (0.87, 1.11)	0.90 (0.80, 1.00)	0.92 (0.81, 1.04)	1.02 (0.89, 1.16)	0.73 (0.63, 0.84)	0.45 (0.39, 0.52)
P^2	0.22	0.21	0.08	0.56	<0.0001	<0.0001
P^3	<0.0001	<0.0001	<0.0001	0.01	0.95	<0.0001
>65						
1997	1 (ref)	1 (ref)	1 (ref)	1 (ref)	1 (ref)	1 (ref)
2002	1.11 (0.97, 1.27)	1.65 (1.44, 1.89)	1.07 (0.90, 1.27)	0.86 (0.74, 1.00)	1.01 (0.87, 1.24)	0.91 (0.77, 1.07)
2007	1.75 (1.53, 2.00)	1.68 (1.47, 1.92)	1.01 (0.84, 1.18)	1.01 (0.88, 1.17)	0.96 (0.80, 1.15)	0.91 (0.77, 1.07)
2012	1.22 (0.99, 1.49)	0.95 (0.77, 1.17)	1.21 (0.93, 1.56)	0.67 (0.53,0.84)	0.91 (0.69, 1.19)	0.62 (0.47, 0.81)
P^2	0.0001	0.64	0.21	0.003	0.38	0.0007
P^3	<0.0001	<0.0001	0.39	0.03	0.53	0.03

[1] Values are ORs (95% CIs). Statistical analysis by using logistic regression was adjusted for age (when stratifying on sex), sex (when stratifying on age), BMI group, smoking, nationality, area of living, civil status, education, income, and occupation. Statistical significance was considered at $P < 0.0001$. The numbers of participants per survey years 1997, 2002, 2007, and 2012, respectively, were 4595, 6139, 5573, and 7270 for men; 5798, 7656, 7098, and 8109 for women; 3573, 3388, 2762, and 3845 for age group 18–35 y; 2853, 4256, 3916, and 4647 for age group 36–50 y; 2250, 3578, 3319, and 3862 for age group 51–65 y; and 1717, 2573, 2674, and 3025 for age group >65 y. ref, reference.

[2] *P*-linear trend calculated by using orthogonal polynomial contrasts.

[3] *P*-quadratic trend calculated by using orthogonal polynomial contrasts.

and socioeconomic groups, interventions should not only target the whole population but also selectively target population subgroups that are most vulnerable to face specific barriers to healthy eating (i.e., taste for people with lower education and price for people with lower income). No birth cohort effect was detected. However, the study covered a relatively short period of time (15 y), so future studies should assess the existence of birth cohort effects over longer periods.

Consequences for public health nutrition

Our results showed that barriers to healthy eating evolve dynamically across all sociodemographic groups. This finding indicates that regular monitoring of the prevalence of these barriers is needed and that nutrition interventions should adapt accordingly. Additionally, the prevalence of certain barriers, such as price constraint, closely respond to food and market price fluctuations, which suggests that price changes have a high

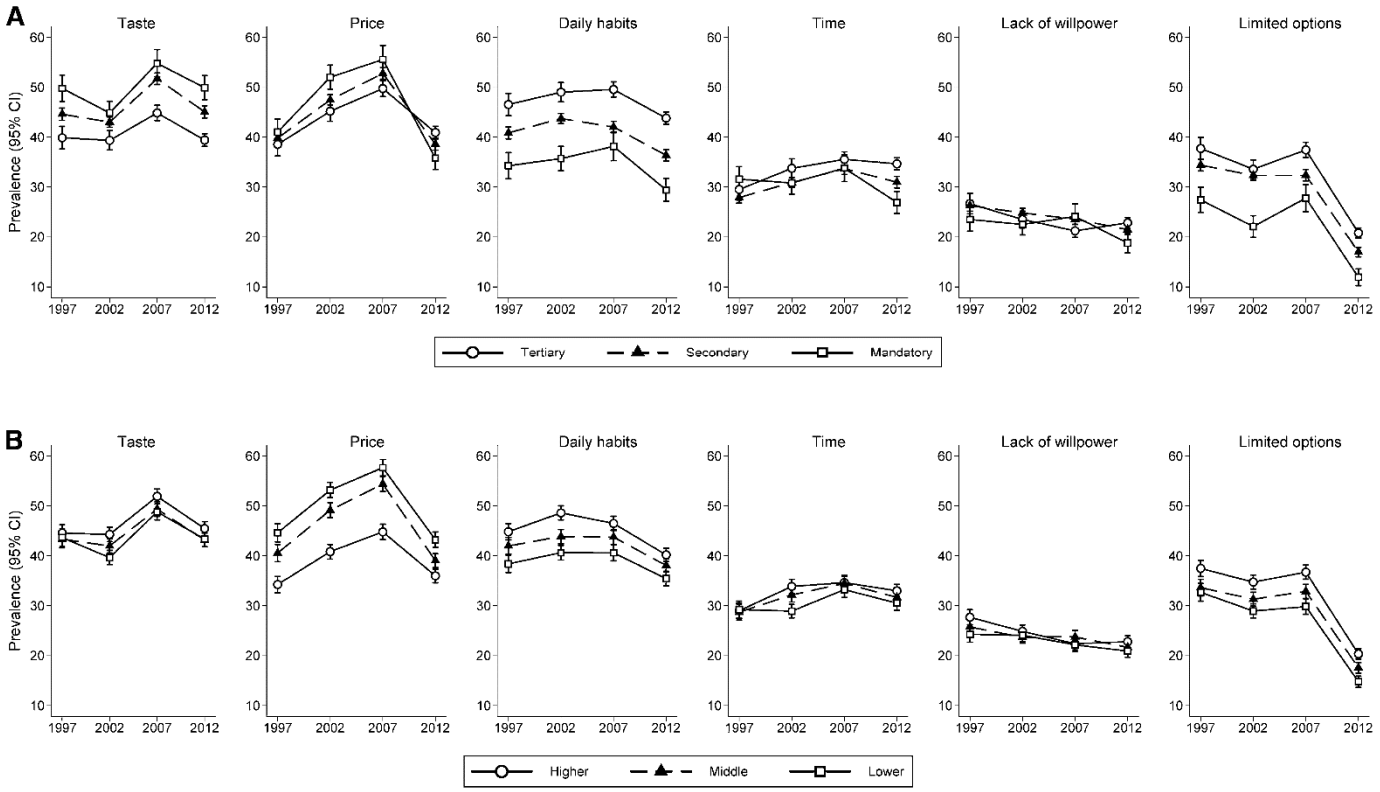

FIGURE 3 Adjusted prevalence (means and 95% CIs) of self-reported barriers to healthy eating in Switzerland by education (A) and income group (B) from the Swiss Health Surveys conducted between 1997 and 2012. Results obtained from logistic regression models adjusted for sex, BMI, smoking, nationality, civil status, living area, occupation, education (when stratifying on income), and income (when stratifying on education). Mandatory education corresponds to 9 y of school. Income was categorized as the following (values expressed in CHF; 1 CHF = 1.04 US$ or 0.92 €)—lower: <2778 CHF, middle: 2778–4000 CHF, and higher: >4000 CHF for 1997; lower: <3000 CHF, middle: 3000–4500 CHF, and higher: >4500 CHF for 2002; lower: <3044 CHF, middle: 3044–4667 CHF, and higher: >4667 CHF for 2007; and lower: <3333 CHF, middle: 3333–4900 CHF, and higher: >4900 CHF for 2012. The numbers of participants per survey years 1997, 2002, 2007, and 2012, respectively, were 2025, 2218, 1367, and 1876 for mandatory education; 6474, 9054, 7107, and 7176 for secondary education; 1894, 2516, 4197, and 6302 for tertiary education; 3199, 4439, 3688, and 4615 for lower income; 3250, 4338, 4255, and 4795 for middle income; and 3337, 4396, 4338, and 4219 for higher income. CHF, Swiss franc.

impact on self-perceived barriers to healthy eating and thus on eating behavior. This is important, because most population-level interventions to improve healthy eating to date have focused on nutrition knowledge (35–37).

To tackle taste as a barrier to healthy eating, the food industry should advertise and promote ready-to-eat and easy-to-prepare foods that are healthy and flavorful (38, 39). To tackle the barrier of price—particularly as it disproportionally affects people of lower SES in Switzerland (16) and elsewhere (8, 9, 19)—food policy should subsidize healthy foods or tax unhealthy foods to reduce the price differential between healthy and unhealthy foods, empowering people to choose healthy foods instead (36, 37). To tackle time as a barrier, measures should be implemented to introduce flexible work schedules; to expand childcare, maternity, and paternity benefits; and to promote healthy eating behaviors at the workplace.

Strengths and limitations

Our analysis benefits from 4 large representative samples and provides the first trend analysis of prevalence of barriers to healthy eating in a population. The large sample size allowed us to conduct stratified analyses with adequate statistical power. Several limitations must also be acknowledged. First, participants' understanding of healthy eating was not assessed, but a study in a Swiss city found that participants had a high level of general nutrition and health knowledge (40), which may indicate adequate understanding of healthy eating in the population. Second, participation rates decreased between 1997 (85%) and 2012 (53%), mirroring general decreasing trends in participation to surveys elsewhere (41). Still, they remained in the upper range of participation rates of national surveys conducted in Europe in the same period (41). Third, 29% of participants were excluded, and they were more likely to be of lower SES, which is associated with higher prevalence of barriers to healthy eating (16). Thus, our estimates might be conservative, and the true prevalence of the barriers to healthy eating might be even higher. Fourth, the questionnaire on barriers was not formally validated, which was also the case for the questionnaire used in the pan-European survey (6). Importantly, the barriers assessed in this study were similar to those in the pan-European survey and in other similar studies (6, 8, 9, 18, 19), thus allowing comparisons between surveys. Finally, the lack of a birth cohort effect might be due to the relatively short time period considered (15 y) and to subtle differences that may be undetectable by the median polish analysis.

TABLE 3
Multivariable analysis of trends in the prevalence of barriers to healthy eating, stratified by education and income level, Swiss Health Survey 1997–2012[1]

	Taste	Price	Daily habits	Time	Lack of willpower	Limited options
Education						
Mandatory						
1997	1 (ref)	1 (ref)	1 (ref)	1 (ref)	1 (ref)	1 (ref)
2002	0.83 (0.72, 0.96)	1.57 (1.36, 1.82)	1.07 (0.91, 1.27)	0.95 (0.81, 1.11)	0.93 (0.77, 1.11)	0.75 (0.62, 0.89)
2007	1.26 (1.08, 1.47)	1.85 (1.58, 2.17)	1.20 (1.00, 1.44)	1.09 (0.92, 1.30)	1.03 (0.85, 1.26)	1.06 (0.88, 1.29)
2012	1.02 (0.87, 1.21)	0.76 (0.64, 0.90)	0.76 (0.63, 0.92)	0.73 (0.6, 0.87)	0.66 (0.53, 0.81)	0.33 (0.26, 0.42)
P^2	0.07	0.01	0.02	0.005	0.0006	<0.0001
P^3	0.84	<0.0001	<0.0001	0.003	0.008	<0.0001
Secondary						
1997	1 (ref)	1 (ref)	1 (ref)	1 (ref)	1 (ref)	1 (ref)
2002	0.93 (0.87, 1.00)	1.36 (1.27, 1.46)	1.14 (1.07, 1.22)	1.16 (1.08, 1.24)	0.93 (0.87, 1.01)	0.91 (0.85, 0.98)
2007	1.35 (1.25, 1.45)	1.69 (1.57, 1.81)	1.06 (0.99, 1.14)	1.31 (1.22, 1.42)	0.87 (0.81, 0.95)	0.91 (0.85, 0.98)
2012	1.02 (0.95, 1.11)	0.96 (0.89, 1.04)	0.82 (0.76, 0.89)	1.15 (1.06, 1.25)	0.78 (0.71, 0.85)	0.39 (0.35, 0.43)
P^2	0.0005	0.49	<0.0001	<0.0001	<0.0001	<0.0001
P^3	<0.0001	<0.0001	<0.0001	<0.0001	0.37	<0.0001
Tertiary						
1997	1 (ref)	1 (ref)	1 (ref)	1 (ref)	1 (ref)	1 (ref)
2002	0.97 (0.86, 1.11)	1.34 (1.18, 1.53)	1.10 (0.97, 1.25)	1.22 (1.07, 1.40)	0.83 (0.72, 0.95)	0.82 (0.73, 0.94)
2007	1.26 (1.12, 1.42)	1.60 (1.42, 1.80)	1.13 (1.01, 1.27)	1.30 (1.15, 1.47)	0.73 (0.64, 0.83)	0.97 (0.87, 1.09)
2012	1.00 (0.89, 1.12)	1.09 (0.97, 1.22)	0.89 (0.79, 0.99)	1.26 (1.12, 1.42)	0.81 (0.72, 0.92)	0.42 (0.37, 0.47)
P^2	0.17	0.02	0.07	<0.0001	0.0002	<0.0001
P^3	0.009	<0.0001	<0.0001	0.004	0.0008	<0.0001
Income						
Lower						
1997	1 (ref)	1 (ref)	1 (ref)	1 (ref)	1 (ref)	1 (ref)
2002	0.84 (0.76, 0.92)	1.41 (1.28, 1.55)	1.12 (1.01, 1.24)	0.98 (0.88, 1.09)	0.99 (0.89, 1.11)	0.84 (0.76, 0.94)
2007	1.24 (1.12, 1.37)	1.68 (1.52, 1.86)	1.12 (1.00, 1.24)	1.19 (1.07, 1.32)	0.89 (0.79, 0.99)	0.88 (0.78, 0.98)
2012	1.01 (0.91, 1.13)	0.91 (0.81, 1.01)	0.89 (0.79, 0.99)	1.04 (0.93, 1.17)	0.83 (0.73, 0.94)	0.35 (0.29, 0.39)
P^2	0.01	0.49	0.07	0.08	0.0007	<0.0001
P^3	0.79	<0.0001	<0.0001	0.15	0.48	<0.0001
Middle						
1997	1 (ref)	1 (ref)	1 (ref)	1 (ref)	1 (ref)	1 (ref)
2002	0.95 (0.86, 1.05)	1.41 (1.28, 1.55)	1.10 (1.01, 1.21)	1.17 (1.05, 1.29)	0.89 (0.81, 0.98)	0.89 (0.81, 0.99)
2007	1.30 (1.18, 1.43)	1.75 (1.59, 1.93)	1.10 (0.99, 1.21)	1.30 (1.18, 1.44)	0.89 (0.80, 0.99)	0.96 (0.87, 1.06)
2012	1.00 (0.90, 1.11)	0.94 (0.85, 1.04)	0.85 (0.76, 0.94)	1.12 (1.01, 1.24)	0.79 (0.70, 0.88)	0.41 (0.36, 0.46)
P^2	0.06	0.91	0.003	0.01	<0.0001	<0.0001
P^3	0.002	<0.0001	<0.0001	<0.0001	0.72	<0.0001
Higher						
1997	1 (ref)	1 (ref)	1 (ref)	1 (ref)	1 (ref)	1 (ref)
2002	1.00 (0.91, 1.10)	1.36 (1.23, 1.49)	1.15 (1.05, 1.27)	1.28 (1.16, 1.41)	0.85 (0.77, 0.94)	0.89 (0.81, 0.97)
2007	1.38 (1.25, 1.52)	1.61 (1.46, 1.77)	1.05 (0.95, 1.15)	1.33 (1.21, 1.47)	0.74 (0.67, 0.83)	0.97 (0.88, 1.07)
2012	1.03 (0.93, 1.13)	1.10 (0.99, 1.21)	0.79 (0.71, 0.86)	1.25 (1.13, 1.38)	0.76 (0.69, 0.85)	0.42 (0.38, 0.46)
P^2	0.01	0.001	<0.0001	<0.0001	<0.0001	<0.0001
P^3	<0.0001	<0.0001	<0.0001	<0.0001	0.01	<0.0001

[1] Values are ORs (95% CIs). Statistical analysis by using logistic regression was adjusted for age, BMI, smoking, nationality, area of living, civil status, occupation, education (when stratifying on income), and income (when stratifying on education). Statistical significance was considered at $P < 0.0001$. Income was categorized as the following (values expressed in CHF; 1 CHF = 1.04 US$ or 0.92 €)—lower: <2778 CHF, middle: 2778–4000 CHF, and higher: >4000 CHF for 1997; lower: <3000 CHF, middle: 3000–4500 CHF, and higher: >4500 CHF for 2002; lower: <3044 CHF, middle: 3044–4667 CHF, and higher: >4667 CHF for 2007; and lower: <3333 CHF, middle: 3333–4900 CHF, and higher: >4900 CHF for 2012. The numbers of participants per survey years 1997, 2002, 2007, and 2012, respectively, were 2025, 2218, 1367, and 1876 for mandatory education; 6474, 9054, 7107, and 7176 for secondary education; 1894, 2516, 4197, and 6302 for tertiary education; 3199, 4439, 3688, and 4615 for lower income; 3250, 4338, 4255, and 4795 for middle income; and 3337, 4396, 4338, and 4219 for higher income. CHF, Swiss franc; ref, reference.

[2] *P*-linear trend calculated by using orthogonal polynomial contrasts.

[3] *P*-quadratic trend calculated by using orthogonal polynomial contrasts.

Conclusion

Between 1997 and 2012, barriers to healthy eating remained highly prevalent (≥20%) in the Swiss population and evolved similarly irrespective of age, sex, education, and income.

The authors' responsibilities were as follows—CdM and PM-V: conceived the manuscript; CdM: analyzed the data and wrote the manuscript; PM-V: supervised the analysis and had primary responsibility for the final content; SK-S, SS, and PM-V: reviewed the manuscript and provided critical recommendations; and all authors: read and approved the final manuscript. None of the authors reported a conflict of interest related to the study.

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Supplementary material

Supplemental table 1. Original statements regarding barriers to healthy eating, Swiss Health Surveys 1997-2012, in German, French and Italian, with English translation

Item	German	French	Italian	English translation	Abridged statement
1	Hofer Zeitaufwand für Einkaufen und Zubereitung.	Les achats et la préparation prennent beaucoup de temps.	Troppo tempo per gli acquisti e la preparazione dei pasti.	Shopping and preparation takes too much time.	"Time"
2	Zu wenig Angebote in den Geschäften.	L'offre dans les magasins est trop restreinte.	L'offerta nei negozi è troppo scarsa.	Options are too limited at the store.	"Limited options at markets"
3	Zu wenig Angebote in Restaurants, Kantinen, usw.	L'offre dans les restaurants, cantines, etc. est trop restreinte.	L'offerta nei ristoranti, mense, ecc. è troppo scarsa.	Options are too limited in restaurants, cafeterias, etc.	"Limited options"
4	Gesundes Essen ist relativ teuer.	Une alimentation saine est relativement chère.	Il costo dell'alimentazione sana è relativamente alto.	Healthy eating is expensive.	"Price"
5	Zu wenig Unterstützung durch Mitmenschen.	Le manque de soutien de la part de mon entourage.	Poco aiuto dalle persone circonstanti.	Lack of support from my social group.	"No social support"
6	Mitmenschen halten davon ab.	Mon entourage fait opposition.	Ostacoli da parte delle persone circonstanti.	Opposition from my social group.	"Social opposition"
7	Grosse Vorliebe für gutes Essen.	J'aime bien manger.	Grande preferenza per il mangiare bene.	Fondness of good food.	"Taste"
8	Grosse Vorliebe für reichliches Essen.	J'aime beaucoup manger.	Grande preferenza per il mangiare molto.	Fondness of abundant food.	"Fondness of abundant food"
9	Gewohnheiten und Zwänge des Alltags.	Les habitudes et contraintes de la vie quotidienne.	Le abitudini e le esigenze della vitaquotidiana lo impediscono.	Habits and constraints of daily life.	"Daily habits"
10	Fehlender Wille, fehlender Glaube an Erfolg.	Le manque de volonté, pas convaincu de l'efficacité.	Poca volontà e scarsa fiducia in un risultato positivo.	Lack of willpower.	"Lack of willpower"

Supplemental table 2. Comparison between included and excluded participants, Swiss Health Surveys, 1997-2012

	Included	Excluded
	N = 52,238	N = 20,829
Age groups		
18-35	13,568 (26.0)	4,386 (23.8)
36-50	15,672 (30.0)	4,741 (25.7)
51-65	13,009 (24.9)	4,156 (22.5)
Above 65	9,989 (19.1)	5,154 (28.0)
p-value		*<0.001*
Women (n, %)	28,661 (54.9)	11,030 (53.0)
p-value		*<0.001*
BMI		
Under/normal	31,886 (61.0)	12,704 (63.8)
Overweight	15,785 (30.2)	5,515 (27.7)
Obese	4,567 (8.7)	1,690 (8.5)
p-value		*<0.001*
Smoking (yes)	15,089 (28.9)	6,201 (29.9)
p-value		*<0.01*
Civil status		
Married	29,072 (55.6)	9,817 (47.2)
Single	13,574 (26.0)	6,920 (33.3)
Widowed	4,072 (7.8)	2,199 (10.6)
Divorced/separated	5,520 (10.6)	1,844 (8.9)
p-value		*<0.001*
Swiss national	45,767 (87.6)	16,762 (80.5)
p-value		*<0.001*
Urban area	36,797 (70.4)	14,610 (70.2)
p-value		*0.43*
Education		
Mandatory	7,486 (14.3)	6,506 (31.4)
Secondary	29,811 (57.1)	10,130 (48.9)
Tertiary	14,909 (28.6)	4,067 (19.6)
p-value		*<0.001*
Income		
Lower	15,941 (31.9)	7,508 (41.8)
Middle	16,818 (33.6)	5,601 (31.2)
Higher	17,290 (34.5)	4,848 (27.0)
p-value		*<0.001*

Results are expressed as number of participants and (%). P-value for between-group comparison using Chi-square test. Income (values expressed in Swiss francs (CHF). 1 CHF = 1.04 US$ or 0.92 €.): 1997 (lower: <2778 CHF; middle: 2778-4000 CHF; higher: >4000 CHF); 2002 (lower: <3000 CHF; middle: 3000-4500 CHF; higher: >4500 CHF); 2007 (lower: <3044 CHF; middle: 3044-4667 CHF; higher: >4667 CHF); 2012 (lower: <3333 CHF; middle: 3333-4900 CHF; higher: >4900 CHF). Statistical significance at p-value<0.0001.

Supplemental table 3. Trends in prevalence of barriers to healthy eating, stratified by gender and age group, Swiss Health Surveys, 1997-2012 (N=52,238)

	Taste	Price	Daily habits	Time	Lack of willpower	Limited options
Men						
1997	49.6 (48.1, 51.1)	36.4 (35.0, 37.9)	42.4 (40.9, 43.8)	26.8 (25.4, 28.1)	25.1 (23.8, 26.4)	34.6 (33.2, 36.1)
2002	48.3 (47.0, 49.5)	42.1 (40.8, 43.4)	44.5 (43.3, 45.8)	28.5 (27.3, 29.7)	24.6 (23.5, 25.7)	30.5 (29.4, 31.7)
2007	57.2 (55.9, 58.5)	46.1 (44.8, 47.5)	43.2 (41.9, 44.5)	32.1 (30.8, 33.4)	22.3 (21.1, 23.4)	31.9 (30.6, 33.1)
2012	50.2 (48.9, 51.4)	35.6 (34.4, 36.8)	37.6 (36.4, 38.7)	29.0 (27.8, 30.1)	21.4 (20.4, 22.5)	17.0 (16.0, 17.9)
p-value [1]	*0.001*	*0.70*	*<0.0001*	*0.0005*	*<0.0001*	*<0.0001*
p-value [2]	*<0.0001*	*<0.0001*	*<0.0001*	*0.0002*	*0.73*	*<0.0001*
Women						
1997	38.8 (37.5, 40.2)	42.4 (41.0, 43.8)	41.5 (40.1, 42.8)	31.1 (29.8, 32.4)	26.6 (25.4, 27.8)	34.9 (33.5, 36.2)
2002	36.6 (35.5, 37.7)	52.2 (51.0, 53.4)	44.6 (43.5, 45.7)	34.6 (33.4, 35.7)	24.0 (23.0, 25.0)	33.0 (31.9, 34.1)
2007	44.1 (42.9, 45.3)	57.1 (55.9, 58.3)	44.4 (43.2, 45.5)	35.9 (34.7, 37.0)	23.2 (22.2, 24.3)	34.7 (33.6, 35.8)
2012	39.1 (37.9, 40.3)	42.6 (41.4, 43.8)	38.6 (37.4, 39.7)	34.0 (32.8, 35.2)	22.3 (21.3, 23.3)	18.6 (17.7, 19.5)
p-value [1]	*0.007*	*0.09*	*0.002*	*0.0008*	*<0.0001*	*<0.0001*
p-value [2]	*0.03*	*<0.0001*	*<0.0001*	*<0.0001*	*0.14*	*<0.0001*
18-35						
1997	41.8 (40.1, 43.6)	37.9 (36.2, 39.6)	54.6 (52.9, 56.3)	32.6 (30.9, 34.2)	31.0 (29.4, 32.6)	38.1 (36.4, 39.8)
2002	37.7 (36.0, 39.4)	44.6 (42.8, 46.4)	56.9 (55.2, 58.7)	37.4 (35.6, 39.1)	30.1 (28.5, 31.7)	35.7 (34.0, 37.4)
2007	45.9 (44.1, 47.8)	50.5 (48.6, 52.4)	55.8 (53.9, 57.7)	39.8 (37.9, 41.7)	27.6 (25.9, 29.3)	33.9 (32.2, 35.7)
2012	40.1 (38.5, 41.8)	40.1 (38.4, 41.7)	46.3 (44.6, 48.0)	38.9 (37.2, 40.5)	28.5 (27.0, 30.1)	18.0 (16.7, 19.3)
p-value [1]	*0.45*	*0.003*	*<0.0001*	*<0.0001*	*0.009*	*<0.0001*
p-value [2]	*0.37*	*<0.0001*	*<0.0001*	*0.0008*	*0.27*	*<0.0001*
36-50						
1997	38.9 (37.0, 40.7)	40.9 (39.0, 42.8)	49.3 (47.4, 51.2)	28.7 (27, 30.5)	29.1 (27.3, 30.8)	39.6 (37.8, 41.5)
2002	35.4 (34.0, 36.9)	46.9 (45.4, 48.4)	52.4 (50.9, 53.9)	32.9 (31.4, 34.3)	24.9 (23.6, 26.2)	36.5 (35.0, 37.9)
2007	42.4 (40.9, 44.0)	54.4 (52.8, 56.0)	53.0 (51.5, 54.6)	35.7 (34.2, 37.2)	24.7 (23.3, 26.0)	38.7 (37.1, 40.2)
2012	38.8 (37.3, 40.2)	40.2 (38.8, 41.7)	46.1 (44.7, 47.6)	32.8 (31.4, 34.2)	22.5 (21.3, 23.8)	20.4 (19.2, 21.6)
p-value [1]	*0.07*	*0.17*	*0.03*	*<0.0001*	*<0.0001*	*<0.0001*
p-value [2]	*0.94*	*<0.0001*	*<0.0001*	*<0.0001*	*0.23*	*<0.0001*
51-65						
1997	46.0 (43.8, 48.2)	40.2 (38.1, 42.4)	36.5 (34.4, 38.7)	27.5 (25.5, 29.4)	24.6 (22.7, 26.5)	34.3 (32.2, 36.4)
2002	46.4 (44.8, 48.1)	48.3 (46.6, 50.0)	40.8 (39.1, 42.4)	29.2 (27.6, 30.7)	23.0 (21.6, 24.5)	31.3 (29.7, 32.8)
2007	53.1 (51.4, 54.8)	51.0 (49.3, 52.7)	38.8 (37.1, 40.5)	30.5 (28.9, 32.1)	20.6 (19.2, 22.0)	35.8 (34.2, 37.5)
2012	45.6 (43.9, 47.3)	37.5 (35.9, 39.2)	34.7 (33.0, 36.3)	27.8 (26.3, 29.4)	19.3 (17.9, 20.6)	19.4 (18.0, 20.7)
p-value [1]	*0.22*	*0.21*	*0.08*	*0.56*	*<0.0001*	*<0.0001*
p-value [2]	*<0.0001*	*<0.0001*	*<0.0001*	*0.01*	*0.95*	*<0.0001*
>65						
1997	50.7 (47.9, 53.6)	40.0 (37.2, 42.9)	17.5 (15.4, 19.6)	30 (27.2, 32.8)	16.3 (14.2, 18.4)	20.1 (17.8, 22.4)
2002	53.4 (51.2, 55.6)	52.1 (49.9, 54.4)	18.5 (16.9, 20.2)	27.0 (25.0, 29.1)	16.8 (15.2, 18.5)	18.6 (16.9, 20.3)
2007	64.1 (62.0, 66.1)	52.6 (50.4, 54.8)	17.5 (16.0, 19.1)	30.3 (28.2, 32.4)	15.7 (14.1, 17.3)	18.7 (17.0, 20.3)
2012	55.5 (52.4, 58.6)	38.8 (35.7, 41.8)	20.4 (17.7, 23.0)	22.4 (19.9, 24.8)	15.0 (12.7, 17.3)	13.6 (11.4, 15.8)
p-value [1]	*0.0001*	*0.64*	*0.21*	*0.003*	*0.38*	*0.0007*
p-value [2]	*<0.0001*	*<0.0001*	*0.39*	*0.03*	*0.53*	*0.03*

Adjusted prevalence and (95% confidence interval) from logistic regression model adjusted for gender (when stratifying on age), age (when stratifying on gender), body mass index group, smoking, nationality, area of living, living situation, education, income, and occupation. P-value for: [1]linear trend; [2] quadratic trend. Statistical significance at p-value<0.0001.

Supplemental table 4. Effects of birth cohort on reporting barriers to healthy eating, Swiss Health Surveys, 1997-2012 (N=52,238)

Birth cohort	Taste	Price	Daily habits	Time	Lack of	Limited options
1930-1934	1 (ref.)	1 (ref.)	1 (ref.)	1 (ref.)	1 (ref.)	1 (ref.)
1935-1939	8.19 (0.66, 18.3)	0.06 (0.01, 1.48)	0.39 (0.02, 6.63)	1.04 (0.11, 9.88)	2.39 (0.47, 12.1)	0.92 (0.03, 31.1)
1940-1944	0.46 (0.04, 5.78)	0.41 (0.05, 3.42)	1.76 (0.13, 28.5)	0.57 (0.06, 5.44)	4.23 (0.84, 21.4)	2.12 (0.06, 70.9)
1945-1949	0.67 (0.05, 8.36)	0.57 (0.07, 4.71)	0.49 (0.03, 8.25)	0.61 (0.06, 5.77)	9.19 (1.82, 46.3)	1.19 (0.04, 40.1)
1950-1954	1.02 (0.08, 12.7)	1.02 (0.12, 8.24)	0.68 (0.04, 11.4)	1.76 (0.19, 16.7)	7.18 (1.42, 36.2)	2.90 (0.09, 98.0)
1955-1959	2.15 (0.17, 26.8)	0.19 (0.02, 1.62)	0.56 (0.03, 8.39)	0.52 (0.05, 4.92)	4.25 (0.84, 21.5)	8.07 (0.24, 27.8)
1960-1964	5.32 (0.43, 66.5)	0.23 (0.03, 1.88)	0.54 (0.03, 9.06)	2.52 (0.27, 23.8)	6.71 (1.33, 33.9)	1.66 (0.05, 56.1)
1965-1969	5.70 (0.46, 71.2)	0.62 (0.08, 5.16)	1.34 (0.08, 22.6)	0.58 (0.06, 5.49)	2.84 (0.56, 14.3)	6.31 (0.19, 21.4)
1970-1974	14.9 (0.99, 31.6)	0.70 (0.08, 5.81)	0.24 (0.01, 4.01)	0.81 (0.09, 7.68)	7.35 (1.46, 37.1)	1.64 (0.05, 55.4)
1975-1979	0.76 (0.13, 4.55)	1.65 (0.36, 7.12)	2.26 (0.31, 16.6)	0.91 (0.19, 4.47)	0.25 (0.08, 0.77)	0.69 (0.06, 8.35)

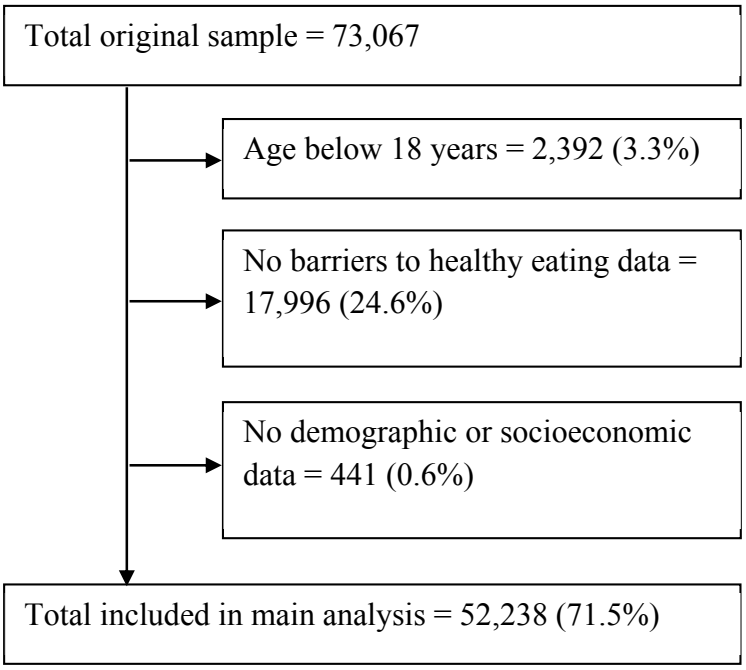
Results from median polish analysis for age-period-cohort effects, presented as estimated rate ratios and (95% confidence intervals).

Supplemental table 5. Trends in prevalence of barriers to healthy eating, stratified by education and income, Swiss Health Surveys, 1997-2012 (N=52,238)

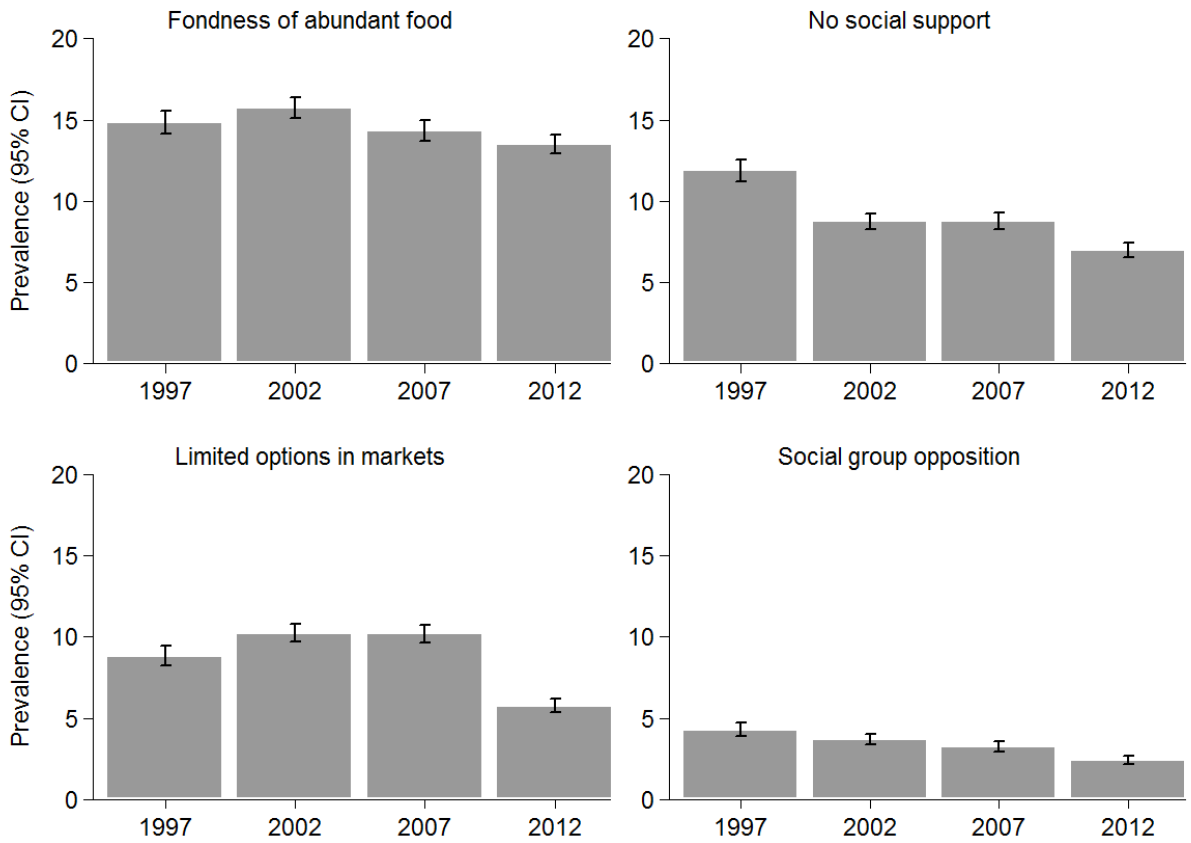
	Taste	Price	Daily habits	Time	Lack of willpower	Limited options
Mandatory						
1997	51.8 (49.1, 54.5)	45.1 (42.4, 47.9)	26.7 (24.4, 28.9)	30.3 (27.8, 32.9)	21.6 (19.4, 23.8)	22.5 (20.2, 24.8)
2002	47.3 (44.9, 49.7)	56.2 (53.8, 58.6)	28.0 (25.9, 30.1)	29.3 (27.1, 31.5)	20.4 (18.5, 22.3)	18.0 (16.2, 19.9)
2007	57.4 (54.6, 60.1)	60.1 (57.3, 62.8)	30.1 (27.5, 32.6)	32.2 (29.6, 34.9)	22.2 (19.8, 24.5)	23.6 (21.1, 26.0)
2012	52.3 (49.6, 55.1)	38.6 (35.9, 41.2)	22.0 (20.0, 24.1)	24.1 (21.8, 26.4)	15.5 (13.7, 17.4)	9.0 (7.6, 10.4)
p-value [1]	*0.07*	*0.01*	*0.02*	*0.005*	*0.0006*	*<0.0001*
p-value [2]	*0.84*	*<0.0001*	*<0.0001*	*0.003*	*0.008*	*<0.0001*
Secondary						
1997	44.4 (43.2, 45.7)	40.2 (38.9, 41.4)	40.4 (39.2, 41.6)	28.1 (26.9, 29.2)	26.4 (25.3, 27.5)	33.9 (32.7, 35.1)
2002	42.8 (41.8, 43.8)	47.6 (46.6, 48.7)	43.4 (42.4, 44.4)	31.1 (30.1, 32.0)	25.1 (24.2, 26.0)	31.9 (30.9, 32.9)
2007	51.5 (50.3, 52.7)	52.9 (51.7, 54.0)	41.8 (40.6, 42.9)	33.8 (32.7, 34.9)	23.9 (22.9, 24.9)	32.0 (30.9, 33.1)
2012	45.0 (43.7, 46.3)	39.2 (37.9, 40.5)	36.0 (34.8, 37.2)	31.0 (29.8, 32.2)	21.8 (20.7, 22.9)	16.9 (16.0, 17.9)
p-value [1]	*0.0005*	*0.49*	*<0.0001*	*<0.0001*	*<0.0001*	*<0.0001*
p-value [2]	*<0.0001*	*<0.0001*	*<0.0001*	*<0.0001*	*0.37*	*<0.0001*
Tertiary						
1997	39.1 (36.9, 41.3)	36.6 (34.3, 38.8)	51.2 (49.0, 53.5)	30.3 (28.2, 32.4)	27.5 (25.4, 29.6)	41.4 (39.1, 43.7)
2002	38.5 (36.6, 40.4)	43.5 (41.5, 45.5)	53.5 (51.5, 55.4)	34.6 (32.7, 36.5)	23.9 (22.2, 25.6)	36.9 (35.0, 38.8)
2007	44.3 (42.8, 45.9)	47.7 (46.1, 49.2)	54.1 (52.6, 55.7)	36.1 (34.6, 37.6)	21.7 (20.4, 23.0)	40.8 (39.2, 42.3)
2012	39.0 (37.8, 40.3)	38.5 (37.3, 39.8)	48.5 (47.2, 49.8)	35.3 (34.0, 36.5)	23.5 (22.4, 24.6)	23.0 (21.9, 24.1)
p-value [1]	*0.17*	*0.02*	*0.07*	*<0.0001*	*0.0002*	*<0.0001*
p-value [2]	*0.009*	*<0.0001*	*<0.0001*	*0.004*	*0.0008*	*<0.0001*
Lower income						
1997	46.1 (44.3, 47.9)	45.5 (43.7, 47.3)	34.4 (32.7, 36.1)	28.9 (27.2, 30.6)	24.0 (22.4, 25.5)	29.0 (27.3, 30.6)
2002	42.0 (40.5, 43.5)	53.9 (52.4, 55.4)	35.8 (34.4, 37.2)	28.2 (26.8, 29.6)	23.3 (22.0, 24.6)	25.8 (24.4, 27.1)
2007	51.9 (50.3, 53.5)	58.3 (56.7, 59.9)	34.5 (33.0, 36.0)	32.0 (30.5, 33.5)	20.9 (19.6, 22.2)	25.9 (24.5, 27.4)
2012	44.8 (43.2, 46.5)	43.4 (41.8, 45.1)	33.9 (32.4, 35.5)	29.9 (28.4, 31.4)	21.2 (19.8, 22.6)	13.7 (12.6, 14.8)
p-value [1]	*0.01*	*0.49*	*0.07*	*0.08*	*0.0007*	*<0.0001*
p-value [2]	*0.79*	*<0.0001*	*<0.0001*	*0.15*	*0.48*	*<0.0001*
Middle income						
1997	43.4 (41.7, 45.1)	40.6 (38.9, 42.4)	42.0 (40.3, 43.7)	29.1 (27.5, 30.7)	26.3 (24.7, 27.8)	33.4 (31.7, 35.1)
2002	42.2 (40.8, 43.7)	49.2 (47.6, 50.7)	43.4 (41.9, 44.8)	32.1 (30.7, 33.5)	23.9 (22.6, 25.2)	31.2 (29.8, 32.6)
2007	49.9 (48.4, 51.4)	54.5 (53.0, 56.0)	42.2 (40.8, 43.7)	34.2 (32.8, 35.7)	23.3 (22.1, 24.6)	32.5 (31.0, 33.9)
2012	42.5 (41.1, 44.0)	39.3 (37.8, 40.8)	39.4 (37.9, 40.8)	31.6 (30.2, 33.0)	22.1 (20.9, 23.4)	17.9 (16.7, 19)
p-value [1]	*0.06*	*0.91*	*0.003*	*0.01*	*<0.0001*	*<0.0001*
p-value [2]	*0.002*	*<0.0001*	*<0.0001*	*<0.0001*	*0.72*	*<0.0001*
Higher income						
1997	42.6 (41.0, 44.3)	33.4 (31.7, 35.0)	49.9 (48.2, 51.6)	30.0 (28.4, 31.6)	28.6 (27.1, 30.2)	40.4 (38.7, 42.1)
2002	42.6 (41.2, 44.1)	40.2 (38.8, 41.7)	52.1 (50.6, 53.5)	34.3 (32.9, 35.7)	24.9 (23.6, 26.2)	37.6 (36.1, 39.1)
2007	50.3 (48.8, 51.7)	44.3 (42.8, 45.8)	49.3 (47.9, 50.8)	35.0 (33.6, 36.4)	22.3 (21.1, 23.6)	39.6 (38.1, 41.1)
2012	42.6 (41.2, 44.0)	35.7 (34.3, 37.0)	44.8 (43.4, 46.2)	34.2 (32.9, 35.6)	23.3 (22.1, 24.6)	22.9 (21.7, 24.1)
p-value [1]	*0.01*	*0.001*	*<0.0001*	*<0.0001*	*<0.0001*	*<0.0001*
p-value [2]	*<0.0001*	*<0.0001*	*<0.0001*	*<0.0001*	*0.01*	*<0.0001*

Adjusted prevalence and (95% Confidence interval) from logistic regression model adjusted for gender, age, body mass index group- smoking, nationality, area of living, living situation, education, income, and occupation Income (values expressed in Swiss francs (CHF). 1 CHF = 1.04 US$ or 0.92 €.): 1997 (lower: <2778 CHF; middle: 2778-4000 CHF; higher: >4000 CHF); 2002 (lower: <3000 CHF; middle: 3000-4500 CHF; higher: >4500 CHF); 2007 (lower: <3044 CHF; middle: 3044-4667 CHF; higher: >4667 CHF); 2012 (lower: <3333 CHF; middle: 3333-4900 CHF; higher: >4900 CHF). P-value for: [1] linear trend; [2] quadratic trend. Statistical significance at p-value<0.0001.

Supplemental figure 1. Participant selection

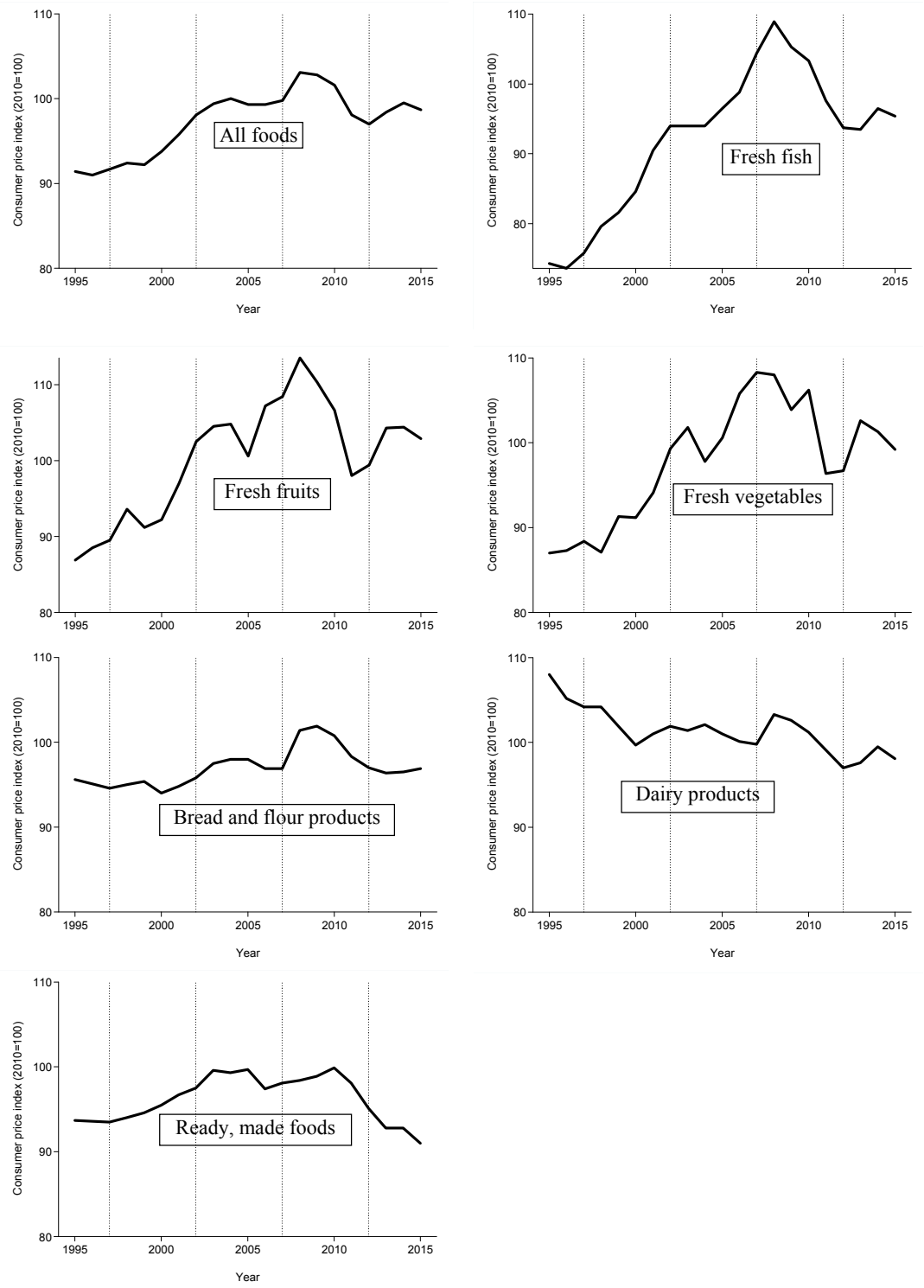


Supplemental figure 2. Overall prevalence of four least prevalent self-reported barriers to healthy eating by survey year, Swiss Health Survey 1997-2012



Adjusted prevalence (%, 95% confidence interval) from multivariable logistic regression adjusted for gender, age, Body Mass Index, living situation, nationality, living area, education, income, and occupation. N per year: 1997 (10,393), 2002 (13,795), 2007 (12,671), 2012 (15,379).

Supplemental figure 3. Food price index for different food categories from 2005 to 2015



Source: Swiss Federal Statistical Office – Consumer Price Index. Available at: http://www.bfs.admin.ch/bfs/portal/en/index/themen/05/02/blank/key/basis_aktuell.html

Chapter 5 Barriers to healthy eating and adherence to dietary recommendations

Manuscript in preparation

Abstract

Background: People perceive many barriers to healthy eating that prevent them from achieving and maintaining a healthy diet.

Objective: To assess the association between ten perceived barriers to healthy eating and adherence to the Swiss dietary guidelines for six food groups.

Methods: Cross-sectional data from the Swiss Health Survey 2012 (N=15450). Barriers and compliance to guidelines were dichotomized into yes/no variables and associations were assessed using multivariable logistic regression.

Results: Participants reporting daily habits as a barrier were less likely to adhere to the guidelines for fruits, odds ratio and (95% confidence interval) 0.91 (0.85-0.98), fish 0.82 (0.75-0.90), meat 0.89 (0.82-0.97), and drinks 0.91 (0.85-0.97). Participants reporting taste as a barrier were less likely to adhere to the guidelines for fruits 0.85 (0.79-0.91), vegetables 0.72 (0.66-0.78), and meat 0.66 (0.61-0.72). Participants reporting lack of time were less likely to adhere to the guidelines for fish 0.86 (0.78-0.94) and dairy 0.88 (0.78-0.99). Participants reporting lack of willpower were less likely to adhere to the guidelines for fish 0.78 (0.70-0.87) and meat 0.84 (0.76-0.92). However, participants reporting price as a barrier were more likely to adhere to the guidelines for fruits 1.13 (1.06-1.21), vegetables 1.20 (1.11-1.30), fish 1.09 (1.01-1.19), and meat 1.29 (1.20-1.40). Similar associations emerged for participants reporting lack of options in restaurants or in markets. There was effect modification by sex, age, body mass index, education, and household composition in several associations.

Conclusion: In the Swiss adult population, the association between barriers to healthy eating and eating behaviors was far more complex than initially thought.

Introduction

A healthy diet is a powerful tool to prevent the development of noncommunicable diseases such as obesity, diabetes, hypertension, cardiovascular disease, and cancer (1, 2). However, healthy eating is hard to achieve for the majority of the population in high-income countries (HICs); consistent evidence over time indicates that only a small proportion of the population adhere to the recommended dietary guidelines (3, 4). This low adherence to dietary guidelines represents a critical challenge as the prevalence of noncommunicable diseases in the population continue to increase (5, 6). Structural, environmental, social, and individual factors interact to influence an individual's dietary behavior (7). Despite the existence of an abundant food supply and widespread dietary guidelines, individuals report perceived barriers to healthy eating that prevent them from achieving and maintaining a healthy diet (8). Across HICs, individuals consistently identify time constraints, taste preference and the costs of foods as important barriers to healthy eating (8). We previously reported that between 20% and 50% of the Swiss population perceived time constraints, taste preference, high cost of healthy foods and daily habits as the main obstacles to healthy eating over time (9), and that these barriers were demographically and socioeconomically patterned (10). However, little research has explored whether perceived barriers to healthy eating are in fact associated with dietary behavior (11, 12).

Therefore, we aimed to assess the association between perceived barriers to healthy eating and adherence to the Swiss dietary guidelines in a representative sample of the adult Swiss population. We hypothesized that perceived barriers to healthy eating would preclude participants to achieve a healthy eating status.

Methods

We used data from the Swiss Health Survey (SHS) from 2012, which sampled 21,597 participants. The SHS is a cross-sectional, nationwide, population-based study and the sample is considered representative of the Swiss adult population. Details of the SHS methodology have been described elsewhere (10).

Exposures

In a written questionnaire, participants answered the question "Please identify which of the following obstacles prevent you from having a healthy diet" by selecting from a list of ten predetermined barriers. A multidisciplinary team of experts set the different items, which reflected those listed in a Pan-European survey and other similar research (8, 13) (Supplementary table 1 lists the barriers as presented in the questionnaire, and supplementary table 2 lists the barriers to healthy eating included in the Pan-European survey).

Outcomes

We focused on six food items in the Swiss dietary guidelines for which adherence data were available and could be derived from the self-reported answers given by participants. These were fruits (≥2 servings/day), vegetables (≥3 servings/day), dairy foods (≥3 servings/day), fish (≥2 servings/week), meat (≤2 servings/week), and non-alcoholic, non-sweetened beverages (≥2 liters/day). We created a dichotomous variable for each guideline to reflect adherence (yes/no).

Covariates

We included the following covariates in our analysis: sex; age categorized into 18-35, 36-50, 51-65, and >65 age groups; body mass index (kg/m^2) categorized into three groups (18.5 ≥ BMI <25; 25 ≥ BMI < 30; BMI ≥30); education categorized as mandatory (lower secondary school), secondary, and tertiary; household composition, as the number of people living with participant, categorized as 1, 2, 3, or ≥4; smoking status, dichotomized as current smoker or not; and language, categorized according to the three major language regions of Switzerland: German, French, and Italian.

Exclusion criteria

We excluded participants who lacked data on barriers to healthy eating, on adherence to the dietary guidelines, as well as with missing information on sex, age, smoking, BMI, education, household composition, and smoking status (**Suppplementary figure 1**).

Statistical analysis

Descriptive results were presented as average ± standard deviation (SD) for continuous data and as number of participants (percentage) for categorical data. We used chi-square test to test for difference between categorical variables, and student t-test for continuous variables. To test for the association between barriers to healthy eating and adherence to the dietary guidelines, we used logistic regression models to generate odds ratios and 95% confidence intervals, first adjusted for age and sex only, and then additionally adjusted for BMI, smoking, education, household composition, and language. We then tested for interaction between the covariates and each barrier to healthy eating; when an interaction was significant ($p<0.05$), the above models were run after stratifying for the corresponding covariate to assess potential differential associations. Statistical analyses were performed using Stata 14 (Stata Corp, College Station, Texas, USA). All tests were two-tailed and statistical significance was considered for $p<0.05$.

Results

Characteristics of included and excluded participants

Of the initial 21,597 participants, 15,450 with complete data were included, 53% of which were women. There were no major differences between included and excluded participants, except that a higher proportion of included participants had a tertiary degree (**Supplementary table 1**). The characteristics of the included participants according to gender are summarized in **Table 1**. Women reported higher adherence to the dietary guidelines than men for all food groups except meat and drinks. Overall, the highest adherence was observed for drinks at 39.4%, followed closely by fruits at 38.8%, and the lowest adherence was for meat at 9.1% (**Table 1**). Perceived barriers to healthy eating, namely price, daily habits, taste, time, and willpower showed a prevalence of >20% and up to 45%, with clear differences between men and women.

Association between barriers to healthy eating and compliance to dietary guidelines

Table 2 displays the result of the multivariable-adjusted logistic regression models. Participants reporting price as a barrier were more likely to adhere to the dietary guidelines for fruits, vegetables, fish, and meat. Those who reported daily habits as a

barrier were less likely to adhere to the dietary guidelines for fruits, fish, meat, and drinks. Similarly, participants reporting taste as a barrier were less likely to adhere to the dietary guidelines for fruits, vegetables, and meat. Participants reporting time as a barrier were less likely to adhere to the dietary guidelines for fish and dairy. Those reporting lack of willpower as a barrier were less likely to adhere to the dietary guidelines for fish and meat. Participants reporting lack of options in restaurants/cafeterias were more likely to adhere to the dietary guidelines for fruits, vegetables, fish, meat, and drinks—similar associations became apparent for those who reported limited options at supermarkets. Those who identified gluttony as a barrier to healthy eating were more likely to adhere to the guidelines for vegetables, and dairy but less likely to adhere to the guidelines for fish, and meat. Finally, participants who reported social group opposition as a barrier were more likely to adhere to the dietary guidelines for vegetables and meat (**Table 2**).

Stratified analyses

In stratified analysis, we found effect modification by several covariates in the above associations (**Supplementary tables 4-8**). The association between price and higher adherence to guidelines for meat was more pronounced among men than among women. Similarly, the association between reporting gluttony as barrier and lower adherence to guidelines for meat was more pronounced among men than among women. The association of limited options at supermarkets with adherence to the fruits and vegetables guidelines remained only among men (**Supplementary table 4**).

The association of time as a barrier with lower adherence to the vegetables guidelines persisted only among participants aged 18-35. Similarly, the association between daily habits and adherence to the fruits recommendations remained only among ages 36 to 65 (**Supplementary table 5**).

The association of lack of options in restaurants with higher adherence to the meat guidelines was evident only among participants with a BMI <30. The association of daily habits with lower adherence to the meat guidelines was more pronounced among participants with a BMI ≥30 (**Supplementary table 6**).

The association between taste and lower adherence to the fruits and meat recommendations was apparent only among participants with secondary and tertiary education. The association of willpower with lower adherence to the meat guidelines remained only among participants with low education. Time was associated with a lower adherence to meat guidelines only among participants with low education (**Supplementary 7**).

The association between lack of options in restaurants and higher adherence to the meat guidelines attenuated gradually with higher number of people in the household. Finally, the association of lack of options in supermarkets with higher adherence to the vegetables guidelines remained only among households with 1 or 2 individuals (**Supplementary table 8**).

Discussion

In this large representative sample of the Swiss adult population, we found that several perceived barriers to healthy eating were differently associated with adherence to the Swiss dietary guidelines. Our results show that the association between barriers to healthy eating and eating behaviors is far more complex that initially thought.

Association between barriers to healthy eating and compliance to dietary guidelines

Barriers regarding price, lack of options in restaurants, and lack of options in supermarkets were associated with increased adherence to most dietary guidelines. These associations contradicted previous reports (11) and our initial hypothesis. A possible explanation is that participants who regularly search for and purchase healthy foods are more aware of the higher price of healthy products and the lack of healthy options in restaurants and supermarkets. In this case, these perceived barriers to healthy eating may be more inconveniences than actual barriers. These findings require further investigation.

Barriers regarding daily habits, taste, time, and willpower were associated with lower adherence to most dietary guidelines, a finding that largely reflects previous published work (11, 12). We also found that individuals who report gluttony, or "I enjoy

eating a lot", were more likely to adhere to the dietary guideline for vegetables and dairy but less likely to meet the guidelines for fish and meat. Importantly, we found no associations between some barriers and food groups, such as time and willpower with fruits and vegetables, in contrast to previous studies (11, 12). Finally, the stratified analysis revealed effect modification by several sociodemographic factors. These also stand in contrast to previous work, which found no effect modification by sex in the association between price and foods groups, as our results showed (11). Population-specific factors that make the association between perceived barriers to healthy eating and actual dietary behavior vary by population may explain the fact that our results differ from those of published work. For instance, previous reports sampled populations in urban regions across five European countries, and stratified analysis revealed some variation across these settings (11).

Strengths and limitations

Strengths of our study include the large population-based representative sample, the largest to date to our knowledge. This large sample size provided enough statistical power to test for interaction. The wide range of barriers to healthy eating measured also allowed assessing a large range of associations.

Nevertheless, our study is limited by the use of cross-sectional data, as well as the self-reported nature of the data, which are susceptible to recall and social desirability bias, particularly in regards to adherence to the dietary guidelines. The dichotomous nature of the barrier variables prevented us from examining potential degrees of the effect of each barrier. Furthermore, the limited data available regarding dietary intake prevented us from examining other important food and nutrient groups, such as whole grains, salt, beans and legumes, and unsaturated fats. Though specific Swiss dietary guidelines do not exist for all foods and nutrients, World Health Organization recommendations, or those include in well-known dietary quality indices such as the Mediterranean Diet Score could be used. Finally, a substantial number of participants were excluded from the analysis; however, this exclusion was necessary as these participants lacked information on barriers to healthy eating, and excluded participants did not differ significantly from included ones.

Importance for public health

Our findings indicate that interventions aimed at increasing adherence to the dietary guidelines need to be sensitive to the way the population perceives how difficult it is to achieve and maintain a healthy diet. Ultimately, interventions that aim to mitigate barriers to healthy eating need to address the determinants of diet in general. These will necessitate policy changes and multi-faceted actions across different levels of society (8, 14-16). One such intervention would be to instill and foment in people knowledge and appreciation of healthy eating as part of healthy living, crucially among children in schools, enabling them to acquire healthy eating behaviors (purchasing, growing, and cooking) from early life (15, 17). Another is taxing unhealthy foods, and limiting or eliminating the promotion and advertisement of unhealthy foods, particularly predatory spread of unhealthy food retailers in disadvantaged neighborhoods. Importantly, a more promising and crucial intervention is increasing government subsidies towards the production of healthy foods, especially given that the current obesity-promoting food system relies heavily on government subsidies for cheaply available staple calories (14-16).

Conclusion

In this study, we found that the highly prevalent barriers to healthy eating in the Swiss population show a complex association with adherence to the dietary guidelines.

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Table 1. Descriptive characteristics of included participants, Swiss Health Survey 2012 (N=15450)

	Total	Men	Women	p-value
N (% women)	15450 (52.8)	7287	8163	
Age, mean (SD)	48.79 (17.4)	48.8 (17.4)	48.78 (17.3)	*0.94*
BMI, mean (SD)	24.78 (4.4)	25.73 (3.8)	23.93 (4.6)	
Current smoker, n (%)	4180 (27.1)	2198 (30.2)	1982 (24.3)	
Educational level, n (%)				*<0.001*
Tertiary	4783 (31.0)	2811 (38.6)	1972 (24.2)	
Secondary	8740 (56.7)	3697 (50.8)	5043 (61.9)	
Mandatory	1894 (12.3)	766 (10.5)	1128 (13.9)	
Household composition, n (%)				*<0.001*
1 person	2628 (17.0)	1056 (14.5)	1572 (19.3)	
2 people	5912 (38.3)	2925 (40.1)	2987 (36.6)	
3 people	2530 (16.4)	1169 (16.0)	1361 (16.7)	
4 people or more	4380 (28.3)	2137 (29.3)	2243 (27.5)	
Adherence to Swiss dietary guidelines				
Fruits	5999 (38.8)	2229 (30.6)	3770 (46.2)	*<0.001*
Vegetables	3167 (20.5)	914 (12.5)	2253 (27.6)	*<0.001*
Dairy	2993 (19.4)	1319 (18.1)	1674 (20.5)	*<0.001*
Fish	3477 (22.5)	1110 (15.2)	2367 (29.0)	*<0.001*
Meat	1413 (9.1)	711 (9.8)	702 (8.6)	*0.01*
Drinks	6069 (39.4)	3223 (44.3)	2846 (34.9)	*<0.001*
Barriers to healthy eating				
Price	6137 (39.7)	2620 (36.0)	3517 (43.1)	*<0.001*
Daily habits	5889 (38.1)	2709 (37.2)	3180 (39.0)	*0.02*
Taste	6932 (44.9)	3717 (51.0)	3215 (39.4)	*<0.001*
Time	4921 (31.9)	2116 (29.0)	2805 (34.4)	*<0.001*
Willpower	3308 (21.4)	1538 (21.1)	1770 (21.7)	*0.38*
Limited options in restaurants	2827 (18.3)	1249 (17.1)	1578 (19.3)	*<0.001*
A lot of food	2088 (13.5)	1196 (16.4)	892 (10.9)	*<0.001*
No social support	1076 (7.0)	442 (6.1)	634 (7.8)	*<0.001*
Limited options at market	930 (6.0)	452 (6.2)	478 (5.9)	*0.37*
Social group opposition	377 (2.4)	136 (1.9)	241 (3.0)	*<0.001*

Statistical significance for difference between groups tested with student t-test for continuous variables, and with Chi-square test for categorical variables.

Table 2. Association between barriers to healthy eating and adherence to dietary guidelines among Swiss adults, Swiss Health Survey 2012 (N = 15450)

	Multivariable-adjusted OR (95% CI)					
Barriers to healthy eating	Fruits	Vegetables	Fish	Meat	Dairy	Drinks
Price	**1.13 (1.06, 1.21)**	**1.20 (1.11, 1.30)**	**1.09 (1.01, 1.19)**	**1.29 (1.20, 1.40)**[a]	0.97 (0.87, 1.09)[a,d,f]	1.06 (0.99, 1.13)
Daily habits	**0.91 (0.85, 0.98)**[b,f]	1.05 (0.97, 1.14)[f]	**0.82 (0.75, 0.90)**	**0.89 (0.82, 0.97)**[b,c,e]	0.97 (0.86, 1.09)[f]	**0.91 (0.85, 0.97)**[d,f]
Taste	**0.85 (0.79, 0.91)**[d,f]	**0.72 (0.66, 0.78)**	1.01 (0.93, 1.10)[d]	**0.66 (0.61, 0.72)**[d,f]	1.03 (0.92, 1.15)[c]	0.98 (0.91, 1.04)
Time	0.97 (0.91, 1.04)	0.97 (0.89, 1.05)[a,b,e]	**0.86 (0.78, 0.94)**[b]	0.97 (0.89, 1.05)[c,d,f]	**0.88 (0.78, 0.99)**	0.93 (0.87, 1.00)[f]
Willpower	0.96 (0.88, 1.04)	0.91 (0.82, 1.00)	**0.78 (0.70, 0.87)**[a]	**0.84 (0.76, 0.92)**[a,f]	1.09 (0.96, 1.24)	0.96 (0.89, 1.04)
Limited options in	**1.33 (1.23, 1.45)**	**1.56 (1.42, 1.72)**	**1.26 (1.14, 1.39)**[d]	**1.56 (1.42, 1.71)**[c,e]	0.94 (0.81, 1.08)	**1.12 (1.03, 1.22)**[f]
Gluttony	1.02 (0.92, 1.12)	**1.17 (1.04, 1.31)**[b]	**0.86 (0.76, 0.98)**[c]	**0.66 (0.58, 0.75)**[a,f]	**1.26 (1.09, 1.46)**[e]	1.07 (0.98, 1.18)
No social support	1.11 (0.98, 1.25)	1.14 (0.98, 1.32)	0.98 (0.84, 1.16)	1.11 (0.96, 1.29)	0.91 (0.73, 1.13)	1.00 (0.88, 1.14)
Limited options at market	**1.18 (1.03, 1.35)**[a,f]	**1.25 (1.07, 1.47)**[a,e]	**1.40 (1.20, 1.63)**	**1.84 (1.59, 2.13)**[f]	0.79 (0.62, 1.02)	1.04 (0.91, 1.20)
Social group opposition	1.10 (0.89, 1.35)	**1.48 (1.18, 1.85)**	1.12 (0.86, 1.45)	**1.29 (1.02, 1.62)**[f]	1.11 (0.80, 1.54)	1.10 (0.90, 1.35)

Odds ratios and 95% confidence intervals adjusted for age, sex, BMI, education, household composition, and language region, computed from logistic regression model run separately for each barrier exposure and adherence food group. Interaction with: [a] sex; [b] age; [c] BMI; [d] education; [e] household composition; [f] language. Results in bold indicate p<0.01

Supplementary table 1. Barriers to healthy eating, Swiss health survey 2012

Item[1]	Original statement in Swiss Health Survey 2012[2]			English translation	Abridged statement
	German	French	Italian		
1	Hofer Zeitaufwand für Einkaufen und Zubereitung.	Les achats et la préparation prennent beaucoup de temps.	Troppo tempo per gli acquisti e la preparazione dei pasti.	Shopping and preparation takes too much time.	"Time constraint"
2	Zu wenig Angebote in den Geschäften.	L'offre dans les magasins est trop restreinte.	L'offerta nei negozi è troppo scarsa.	Options are too limited at the store.	"Limited options at market"
3	Zu wenig Angebote in Restaurants, Kantinen, usw.	L'offre dans les restaurants, cantines, etc. est trop restreinte.	L'offerta nei ristoranti, mense, ecc. è troppo scarsa.	Options are too limited in restaurants, cafeterias, etc.	"Limited options in restaurants"
4	Gesundes Essen ist relativ teuer.	Une alimentation saine est relativement chère.	Il costo dell'alimentazione sana è relativamente alto.	Healthy eating is expensive.	"Price"
5	Zu wenig Unterstützung durch Mitmenschen.	Le manque de soutien de la part de mon entourage.	Poco aiuto dalle persone circonstanti.	Lack of support from my social group.	"Lack of social support"
6	Mitmenschen halten davon ab.	Mon entourage fait opposition.	Ostacoli da parte delle persone circonstanti.	Social group opposition.	"Social group opposition"
7	Grosse Vorliebe für gutes Essen.	J'aime bien manger.	Grande preferenza per il mangiare bene.	Fondness of good food.	"Fondness of good food"
8	Grosse Vorliebe für reichliches Essen.	J'aime beaucoup manger.	Grande preferenza per il mangiare molto.	Fondness of abundant food.	"Fondness of abundant food"
9	Gewohnheiten und Zwänge des Alltags.	Les habitudes et contraintes de la vie quotidienne.	Le abitudini e le esigenze della vitaquotidiana lo impediscono.	Habits and constraints of daily life.	"Daily habits, constraints"
10	Fehlender Wille, fehlender Glaube an Erfolg.	Le manque de volonté, pas convaincu de l'efficacité.	Poca volontà e scarsa fiducia in un risultato positivo.	Lack of willpower.	"Lack of willpower"

[1] item position in the original written questionnaire.

[2] Questionnaire was given in German, French, and Italian, Switzerland's three national languages**.** For simplicity, abridged statements are used throughout the text. Link to Swiss Health Survey 2012 questionnaires in German, French and Italian: http://www.bfs.admin.ch/bfs/portal/fr/index/infothek/erhebungen__quellen/blank/blank/ess/03.html

Supplementary table 2. Perceived barriers to healthy eating included in the Pan-European Survey.

Irregular working hours
Busy lifestyle
Willpower
I do not want to change my eating habits
Too great a change from my current diet
Cooking skills
Healthy foods are more perishable
Lengthy preparation
Storage facilities, limited cooking facilities
Price of healthy foods
Giving up foods I like
Feeling conspicuous amongst others
Taste preferences of families and friends
Not knowing enough about healthy eating
Experts keep changing their minds
Healthy options not available in shop or canteen or
Not enough food to satisfy hunger
No difficulty
Unappealing foods
Strange or unusual foods

Supplementary table 3. Descriptive characteristics of participants included versus excluded from analysis, Swiss Health Survey 2012

	Included	Excluded	p
N (% women)	15450 (52.8)	6147 (51.3)	0.04
Age, mean (SD)	48.8 (17.4)	46.7 (21.4)	<0.001
BMI, mean (SD)	24.8 (4.4)	24.2 (4.4)	<0.001
Current smoker, n (%)	4180 (27.1)	1771 (28.8)	
Educational level			<0.001
Tertiary	4783 (31.0)	1269 (20.9)	
Secondary	8740 (56.7)	2828 (46.6)	
Mandatory	1894 (12.3)	1974 (32.5)	
Household composition			<0.001
1 person	3477 (22.5)	1377 (22.5)	
2 people	1413 (9.1)	605 (9.9)	
3 people	6069 (39.4)	2223 (36.4)	
4 people or more	4380 (28.3)	2075 (33.8)	
Language region			<0.001
German	10103 (65.4)	4190 (68.2)	
French	4188 (27.1)	1520 (24.7)	
Italian	1159 (7.5)	437 (7.1)	

Statistical significant for difference of mean between groups tested with student t-test, and between categorical variables with Chi-square test.

Supplementary table 4. Association between barriers to healthy eating and adherence to dietary guidelines among Swiss adults stratified by sex, Swiss Health Survey 2012 (N = 15450)

		Multivariable-adjusted OR (95% CI)					
	Barriers to healthy eating	Fruits	Vegetables	Fish	Meat	Dairy	Drinks
Men	Price				1.58 (1.39, 1.81)		
	Daily habits					0.90 (0.77, 1.07)	
	Taste						
	Time		1.06 (0.91, 1.23)				
	Willpower			0.68 (0.57, 0.80)	0.74 (0.62, 0.89)		
	Limited options in						
	Gluttony				0.53 (0.43, 0.66)		
	No social support						
	Limited options at market	1.40 (1.14, 1.71)	1.75 (1.37, 2.23)				
	Social group opposition						
Women	Price				1.16 (1.05, 1.28)		
	Daily habits					1.02 (0.87, 1.21)	
	Taste						
	Time		0.92 (0.83, 1.02)				
	Willpower			0.87 (0.76, 1.01)	0.86 (0.76, 0.97)		
	Limited options in						
	Gluttony				0.77 (0.66, 0.92)		
	No social support						
	Limited options at market	1.02 (0.85, 1.24)	1.07 (0.87, 1.32)				
	Social group opposition						

Odds ratios and 95% confidence intervals adjusted for age, BMI, education, household composition, and language region, computed from logistic regression model run separately for each barrier exposure and adherence food group, stratified by sex.

Supplementary table 5. Association between barriers to healthy eating and adherence to dietary guidelines among Swiss adults stratified by age group, Swiss Health Survey 2012 (N = 15450)

		Multivariable-adjusted OR (95% CI)					
	Barriers to healthy eating	Fruits	Vegetables	Fish	Meat	Dairy	Drinks
18 - 35	Price						
	Daily habits	1.07 (0.93, 1.23)			0.88 (0.75, 1.04)		
	Taste						
	Time		0.82 (0.69, 0.96)	0.80 (0.66, 0.96)			
	Willpower						
	Limited options in						
	Gluttony		0.88 (0.72, 1.07)				
	No social support						
	Limited options at market						
	Social group opposition						
36 - 50	Price						
	Daily habits	0.85 (0.75, 0.97)			0.77 (0.67, 0.89)		
	Taste						
	Time		1.03 (0.88, 1.19)	0.86 (0.73, 1.01)			
	Willpower						
	Limited options in						
	Gluttony		1.54 (1.25, 1.89)				
	No social support						
	Limited options at market						
	Social group opposition						
51 - 65	Price						
	Daily habits	0.84 (0.73, 0.96)			0.92 (0.78, 1.09)		
	Taste						
	Time		0.98 (0.82, 1.18)	0.91 (0.76, 1.09)			
	Willpower						

	Limited options in Gluttony		1.34 (1.03, 1.74)		
	No social support				
	Limited options at market				
	Social group opposition				
Above 65	Price				
	Daily habits	0.93 (0.77, 1.14)			0.89 (0.70, 1.13)
	Taste				
	Time		1.08 (0.87, 1.35)	0.93 (0.75, 1.16)	
	Willpower				
	Limited options in Gluttony		1.27 (0.88, 1.84)		
	No social support				
	Limited options at market				
	Social group opposition				

Odds ratios and 95% confidence intervals adjusted for sex, BMI, education, household composition, and language region, computed from logistic regression model run separately for each barrier exposure and adherence food group, stratified by age group.

Supplementary table 6. Association between barriers to healthy eating and adherence to dietary guidelines among Swiss adults stratified by body mass index group, Swiss Health Survey 2012 (N = 15450)

		Multivariable-adjusted OR (95% CI)					
	Barriers to healthy eating	Fruits	Vegetables	Fish	Meat	Dairy	Drinks
18.5 to <25	Price						
	Daily habits				0.90 (0.81, 1.00)		
	Taste					1.16 (0.99, 1.34)	
	Time				0.99 (0.89, 1.10)		
	Willpower						
	Limited options in				1.66 (1.47, 1.87)		
	Gluttony						
	No social support			0.84 (0.67, 1.06)			
	Limited options at market						
	Social group opposition						
25 to <30	Price						
	Daily habits				0.91 (0.77, 1.07)		
	Taste					0.97 (0.79, 1.18)	
	Time				0.95 (0.81, 1.12)		
	Willpower						
	Limited options in				1.46 (1.21, 1.76)		
	Gluttony						
	No social support			1.14 (0.84, 1.53)			
	Limited options at market						
	Social group opposition						
≥30	Price						
	Daily habits				0.64 (0.47, 0.86)		
	Taste					0.67 (0.47, 0.94)	
	Time				0.74 (0.54, 1.01)		
	Willpower						

Limited options in Gluttony		0.96 (0.67, 1.39)
No social support	1.59 (1.06, 2.39)	
Limited options at market		
Social group opposition		

Odds ratios and 95% confidence intervals adjusted for sex, age group, education, household composition, and language region, computed from logistic regression model run separately for each barrier exposure and adherence food group, stratified by BMI group.

Supplementary table 7. Association between barriers to healthy eating and adherence to dietary guidelines among Swiss adults stratified by education group, Swiss Health Survey 2012 (N = 15450)

		Multivariable-adjusted OR (95% CI)					
	Barriers to healthy eating	Fruits	Vegetables	Fish	Meat	Dairy	Drinks
Tertiary	Price					1.10 (0.89, 1.36)	
	Daily habits						0.86 (0.76, 0.97)
	Taste	0.72 (0.63, 0.82)		0.96 (0.83, 1.12)	0.49 (0.42, 0.57)		
	Time				1.02 (0.88, 1.19)		
	Willpower						
	Limited options in			1.31 (1.11, 1.55)			
	Gluttony						
	No social support						
	Limited options at market						
	Social group opposition						
Secondary	Price					0.93 (0.80, 1.08)	
	Daily habits						0.91 (0.83, 1.01)
	Taste	0.88 (0.80, 0.97)		1.02 (0.90, 1.14)	0.73 (0.65, 0.81)		
	Time				1.00 (0.89, 1.12)		
	Willpower						
	Limited options in			1.31 (1.14, 1.51)			
	Gluttony						
	No social support						
	Limited options at market						
	Social group opposition						
Mandatory	Price					0.89 (0.65, 1.21)	
	Daily habits						1.04 (0.82, 1.32)
	Taste	0.98 (0.81, 1.19)		1.16 (0.93, 1.45)	0.90 (0.72, 1.12)		
	Time				0.63 (0.48, 0.82)		
	Willpower						

Limited options in Gluttony	0.79 (0.55, 1.14)
No social support	
Limited options at market	
Social group opposition	

Odds ratios and 95% confidence intervals adjusted for sex, age group, BMI, household composition, and language region, computed from logistic regression model run separately for each barrier exposure and adherence food group, stratified by education group.

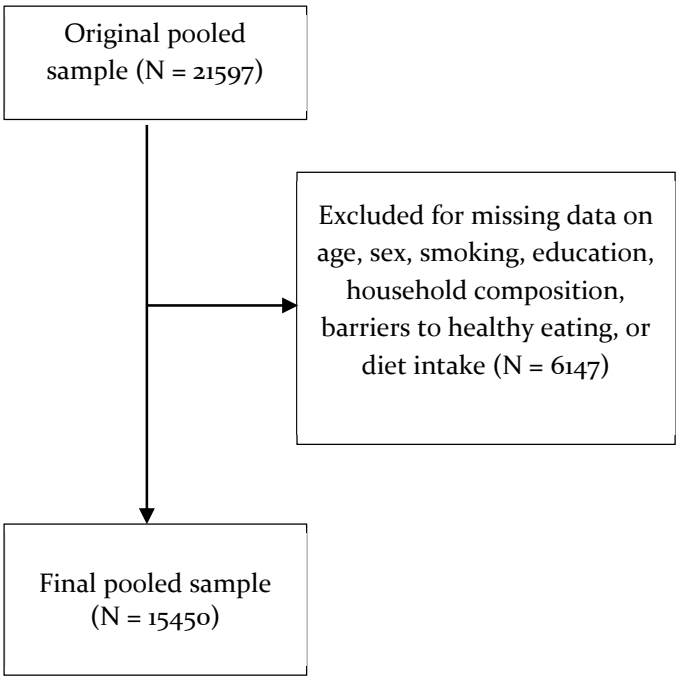
Supplementary table 8. Association between barriers to healthy eating and adherence to dietary guidelines among Swiss adults stratified by household composition group, Swiss Health Survey 2012 (N = 15450)

		Multivariable-adjusted OR (95% CI)					
	Barriers to healthy eating	Fruits	Vegetables	Fish	Meat	Dairy	Drinks
1	Price						
	Daily habits				0.83 (0.69, 1.00)		
	Taste						
	Time		0.80 (0.64, 1.00)				
	Willpower						
	Limited options in				1.80 (1.46, 2.23)		
	Gluttony					1.16 (0.77, 1.73)	
	No social support						
	Limited options at market		1.63 (1.12, 2.38)				
	Social group opposition	1.25 (0.70, 2.25)					
2	Price						
	Daily habits				0.82 (0.71, 0.94)		
	Taste						
	Time		0.97 (0.84, 1.12)				
	Willpower						
	Limited options in				1.67 (1.43, 1.94)		
	Gluttony					1.03 (0.77, 1.37)	
	No social support						
	Limited options at market		1.47 (1.13, 1.92)				
	Social group opposition	1.57 (1.07, 2.29)					
3	Price						
	Daily habits				0.87 (0.72, 1.06)		
	Taste						
	Time		1.01 (0.82, 1.24)				
	Willpower						
	Limited options in				1.37 (1.09, 1.72)		

	Gluttony				1.33 (0.92, 1.92)
	No social support				
	Limited options at market		1.10 (0.76, 1.60)		
	Social group opposition	1.07 (0.65, 1.74)			
4 or more	Price				
	Daily habits			0.98 (0.83, 1.16)	
	Taste				
	Time		1.01 (0.87, 1.19)		
	Willpower				
	Limited options in			1.26 (1.02, 1.55)	
	Gluttony				1.39 (1.07, 1.79)
	No social support				
	Limited options at market		1.07 (0.79, 1.46)		
	Social group opposition	0.77 (0.53, 1.12)			

Odds ratios and 95% confidence intervals adjusted for age group. sex, BMI, education, and language region, computed from logistic regression model run separately for each barrier exposure and adherence food group, stratified by household composition.

Supplementary figure 1. Flowchart of participant inclusion



Chapter 6 The contribution of diet quality to socioeconomic inequalities in obesity in the Swiss adult population

Manuscript in preparation

Abstract

Background: Obesity is a major risk factor for chronic diseases, and its prevalence in the population of high-income countries follows a social gradient. More disadvantaged individuals are less likely to have healthy diets, thereby increasing their risk of developing obesity and chronic diseases. Yet few studies have comprehensively measured diet quality and assessed its contribution to social inequalities in obesity.

Objective: To assess the mediation of diet quality in the association of socioeconomic status (SES) with obesity in a representative sample of the Swiss population.

Methods: Data from the menuCH survey, a cross-sectional representative sample of the adult Swiss population (N=1860). Dietary intake was assessed using two 24h dietary recalls from which we constructed the Alternate Healthy Eating Index (AHEI). Obesity markers included body mass index (BMI), waist circumference (WC), waist-to-hip ratio (WHR), and waist-to-height ratio (WHtR). We used education (university degree, yes/no) to define SES. We used the counterfactual method to calculate the Marginal Total Effect, Natural Direct Effect, Natural Indirect Effect, and the Proportion Mediated.

Results: Participants with less than a university degree were 2.17 (1.63, 2.90) more likely to have the unhealthiest diets. Those in the unhealthiest AHEI quintile were thrice more likely to be obese. The marginal total effects of low education on obesity was 3.36 (2.01, 5.66) for BMI obesity, 2.44 (1.58, 3.75) for WC obesity, 2.48 (1.63, 3.78) for WHR obesity, and 2.04 (1.43, 2.96) for WHtR obesity. The natural indirect effect of low education on obesity was 1.18 (1.06, 1.36) for BMI obesity, as was similar for the other markers. Accordingly, the proportion of the association between low education and obesity that was mediated by diet quality was 22.1% for BMI obesity, 26.6% for WC obesity, 31.4% for WHtR obesity, and 35.8% for WHR obesity.

Conclusion: Dietary quality contributes substantially to the educational inequalities in obesity. These results confirm the importance of improving the diet quality of disadvantaged groups to tackle the continuous rise of obesity and its associated chronic conditions.

Introduction

Obesity is a main contributor to the development of diabetes, hypertension, cardiovascular disease, and many cancers (1-3), which are diseases that disproportionally affect socioeconomically disadvantaged people (4-6). In populations of high-income countries (HICs), the prevalence of obesity has increased steadily since 1980 (2), and this increase has disproportionally affected individuals in more socioeconomically disadvantaged groups. In Switzerland, evidence from the CoLaus study revealed that the prevalence of obesity among people with an university degree was around 5%, while among people with lower secondary education, it was 15% (7). Extensive evidence indicates that unhealthy diets lead to weight gain (8-11), and that individuals in socioeconomically disadvantaged groups are more likely to follow unhealthy diets—consuming less fruits and vegetables, whole grains, nuts and seeds, lean meats and fish, but consuming more highly processed foods and meats, refined grains, and sugar sweetened beverages (12-14). Thus, it is likely that diet quality contributes to the widespread socioeconomic inequalities in obesity across HICs. To date, however, few studies have examined the mediating role of diet quality in the association between socioeconomic status (SES) and obesity. These studies have found that diet contributed to between 12% and 50% of the socioeconomic inequalities in obesity (15-18). Importantly, these studies presented limitations to their findings as they relied on self-reported measures of obesity, and crucially, assessed diet quality only via simple and limited measures (mostly fruits and/or vegetables consumption) (15-19). This is unsurprising, as comprehensively measuring diet quality remains a complex task (8). Nevertheless, there remains a need to measure diet in such a comprehensive way to evaluate the impact that overall diets have on socioeconomic inequalities in obesity. The Alternate Healthy Eating Index (AHEI), for instance, provides a comprehensive picture of diet quality and is associated to chronic diseases (8, 20), including weight gain (14, 21).

In light of this gap in the literature, we aimed to assess the contribution of diet quality, as quantified by the AHEI, to the association between SES and four different objectively measured obesity indicators. We hypothesized that diet quality would contribute substantially to the socioeconomic inequality in obesity.

Methods

We used data from the menuCH project, a population-based cross-sectional survey conducted among non-institutionalized adults in the Swiss population in 2014-2015. Dietary intake was assessed via two non-consecutive 24h dietary recalls, as described in detail elsewhere (22).

Socioeconomic status

We dichotomized educational level of the participant as the measure of SES (university degree: yes/no), as it is highly correlated with other indicators of SES such as income and occupation (23, 24).

Diet quality

We estimated diet quality via the Alternate Healthy Eating Index (AHEI), which has been extensively used to study the association between diet quality and a series of chronic disease risk factors and diseases, as well as cause-specific and all-cause mortality (20, 21, 25). Briefly, the AHEI is an index composed of food- and nutrient-specific scores, including for fruits, vegetables, whole grains, nuts, fish, red and processed meats, sweetened beverages, fats, sodium, and alcohol intake (20). The total score ranges from 0 to 100, with a higher score indicating higher diet quality. We created quintiles of the AHEI to use in the analysis.

Obesity markers

We used four different measures of obesity, all of which have been shown to be associated with adiposity and risk of cardiovascular disease (1). The following obesity markers constructed from objectively measured height, weight, and waist and hip circumference: 1) Body mass index (BMI, weight (kg)/height (m^2)), 2) waist circumference (WC), 3) waist-to-hip ratio (WHR), and 4) waist-to-height ratio (WHtR). For each obesity marker, we defined obesity as follows: 1) BMI ≥30 kg/m^2, 2) WC > 102 cm for men, >88 cm for women, 3) WHR ≥0.90 for men, ≥0.85 for women; and 4) WHtR ≥0.5 for both men and women as recommended (26, 27).

Covariates

We used age (continuous), sex, daily energy intake (Kilocalories), self-reported smoking (smoker versus non-smoker) and physical activity. Physical activity was assessed with the short-form International Physical Activity Questionnaire (IPAQ, six questions); data were converted into Metabolic Equivalent of Task (MET) minutes per week (28).

Statistical analysis

Since we used education as our measure of SES, we excluded participants below the age of 25, as they are likely to still be studying. First, we assessed the association between quintiles of the AHEI and socioeconomic status using multinomial logistic regression, adjusting for age, sex, and physical activity. Then, we assessed the association between each of the obesity markers and quintiles of the AHEI, adjusting for age, sex, physical activity and daily calories. We tested for linear trends across quintiles of the AHEI using the orthogonal polynomial test. We imputed missing values of physical activity using chained multiple imputation with twenty imputations. Finally, we examined the mediation of diet quality in the association between socioeconomic status and obesity markers using the counterfactual method, adjusting for age, sex, physical activity, daily calories, and smoking behavior. This method captures mediation effects accounting for potential interaction between the exposure and mediator, which other mediation methods fail to do (i.e. difference method) (29). It includes the following components: 1) the natural direct effect (NDE), the effect of the exposure on the outcome (Odds ratio) via pathways that exclude the mediator; 2) the natural indirect effect (NIE), the effect of the exposure on the outcome via the mediator; 3) the marginal total effect (MTE), the total effect of the exposure on the outcome; and 4) the proportion mediated (PM), the proportion of the exposure-outcome association that is mediated by the mediator. We computed 95% confidence intervals for the above counterfactual components using bootstrap procedures with 1000 simulations. (29). In sensitivity analyses, we used the different method to assess the mediation of diet. All analyses were conducted using Stata version 14 (Stata Corp, College Station, TX, USA).

Results

Characteristics of the sample

Table 1 shows the distribution of the included sample in terms of sociodemographic factors. In total, 1860 participants were included in the analysis, of which 54% were women, with a mean age of 49.2, and the majority possessed a university degree. The mean AHEI was 48.8, higher among women than among men. The prevalence of obesity ranged from 11% for BMI obesity to 43% for WHtR obesity, with marked differences between men and women for WHR and WHtR obesity.

Associations between education, obesity and dietary quality

Table 2 displays the association between quintiles of the AHEI and educational level. A clear gradient emerged showing that low education was associated with progressively worse diet. Compared with participants with a university degree, those with less than a university degree were 1.60 more likely (95% CI: 1.21, 2.12) to be in the unhealthier quintile of the AHEI, and 2.17 (1.63, 2.90) more likely to be in the unhealthiest quintile.

Table 3 reveals the association between quintiles of the AHEI and each obesity marker. A clear gradient became evident in this association as well—the poorer the diet quality, the higher the likelihood of obesity, irrespective of marker. Participants in the unhealthier quintile of the AHEI, for instance, relative to those in the healthiest quintile, were more than twice more likely to be BMI obese, and those in the unhealthiest quintile were more than thrice more likely to be BMI obese.

Mediation of diet quality in the education-obesity association

Table 4 shows the results of the counterfactual mediation analysis. They indicated that low education was associated with higher likelihood of obesity, regardless of the obesity marker. The marginal total effect of low education on obesity ranged from 2.04 (1.42, 2.96) for WHtR obesity to 3.36 (2.01, 5.66) for BMI obesity. There were corresponding natural direct effects of low education on obesity ranging from 1.67 (1.18, 2.39) for WHtR obesity to 2.84 (1.68, 4.94) for BMI obesity. The natural indirect effect

was 1.18 (1.06, 1.36) for BMI obesity and similar effects were observed for the other obesity markers. Accordingly, the promotion of the association between low education and obesity that was mediated by diet quality was 22.1% for BMI obesity, 26.6% for WC obesity, 31.4% for WHtR obesity, and 35.8% for WHR obesity. In sensitivity analyses, evaluating the mediation of diet with the commonly used difference method revealed lower mediation of diet (**Supplementary table Table 1**).

Discussion

In this sample of adults in the Swiss population, we found that participants with lower education were more than twice more likely to be obese, regardless of the obesity marker, findings that reflect those in the literature (9-11). Lower education was also associated with poorer diet quality, and poorer diet quality was associated with obesity, regardless of the obesity marker. These findings also agree with previous reports (10, 30, 31). Consequently, as we had hypothesized, we found evidence of substantial mediation by dietary quality in the association between education and obesity.

Comparing our mediation results to the literature is limited by the fact that previous reports have used widely differing analytical mediation methods, relied on self-reported measures of obesity (mostly BMI obesity), and most importantly, measured diet in a less comprehensive way (consumption of fruits and vegetables, sweetened beverages, or take-away foods) (15-19). As such, these studies have reported that diet intake mediate between 12 and 50% of the socioeconomic inequalities in obesity. Our findings are in line with these reports, and provide a more precise estimation of the contribution of diet quality to socioeconomic inequalities in obesity.

Implications for public health

Given the continuous expansion of obesity and its deleterious effect on chronic disease risk and quality of life, our findings strengthen the argument to strive for improvements in diet quality among disadvantaged populations. This would help reduce socioeconomic inequalities in health and the overall disease burden in the population. To date, however, most interventions to improve healthy eating in the general population and in specific groups have relied on individual level factors,

primarily in nutrition knowledge, even though the evidence shows these have limited impact and often exacerbate inequalities (9, 32). To achieve and maintain healthy diets, as public health experts have extensively argued, major structural changes to the food system and food environment must take place, with food policy at national and local levels the most important starting point (9, 33-35).

Study strengths and limitations

A main strength of our sample lies in the objectively measured dietary intake using two 24h dietary recalls, which are more accurate to measure daily intake than the most commonly applied food frequency questionnaires (36). Another main strength is the use of four different objectively measured markers of obesity, all of which showed consistency of associations in our results. We also used a sample that is representative of the adult Swiss population. To our knowledge, ours is the first study to assess the mediation of diet using the AHEI calculated from dietary intake from two 24h dietary recalls, and using four objective markers of obesity. Additionally, the counterfactual method to assess mediation is more accurate tool in presence of interaction between the exposure and the mediator, which is the case between socioeconomic status and diet quality (29). As shown in the sensitivity analysis, the difference method found reduced mediation of diet since it does not take into account the interaction between education and the AHEI.

Our study is not, of course, without its limitations. The main one is the cross-sectional nature of the sample, which does not allow for temporal examination of exposure and outcome. The sample size is also not optimal, and this likely explains the broad confidence intervals—that nevertheless remained significantly different from no effect. It is likely that participants underreported their intake of well-known unhealthier foods and over reported their intakes of healthier foods. Nevertheless, the consistent associations we found in our analysis (between exposure and mediator, mediator and outcome, and exposure and outcome) are in agreement with an extensive literature linking diet quality to obesity and socioeconomic status. Participants in the survey may have been more health and nutrition conscious than non-participants. However, the

prevalence of BMI obesity of our sample was similar to the one reported in other Swiss surveys (7, 37).

Conclusion

In a representative sample of the adult Swiss population, we found evidence that dietary quality substantially contributes to the socioeconomic inequalities in obesity. These results emphasize the importance of helping disadvantaged populations to improve the quality of their diets, which will ultimately contribute to a decrease in the overall burden of disease and reduce socioeconomic inequalities in health.

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Table 1. Characteristic of the included sample, menuCH study (N=1860)

	Total	Women	Men	p-value
N	1860	1009 (54.3)	851 (45.8)	
Age, mean (SD)	49.2 (14.1)	48.5 (14.1)	50.1 (14.0)	0.02
Educational level, n (%)				<0.001
University degree	972 (52.3)	469 (46.7)	503 (59.1)	
Lower than	888 (47.7)	540 (53.5)	348 (40.9)	
Dietary index, mean				
AHEI	48.8 (14.4)	50.7 (13.9)	46.5 (14.5)	<0.001
Obese, n (%) by				
Body mass index	198 (10.6)	95 (9.4)	103 (12.1)	0.05
Waist circumference	347 (18.8)	185 (18.7)	162 (19.0)	0.84
Waist-to-hip ratio	552 (30.0)	144 (14.5)	408 (47.9)	<0.001
Waist-to-height ratio	791 (43.0)	301 (30.4)	490 (57.7)	<0.001

Statistical difference between sex groups for categorical variables assessed by Chi-square test, and for continuous variables using student T-test.

Table 2. Association between educational level and quintiles of the AHEI

AHEI quintiles	Mean	Low vs high OR (95% CI)	p[a]
Healthiest	69.5 (7.1)	1.00 (reference)	
Healthier	55.6 (2.8)	1.10 (0.84, 1.46)	*0.49*
Middle	47.2 (2.3)	1.35 (1.02, 1.78)	*0.03*
Unhealthier	39.5 (2.3)	1.60 (1.21, 2.12)	*0.001*
Unhealthiest	29.1 (4.6)	2.17 (1.63, 2.90)	*<0.001*

Odds ratio and 95% confidence interval adjusted for age and sex, from multinomial logistic regression, comparing likelihood of being in the lowest quintile of the AHEI for lower educational level relative to the higher educational level.

[a] p for statistically significant difference between low and high educational groups.

Table 3. Association between obesity markers and quintiles of the AHEI

	AHEI quintiles				
	Healthier	Middle	Unhealthier	Unhealthiest	
Obesity	OR (95% CI)	OR (95% CI)	OR (95% CI)	OR (95% CI)	P[a]
BMI	1.20 (0.69, 2.07)	1.89 (1.14, 3.13)	2.10 (1.27, 3.46)	3.13 (1.90, 5.15)	*<0.0001*
WC	1.50 (1.00, 2.25)	1.71 (1.14, 2.55)	2.27 (1.53, 3.38)	3.18 (2.12, 4.78)	*<0.0001*
WHR	1.71 (1.16, 2.51)	1.86 (1.27, 2.73)	2.62 (1.78, 3.85)	3.19 (2.16, 4.74)	*<0.0001*
WHtR	1.74 (1.25, 2.43)	2.07 (1.48, 2.88)	3.08 (2.20, 4.32)	3.53 (2.49, 5.00)	*<0.0001*

Odds ratio and 95% confidence interval for the likelihood of being in obesity category according to each obesity marker, for individuals in each quintile of the AHEI *relative to those in the highest (healthiest) quintile* (reference group), adjusted for age, sex, physical activity, and total energy intake. BMI, Body mass index; WC, waist circumference; WHR, waist-to-hip ratio; WHtR, waist-to-height ratio.

[a] p for trend across quintiles of AHEI, assessed via orthogonal polynomial linear hypothesis test.

Table 4. Results from counterfactual mediation of diet in the association of educational level with obesity markers

	MTE	NDE	NIE	PM
Obesity marker	OR (95% CI)	OR (95% CI)	OR (95% CI)	% (95% CI)
BMI	3.36 (2.01, 5.66)	2.84 (1.68, 4.94)	1.18 (1.06, 1.36)	22.1 (8.5, 41.6)
WC	2.44 (1.58, 3.75)	2.06 (1.34, 3.18)	1.19 (1.07, 1.34)	26.6 (11.4, 48.4)
WHR	2.48 (1.63, 3.78)	2.01 (1.35, 3.03)	1.23 (1.10, 1.41)	31.4 (16.1, 53.3)
WHtR	2.04 (1.43, 2.96)	1.67 (1.18, 2.39)	1.22 (1.11, 1.39)	35.8 (19.2, 63.4)

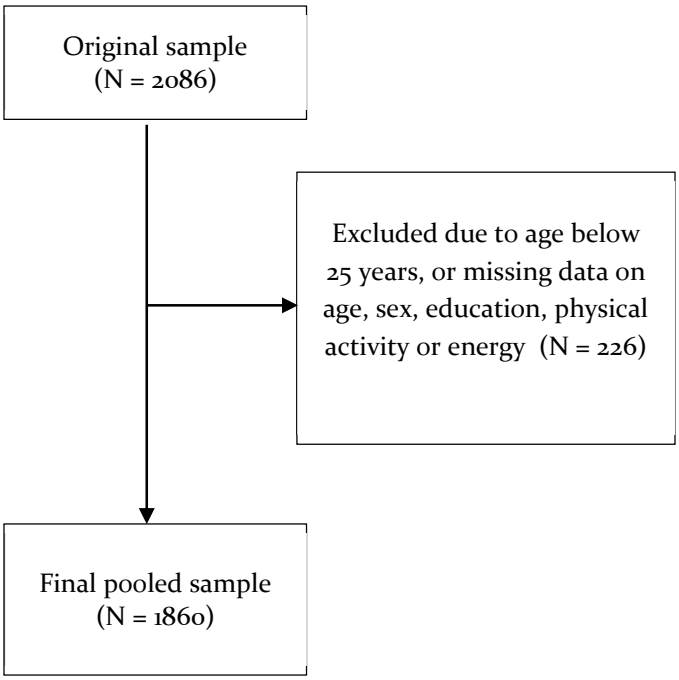
MTE, marginal total effects; NDE, natural direct effect (OR, 95% CI); NIE, natural indirect effect (OR, 95% CI); PM, proportion of the association between educational level and obesity markers which is mediated by the AHEI.

Supplementary table 1. Association of educational level with obesity outcomes, and the mediation of diet in this association, assessed via the different method

	Model 1	Model 1 + AHEI	
Obesity	OR (95% CI)	OR (95% CI)	%
BMI	2.96 (1.91, 4.59)	2.60 (1.67, 4.06)	12.0
WC	2.64 (1.86, 3.75)	2.35 (1.65, 3.35)	12.0
WHR	2.71 (1.89, 3.88)	2.39 (1.66, 3.44)	12.6
WHtR	3.01 (2.16, 4.19)	2.62 (1.88, 3.67)	12.6

Odds ratios and 95% confidence intervals, adjusted for age, sex, physical activity, and total energy intake using logistic regression models. AHEI, Alternate healthy eating index, in quintiles, as categorical variable. % attenuated = [(coeff of model 1) – (coeff of model 1 + AHEI)]/(coeff of model 1) * 100.

Supplementary figure 1. Flowchart of participant inclusion



Chapter 7 The contribution of diet quality to socioeconomic inequalities in cardiometabolic disorders: a multi-cohort study

Manuscript in preparation

Abstract

Background: Diet quality has been proposed as an important mediator of socioeconomic differences in chronic disease. In examining this potential mediation, however, most studies do date have used mediation methods and measures of diet that present important limitations. There remains a need to assess the contribution of comprehensively measured diet quality to socioeconomic inequalities in chronic disease.

Objective: To assess the contribution of dietary quality in social inequalities in cardiometabolic disorders.

Methods: Data were drawn from seven cohorts in six countries across the world, comprising 160'916 participants (70% women, mean age (SD) = 50.1 (10.8)). Participant's information was collected between 1993 and 2016. Education served as the indicator of socioeconomic status. Dietary intake was measured via food frequency questionnaires, with which we constructed a modified version of the alternate healthy eating index (mAHEI) and divided it into tertiles. Our outcomes included four cardiometabolic disorders: obesity, diabetes, hypertension, and cardiovascular disease (CVD). We applied the counterfactual method to assess the mediation of diet quality in the association between education and each cardiometabolic disorder.

Results: A clear educational gradient emerged across all cardiometabolic disorders. Women with low education were more likely to have obesity (OR; 95% CI: 2.29; 2.15), diabetes (2.03; 1.79, 2.30), hypertension (1.59; 1.51, 1.66), and CVD (1.18; 1.08, 1.28). The same pattern of association, though less pronounced, emerged among men, except for CVD, which was more pronounced than among women (1.26; 1.15, 1.39). An educational gradient also became evident in dietary quality. Low education was associated with higher likelihood of having a poorer diet for men (1.60; 1.50, 1.71) and women (1.79; 1.70, 1.88). In turn, participants in the unhealthier mAHEI tertile were more likely to have obesity [(1.26; 1.18, 1.35) in men; (1.23; 1.17, 1.29) in women]; hypertension [(1.27; 1.20, 1.33) in men; (1.10; 1.06, 1.14) in women]; and CVD [(1.10; 1.02, 1.20) in men; (1.10; 1.04, 1.16) in women]. Among men, diet quality contributed to 8.1% (95% CI; 4.9%, 11.7%) of the educational inequalities in hypertension, and to 7.0% (1.2%, 15.5%) of inequalities in

CVD. Among women, diet quality contributed little to the educational inequalities in obesity (2.5%; 1.0%, 4.0%) and in hypertension (2.3%; 0.2%, 4.4%); however, it contributed to 16.8% (6.2%, 41.9%) of the educational inequalities in CVD.

Conclusion: In this multi-cohort study, we found evidence of strong educational inequalities in cardiometabolic disorders, and substantial educational inequalities in diet quality. We also found that diet quality appears to contribute to a small to moderate extent to educational inequalities in cardiometabolic disorders.

Introduction

It is well documented that socioeconomic disadvantaged individuals disproportionally suffer from cardiometabolic disorders including obesity, diabetes, hypertension, and cardiovascular disease (CVD), eventually leading to premature death (1-3). Modifiable risk factors such as smoking, alcohol intake, physical inactivity, and diet quality have been investigated as potential mechanisms driving these socioeconomic inequalities in chronic disease (4)—combined, these behavioral risk factors have been shown to explain a substantial portion (13% to 60%) of socioeconomic inequalities in health (4-6). While the measurement of smoking, though subject to response bias, is relatively straightforward and simple, the measurement and quantification of diet quality represents a challenge. Unsurprisingly, to date, studies that have examined the contribution of diet quality to socioeconomic inequalities in chronic disease have relied on simple surrogates of diet, particularly fruits and/or vegetables consumption (4-7). While lower intake of fruits and vegetables has been found to be associated with an increased risk of cardiometabolic disorders, these food groups fail to capture the overall quality of the diet (8-10). Dietary indices such as the Alternate Healthy Eating Index (AHEI)(11) offer a more comprehensive picture of overall dietary quality, and have been extensively documented to predict risk of obesity, diabetes, hypertension, cardiovascular disease (CVD) and cancer (9, 11, 12). Furthermore, studies have relied on mediation analysis methods that present limitations, namely the difference method, which fails to account for potential interaction between the exposure and mediator (13). As such, there remains a need to examine the contribution of diet quality in the association between socioeconomic status (SES) and cardiometabolic disorders, using more comprehensive diet quality assessments and more accurate mediation tools.

Thus, we aimed to examine the mediation of diet quality, as assessed by a modified version of the AHEI, in the association between SES and cardiometabolic disorders, using a large multi-cohort pooled sample of participants originating from six countries around the world.

Methods

Study populations

This study forms part of the LIFEPATH project, a European Commission Horizon 2020 consortium. It included seven cohort studies comprising 265'896 men and women from six countries: Australia (Melbourne Collaborative Cohort Study, MCCS), France (Constances and E3N), Italy (EPIC-Italy), Portugal (EpiPorto), Switzerland (CoLaus) and the United Kingdom (Whitehall II). Data collection occurred between 1993 and 2012. All studies included information on socioeconomic status, diet, and cardiometabolic disorders. The relevant local or national ethics committees approved each cohort study, and participants provided informed consent Details of the included cohorts and methodologies have been described in detail elsewhere (2, 14, 15).

Socioeconomic status

We used educational level and occupational class—both predefined and harmonized socioeconomic measures within the LIFEPATH consortium, described in detail elsewhere (14, 15). We categorized educational level into three groups: 1) primary and lower secondary school, 2) higher secondary school, and 3) tertiary education. Occupational class was based on the participant's current or last-known occupation, categorized into three groups according to the European Socioeconomic Classification system: 1) High (higher professional/managers, lower professionals/managers, higher clerical), 2) Medium (small business employers and self-employed, farmers, lower supervisors and technicians), and 3) Low (lower clerical, sales workers, skilled/unskilled workers) (15).

Cardiometabolic disorders

We focused on four common cardiometabolic disorders: obesity, diabetes, hypertension, and CVD. A participant's hypertension case was defined as having systolic/diastolic blood pressure ≥140/90 mmHg, reporting the use of anti-hypertensive drugs or having had a physician's diagnosis of hypertension. CVD was defined as self-reporting or having a diagnosis of at least one cardiovascular event, including

myocardial infarction, angina, stroke, coronary artery bypass, transient ischemic heart attack, and others. Weight (kg) and height (cm) were objectively measured using standard procedures, and obesity was defined as having a body mass index (BMI) ≥30 kg/m^2. Diabetes was defined as using an anti-diabetes drug, physician diagnosis, or fasting blood glucose ≥7 mmol/L or glycated hemoglobin (Hba1c) ≥6.5% at clinical visit.

Diet quality

The seven included cohort studies each employed a food frequency questionnaire to quantify daily consumption of foods and nutrients. We constructed the AHEI (11), modified to the harmonized dietary data across LIFEPATH cohorts (mAHEI). This mAHEI was composed of ten diet groups, as following: 1) fruits, 2) vegetables, 3) whole grains, 4) nuts, legumes, and soy products, 5) fish intake, 6) red and processed meats, 7) ratio of saturated to unsaturated fats, 8) sugar-sweetened beverages, 9) sodium, and 10) alcohol. Each diet group ranged in score from 0 (indicating poorest adherence) to 10 (indicating complete adherence), and the maximum score possible being 100. **Supplementary table 1** details the scoring system. We then created cohort-specific tertiles of the mAHEI.

Covariates

We considered self-reported smoking status (current smoker versus ex/current) and sedentary behavior (yes/no; harmonized across LIFEPATH cohorts, and described elsewhere (2)) as potential additional mediators. We also included dummy variables for cohort and study period, and age as continuous.

Statistical analysis

We excluded participants who had missing data on age, sex, education, sedentary behavior and smoking. We conducted all analyses separately for men and women, using pooled data in fixed effect models. First, to test the association between education and each cardiometabolic disorders, we used logistic regression models to generate odds ratios and 95% confidence intervals adjusted for age, cohort, study period, smoking status, and sedentary behavior. We then assessed the association between tertiles of the

mAHEI and education multinomial logistic regression models, adjusting the effect size for age, cohort, and period. Subsequently, to test the association between cardiometabolic outcomes and tertiles of the mAHEI, we used logistic regression models, adjusting the effect size for age, cohort, period, smoking status, and sedentary behavior. Finally, we applied the counterfactual mediation method to assess the mediating effect of each mAHEI tertiles in the socioeconomic status-cardiometabolic disorder association. This method captures mediation effects accounting for potential interaction between the exposure and mediator, which other mediation methods fail to do (i.e. difference method). It includes three effect components: 1) the natural direct effect (NDE), the effect of the exposure on the outcome (Odds ratio) via pathways that exclude the mediator; 2) the natural indirect effect (NIE), the effect of the exposure on the outcome via the mediator; 3) the marginal total effect (MTE), the total effect of the exposure on the outcome; and 4) the proportion mediated (PM), the proportion of the exposure-outcome association that is mediated by the mediator (PM). We computed 95% confidence intervals for the above counterfactual components using bootstrap procedures with 10000 simulations. To test for potential bias that would result from missing data, we conducted sensitivity analyses with imputed missing data for health behaviors—imputed via multiple imputation with chained equations, predicted by sex, age, socioeconomic indicators, cohort, study period, and cardiometabolic disorders. We used Stata version 14 for all analyses (Stata Corp, College Station, TX, USA).

Results

The pooled seven-cohort sample yielded 160'916 eligible participants with data on dietary intake and socioeconomic indicators. We excluded 19'987 participants from the analysis because they lacked data on health behaviors (**Supplementary figure 1** shows participant inclusion flowchart). **Supplementary table 2** displays the characteristics of included and excluded participants. Compared with those included, a lower proportion of excluded participants were men, had a low education, were current smokers, and obese. Excluded participants also had higher mean mAHEI, and a higher prevalence of CVD.

Table 1 presents the characteristics of included participants, overall and by cohort. The proportion of women ranged from 27% in the Whitehall II sample to 100% in the E3N sample, and 70% in the pooled sample. The mean age (SD) was 50.1 (10.8), ranging from 46.7 (13.8) in the Constances sample to 58.2 (8.5) in the MCCS sample. The educational level also varied widely across cohort samples; the proportion with low education ranged from 3% in the E3N sample to 58% in the MCCS sample. Similarly, the prevalence of obesity ranged from 3% in E3N to 24% in the MCCS and EpiPorto samples; that of diabetes ranged from 4% in the Whitehall II sample to 13% in EpiPorto. The prevalence of hypertension raged from 29% in the E3N sample to 51% in the EpiPorto sample, and that of CVD ranged from 4% in the MCCS and EPIC Italy samples to 25% in the EpiPorto sample (Table 1).

Table 2 displays the association between educational level and cardiometabolic disorders. A clear socioeconomic gradient emerged for all four cardiometabolic disorders. Participants with low education were more likely to be obese; the OR (95% CI) for men and women, respectively, were 2.29 (2.15, 2.43) and 1.99 (1.85, 2.14). Similar patterns of association, albeit with progressively smaller effect size, were observed for diabetes [(2.03; 1.79, 2.30) among women; (1.71; 1.54, 1.90) among men], for hypertension [(1.59; 1.51, 1.66) among women; (1.39; 1.31, 1.46) among men)], and for CVD [(1.26; 1.15, 1.39) among men; (1.18; 1.08, 1.28) among women] (Table 2).

Table 3 shows the association between tertiles of the mAHEI and educational level. An educational gradient was evident, with low education more strongly associated with poorer diet quality than middle education. Relative to participants with high education, those with low education were more likely to have an unhealthier diet [(1.60; 1.50, 1.71) for men, and (1.79; 1.70, 1.88) for women] (Table 3).

Table 4 presents the association between tertiles of the mAHEI and cardiometabolic disorders. A gradient was observed, whereby the likelihood of having a cardiometabolic disorder increased progressively with the lower two mAHEI tertiles, except for diabetes. The unhealthier mAHEI tertile was associated with higher likelihood of being obese, similarly among men (1.26; 1.18, 1.35) and women (1.23; 1.17, 1.29); with higher likelihood of having hypertension, among men (1.27; 1.20, 1.33) and women (1.10;

1.06, 1.14); and with increased odds of having CVD, similarly among men (1.10; 1.02, 1.20) and women (1.10; 1.04, 1.16) (Table 4).

Table 5 shows the results of the counterfactual mediation analysis. Among men, there was no evidence of mediation by diet quality in the association between low education and obesity; however, diet quality appeared to contribute to 8.1% (95% CI: 4.9%, 11.7%) of educational inequalities in hypertension and to 7.0% (1.2%, 15.5%) of inequalities in CVD. Among women, there was evidence of small mediation of diet in the association between low education and obesity (2.5%; 1.0%, 4.0%) and with hypertension (2.3%; 0.2%, 4.4%); finally, diet quality appeared to contribute to 16.8% (6.2%, 41.9%) of educational inequalities in CVD (Table 5).

In sensitivity analyses, we imputed values for 19'987 participants who lacked data on health behaviors, repeated the analyses, and found largely the same results (results available upon request). To explore heterogeneity of associations across cohorts, we run the analyses independently for each cohort sample. Overall, the same patterns of associations were observed between educational level and tertiles of the mAHEI, although the strength of association varied by cohort. Similarly, the pattern of association between tertiles of the mAHEI and cardiometabolic disorders were similar for obesity and hypertension, but not diabetes and CVD (**Supplementary tables 3-5**). Little to no mediation was observed within each cohort Furthermore, repeating the analyses with occupation as the socioeconomic measures of interest yielded similar results (results available upon request).

Discussion

In this large multi-cohort study, we found that participants with low education were more likely to be obese and have diabetes, hypertension, and CVD. We also found that participants with low education tended to have a poorer diet quality, as assessed by the mAHEI. Additionally, we found that an unhealthier diet quality was associated with obesity, hypertension, and CVD, though not diabetes. Finally, we found that poorer diet quality appears to have a small to moderate contribution to the educational inequalities in obesity, hypertension, and CVD.

These results are in line with previous works that have consistently found higher risk of cardiometabolic disorders among socioeconomically disadvantaged groups (1-4). Our results also reflect those that have shown an association between diet quality and SES, assessed either with food groups or dietary indices (16-18). Individuals with low education tend to also be disadvantaged in terms of their employment and income, as well as their living conditions and the neighborhoods they live in, which together represent environments that are not conducive to attaining and sustaining healthy eating behaviors (16, 19). In fact, these socioeconomically deprived environments promote and support the consumption of unhealthy foods (10, 20-23). Evidence shows that healthier foods tend to cost more (16, 24, 25) and be less accessible in more socioeconomically disadvantaged neighborhoods (21, 23). Although the magnitude of socioeconomic inequalities in healthy eating within populations tend to vary across countries, some evidence indicates that the diet quality of the less privileged may be deteriorating while that of the more privileged may be improving (17, 26).

Our results also confirm the extensively reported association of poor diet quality with obesity, hypertension, and CVD (9, 11, 27). The lack of association with diabetes observed among women, and the positive association among men, are likely due to the fact that diabetes treatment emphasizes improvement of dietary quality—although the evidence is mixed on whether people diagnosed with diabetes tend to improve their diets (28, 29)—and that this was a cross-sectional examination. A recent cross-sectional study found the same positive association between diet quality and diabetes (30). However, extensive evidence from prospective studies indicates that a poorer quality diet is indeed associated with higher risk of diabetes (9, 11, 31). A prospective assessment of this association is warranted to elucidate the association of diet quality with cardiometabolic disorders.

Comparison our results of the mediation analysis to the literature is hindered by the fact that studies differ greatly in their mediation methodology and diet quality assessment (4-7). As we recently reported in a systematic review, among 31 studies, diet contributed between 7% to 24% to the socioeconomic gradient in cardiovascular disorders, and around 10% to the socioeconomic gradient in metabolic disorders (4). However, most reports to date have relied on consumption of foods and vegetables to

assess diet quality, and applied the difference method to examine mediation, both of which present limitations (4, 13). Longitudinal assessments with repeated measurements of diet intake are needed to help elucidate its contribution to inequalities in health.

Strengths and limitations

This is, to our knowledge, the first study to assess the mediation of diet in the association between SES and cardiometabolic disorders using a comprehensive and well-known index of diet quality. We used a large pooled sample from seven cohorts across five European countries, and Australia, which allowed us sufficient power to examine mediation using the counterfactual method. These cohort samples had dietary intake data from food frequency questionnaires, which could be harmonized to construct a modified version of the AHEI, a well-known index of diet quality that is associated with cardiometabolic risk. Furthermore, we used objectively measured indicators to define the cardiometabolic outcomes.

Despite these strengths, our study is not, of course, without its limitations. The cross-sectional nature of our study presents a major limitation to assess mediation, particularly given the latency period in the association between dietary behavior and development of cardiometabolic outcomes. We will aim to replicate this analysis in a longitudinal framework to better measure the mediating role of diet. The cohort samples originated from countries that have shown differing patterns of socioeconomic inequalities in cardiometabolic outcomes and diet quality—for instance, socioeconomic inequalities in health and diet are less pronounced in southern European countries than in Northern European countries, which may have introduced substantial heterogeneity in our analysis. Additionally, four out of seven cohorts (the largest ones) only had diet data for seven of the ten food groups that comprised our mAHEI. Furthermore, the food frequency questionnaires applied in each cohort differed in the food items that were assessed, which led to heterogeneity across cohort in the number of food items that comprised each food group. These last two limitations may have underestimated or prevent the detection of the true effect size of the association between diet quality and cardiometabolic outcomes.

Conclusion

In this large multi-cohort pooled sample, we found evidence of small to moderate contribution of diet quality to social inequalities in obesity, hypertension, and CVD, but not diabetes. Given the cross-sectional nature of this study, longitudinal assessments are needed to better capture the mediation of diet quality in socioeconomic inequalities. Nevertheless, the limited evidence in this study indicates that diet quality is an important entry point to reduce socioeconomic inequalities, particularly for CVD.

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Table 1. Characteristics of participants included in the analysis according to cohort

	Whitehall II	MCCS	CoLaus	Epiporto	Constances	EPIC Italy	E3N	Pooled
N (% of women)	3962 (27)	20883 (62)	3244 (54)	1501 (62)	51887 (53)	33297 (66)	46142 (100)	160916 (70)
Age (mean, SD in years)	55.7 (6.1)	58.2 (8.5)	57.6 (10.4)	57.9 (14.5)	46.9 (13.8)	49.7 (8.0)	49.0 (6.5)	50.1 (10.8)
Education [a] (N, %)								
High	1204 (30)	6659 (32)	1103 (34)	409 (27)	30034 (58)	4135 (12)	17327 (38)	60871 (38)
Middle	1937 (49)	2139 (10)	474 (15)	205 (14)	17553 (34)	8214 (25)	27365 (59)	57887 (36)
Low	821 (21)	12085 (58)	1667 (51)	887 (59)	4300 (8)	20948 (63)	1450 (3)	42158 (26)
Dietary quality								
mAHEI (mean, SD)	52.2 (10.7)	47.6 (10.4)	48.5 (11.7)	49.7 (10.5)	47.1 (11.7)	53.4 (12.7)	58.6 (12.5)	51.9 (12.9)
Health behaviors (N, %)								
Current smoker	334 (8)	1775 (9)	687 (21)	258 (17)	10600 (20)	8810 (27)	6232 (14)	28696 (18)
Sedentary behavior	199 (5)	4259 (20)	1016 (31)	1126 (75)	11836 (23)	10240 (31)	9280 (20)	37956 (24)
Cardiometabolic disorders (N,								
Obesity	427 (13)	4874 (24)	555 (17)	364 (24)	5839 (12)	5214 (16)	1154 (3)	18427 (12)
Diabetes	136 (4)	1445 (8)	391 (12)	198 (13)	1693 (3)	1677 (5)	-	5540 (5)
Hypertension	1078 (27)	8590 (48)	1454 (45)	760 (51)	14067 (28)	14394 (44)	8048 (29)	48391 (35)
CVD	762 (20)	886 (4)	580 (18)	370 (25)	3430 (7)	1433 (4)	5179 (11)	12640 (8)

[a] High education corresponds to tertiary education, middle education to higher secondary school, low education to primary and lower secondary school.

MCCS, Melbourne Collaborative Cohort Study; mAHEI, modified alternate healthy eating index; CVD, cardiovascular disease.

Table 2. Association between socioeconomic indicators and cardiometabolic disorders, pooled data from seven cohorts (Whitehall, MCCS, CoLaus, EpiPorto, Constances, EPIC Italy, E3N)

	Educational level	Obesity	Diabetes	Hypertension	CVD
Men	High	1.00 (ref)	1.00 (ref)	1.00 (ref)	1.00 (ref)
	Middle	1.51 (1.41, 1.61)	1.43 (1.29, 1.58)	1.34 (1.28, 1.41)	1.14 (1.05, 1.23)
	Low	1.99 (1.85, 2.14)	1.71 (1.54, 1.90)	1.39 (1.31, 1.46)	1.26 (1.15, 1.39)
	p-trend	*<0.0001*	*<0.0001*	*<0.0001*	*<0.0001*
Women	High	1.00 (ref)	1.00 (ref)	1.00 (ref)	1.00 (ref)
	Middle	1.53 (1.44, 1.62)	1.41 (1.22, 1.62)	1.29 (1.24, 1.34)	1.05 (0.99, 1.10)
	Low	2.29 (2.15, 2.43)	2.03 (1.79, 2.30)	1.59 (1.51, 1.66)	1.18 (1.08, 1.28)
	p-trend	*<0.0001*	*<0.0001*	*<0.0001*	*0.0001*

[a] N included in the analysis of each cardiometabolic disorder

[b] Odds ratios and 95% confidence intervals for the association of education (low versus high group, and middle versus high) with tertiles of the mAHEI, from multinomial logistic regression model, with the effect size adjusted for age, cohort, and period. Obesity analysis N=47420 men, N=110765 women; Diabetes analysis N=46845 men, N=63498 women); Hypertension analysis N=46623 men, N=91311 women; CVD analysis N=48015 men, 111666 women.

Table 3. Association between education and diet quality, pooled data from seven cohorts (Whitehall, MCCS, CoLaus, EpiPorto, Constances, EPIC Italy, E3N)

		Low vs high education		Middle vs high education		
mAHEI tertiles	Mean (SD)	OR (95% CI)[a]	p[b]	OR (95% CI)[a]	p[b]	N
Men						48730
Healthier	61.1 (6.7)	1.00 (ref)		1.00 (ref)		
Middle	48.9 (4.1)	1.25 (1.17, 1.34)	<0.001	1.20 (1.13, 1.27)	<0.001	
Unhealthier	35.9 (6.5)	1.60 (1.50, 1.71)	<0.001	1.43 (1.35, 1.52)	<0.001	
Women						112285
Healthier	66.3 (8.1)	1.00 (ref)		1.00 (ref)		
Middle	53.5 (6.1)	1.40 (1.34, 1.47)	<0.001	1.16 (1.12, 1.20)	<0.001	
Unhealthier	40.5 (7.6)	1.79 (1.70, 1.88)	<0.001	1.23 (1.19, 1.27)	<0.001	

mAHEI, modified alternate healthy eating index.

[a] Odds ratios and 95% confidence intervals for the association of education (low versus high group, and middle versus high) with tertiles of the mAHEI, from multinomial logistic regression model, with the effect size adjusted for age, cohort, and period.

[b] P-values for difference between low and high education groups, and between middle and high education groups.

Table 4. Association of diet quality with cardiometabolic disorders, pooled data from seven cohorts (Whitehall, MCCS, CoLaus, EpiPorto, Constances, EPIC Italy, E3N)

	Cardiometabolic	mAHEI tertile	OR (95% CI) [a]	p-value [b]	N
Men	Obesity	Healthier	1 (ref)		47915
		Middle	1.20 (1.13, 1.29)	<0.001	
		Unhealthier	1.26 (1.18, 1.35)	<0.001	
	Diabetes	Healthier	1 (ref)		46925
		Middle	0.96 (0.88, 1.06)	0.15	
		Unhealthier	0.92 (0.83, 1.01)	0.06	
	Hypertension	Healthier	1 (ref)		46717
		Middle	1.10 (1.04, 1.15)	<0.001	
		Unhealthier	1.27 (1.20, 1.33)	<0.001	
	CVD	Healthier	1 (ref)		48216
		Middle	0.99 (0.91, 1.08)	0.63	
		Unhealthier	1.10 (1.02, 1.20)	0.02	
Women	Obesity	Healthier	1 (ref)		110887
		Middle	1.14 (1.09, 1.20)	<0.001	
		Unhealthier	1.23 (1.17, 1.29)	<0.001	
	Diabetes	Healthier	1 (ref)		63506
		Middle	1.07 (0.97, 1.17)	0.19	
		Unhealthier	1.00 (0.90, 1.11)	0.98	
	Hypertension	Healthier	1 (ref)		91322
		Middle	1.03 (0.99, 1.07)	0.09	
		Unhealthier	1.10 (1.06, 1.14)	<0.001	
	CVD	Healthier	1 (ref)		111715
		Middle	1.05 (0.99, 1.10)	0.11	
		Unhealthier	1.10 (1.04, 1.16)	0.001	

mAHEI, modified alternate healthy eating index; CVD, cardiovascular disease.

[a] Odds ratio and 95% confidence intervals for the association of cardiometabolic disorders with tertiles of the mAHEI (unhealthier versus healthier tertile, and middle versus healthier tertile), from multinomial logistic regression model, with the effect size adjusted for age, cohort, and study period.

[b] P-values for difference between unhealthier and healthier groups, and between middle and healthier education groups.

Table 5. Estimates of the counterfactual mediation analysis by diet quality in the association between low educational level and cardiometabolic disorders, pooled data from seven cohorts (Whitehall, MCCs, CoLaus, EpiPorto, Constances, EPIC Italy, E3N)

		MTE	NDE	NIE	PM
	Cardiomatebolic disorders	OR (95% CI)	OR (95% CI)	OR (95% CI)	(95% CI)
Men	Obesity	1.90 (1.74, 2.07)	1.89 (1.72, 2.06)	1.01 (0.99, 1.02)	1.1 (-1.6, 3.5)
	Diabetes	1.63 (1.45, 1.87)	1.68 (1.49, 1.92)	0.97 (0.95, 0.99)	-7.3 (-12.9, -2.6)
	Hypertension	1.42 (1.34, 1.52)	1.39 (1.30, 1.48)	1.02 (1.01, 1.04)	8.1 (4.9, 11.7)
	CVD	1.25 (1.13, 1.39)	1.23 (1.11, 1.38)	1.02 (1.01, 1.03)	7.0 (1.2, 15.5)
Women	Obesity	2.31 (2.17, 2.48)	2.28 (2.14, 2.44)	1.01 (1.01, 1.02)	2.5 (1.0, 4.0)
	Diabetes	2.02 (1.76, 2.34)	2.05 (1.79, 2.38)	0.98 (0.96, 1.01)	-3.1 (-7.3, 1.3)
	Hypertension	1.61 (1.55, 1.74)	1.59 (1.51, 1.68)	1.01 (1.00, 1.02)	2.3 (0.2, 4.4)
	CVD	1.17 (1.10, 1.30)	1.13 (1.04, 1.24)	1.02 (1.01, 1.04)	16.8 (6.2, 41.9)

mAHEI, modified alternate healthy eating index; NDE, natural direct effect (Odds ratio and 95% confidence interval), the effect of low educational level on each cardiometabolic disorder independent from mAHEI; TME, total marginal effects (Odds ratio and 95% confidence interval), the total effect of the exposure on the outcome; NIE, natural indirect effect the effect of low educational level on each cardiometabolic disorder via the mAHEI; PM, proportion mediated: the proportion of the association of low educational level with each cardiometabolic disorder which is mediated by the unhealthier tertile of the mAHEI. Confidence intervals for NDE, NIE, and PM estimations were computed via boostrapping (10000 simulations).

Supplementary material

Supplementary table 1. Modified alternate healthy eating index

Component	Criteria for minimum score of 0	Criteria for maximum score of 10
Vegetables (servings/day)	0	5
Fruit (servings/day)	0	4
Whole grains (servings/day)		
Women	0	5
Men	0	6
Sugar-sweetened beverages/fruit juice (servings/day)	≥1	<1
Nuts, legumes and vegetables protein (servings/day)	0	≥1
Red/processed meat (servings/day)	≥1.5	<1/month
Fish (servings/week)	0	≥2/week
Ratio of polyunsaturated to saturated fats	≤0.1	≥1
Sodium (g/day)	highest decile	lowest decile
Alcohol (servings/day)		
Women	0 or >2.5	0.5-1.5
Men	0 or >3.5	1.5-2.5
Total score	0	100

Modified from Chiuve et al. (9).

Supplementary table 2. Characteristics of included and excluded participants

	Included	Excluded	p-value
N (% women)	160916 (70)	19981 (87)	<0.001
Age (mean, SD in years)	50.1 (10.8)	50.4 (8.6)	<0.001
Education			<0.001
High	60871 (38)	6404 (38)	
Middle	57887 (37)	8623 (46)	
Low	42158 (26)	1701 (10)	
Father's occupation			0.01
High	19490 (16)	2466 (16)	
Middle	49188 (33)	6464 (34)	
Low	50353 (42)	6269 (41)	
AHEI (mean, SD)	51.9 (12.9)	55.7 (13.2)	<0.001
Behavioral factors			
Smoker	28696 (18)	2259 (13)	<0.001
Sedentary	37956 (24)	1019 (23)	0.08
Cardiometabolic disorders			
Obesity	18427 (12)	951 (5)	<0.001
Diabetes	5540 (5)	244 (5)	0.86
Hypertension	48391 (35)	3964 (32)	<0.001
CVD	12640 (8)	2215 (12)	<0.001

p-value for difference between included and excluded participants, from Chi-square test for categorical covariates, and from t student test for continuous covariates.

Supplementary table 3. Association between educational level and mAHEI tertiles according to cohort

		OR (95% CI)	p-value	N
Whitehall	Men			2975
	Healthier tertile	1.00 (ref)		
	Middle tertile	1.29 (0.98, 1.70)	0.07	
	Unhealthier	1.42 (1.07, 1.87)	0.01	
	Women			1086
	Healthier tertile	1.00 (ref)		
	Middle tertile	1.22 (0.80, 1.85)	0.36	
	Unhealthier	1.67 (1.07, 2.62)	0.02	
MCCS	Men			8042
	Healthier tertile	1.00 (ref)		
	Middle tertile	1.01 (0.89, 1.15)	0.85	
	Unhealthier	1.05 (0.93, 1.19)	0.39	
	Women			12841
	Healthier tertile	1.00 (ref)		
	Middle tertile	1.39 (1.26, 1.52)	<0.001	
	Unhealthier	1.47 (1.33, 1.63)	<0.001	
CoLaus	Men			1504
	Healthier tertile	1.00 (ref)		
	Middle tertile	1.08 (0.80, 1.46)	0.60	
	Unhealthier	1.20 (0.90, 1.60)	0.23	
	Women			1740
	Healthier tertile	1.00 (ref)		
	Middle tertile	1.06 (0.82, 1.36)	0.66	
	Unhealthier	1.80 (1.36, 2.39)	<0.001	
EpiPorto	Men			570
	Healthier tertile	1.00 (ref)		
	Middle tertile	0.67 (0.39, 1.16)	0.16	
	Unhealthier	1.29 (0.75, 2.22)	0.35	
	Women			931
	Healthier tertile	1.00 (ref)		
	Middle tertile	1.19 (0.81, 1.76)	0.38	
	Unhealthier	1.52 (0.98, 2.37)	0.06	
Constances	Men			24429
	Healthier tertile	1.00 (ref)		
	Middle tertile	1.48 (1.33, 1.64)	<0.001	
	Unhealthier	2.00 (1.80, 2.23)	<0.001	
	Women			27458
	Healthier tertile	1.00 (ref)		
	Middle tertile	1.64 (1.50, 1.80)	<0.001	
	Unhealthier	2.17 (1.96, 2.41)	<0.001	
EPIC Italy	Men			11210
	Healthier tertile	1.00 (ref)		
	Middle tertile	1.16 (1.02, 1.32)	0.03	
	Unhealthier	1.38 (1.21, 1.58)	<0.001	
	Women			22087

	Healthier tertile	1.00 (ref)		
	Middle tertile	1.49 (1.36, 1.64)	<0.001	
	Unhealthier	2.11 (1.91, 2.33)	<0.001	
	Women			46142
E3N	Healthier tertile	1.00 (ref)		
	Middle tertile	1.09 (1.01, 1.19)	0.04	
	Unhealthier	1.17 (1.08, 1.27)	<0.001	

mAHEI, modified alternate healthy eating index.

[a] Odds ratios and 95% confidence intervals for the association of education (low versus high group) with tertiles of the mAHEI, from multinomial logistic regression model, with the effect size adjusted for age, smoking and sedentary behavior.

Supplementary table 4. Association between tertiles of mAHEI and cardiometabolic disorders according to cohort

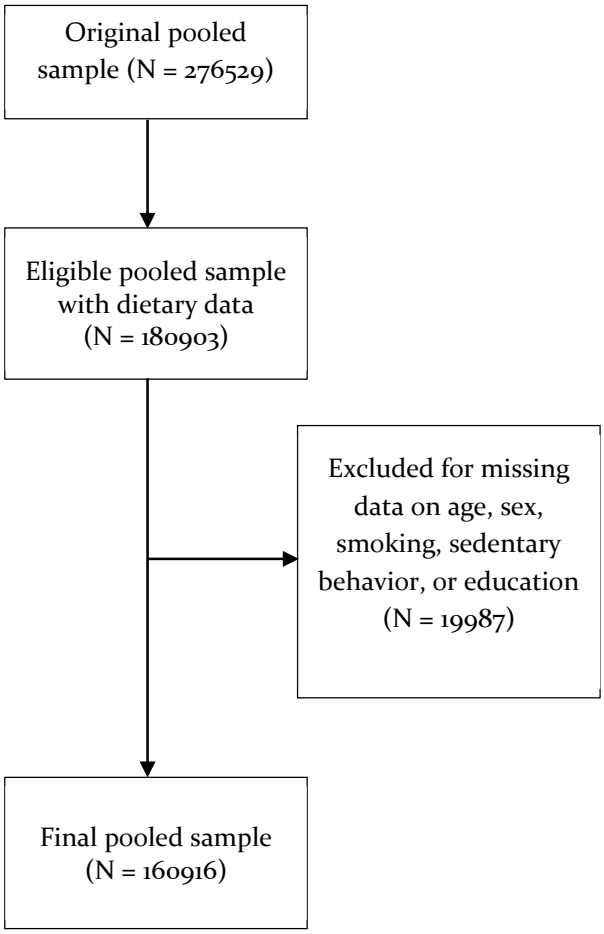
			Men			Women		
	Cardiometab	mAHEI	OR (95% CI)	p-	N	OR (95% CI)	p-	N
Whitehall	Obesity	Healthier	1.00 (ref)		2959	1.00 (ref)		1082
		Middle	1.18 (0.90, 1.55)	0.22		1.25 (0.88, 1.76)	0.21	
		Unhealth	1.52 (1.17, 1.97)	0.001		1.46 (1.02, 2.08)	0.04	
	Diabetes	Healthier	1.00 (ref)		2936	1.00 (ref)		1066
		Middle	0.92 (0.63, 1.36)	0.69		0.75 (0.37, 1.53)	0.44	
		Unhealth	1.08 (0.74, 1.57)	0.70		1.19 (0.61, 2.31)	0.61	
	Hypertension	Healthier	1.00 (ref)		2973	1.00 (ref)		1085
		Middle	0.93 (0.77, 1.13)	0.48		0.85 (0.63, 1.15)	0.29	
		Unhealth	1.04 (0.86, 1.25)	0.70		1.00 (0.73, 1.36)	0.98	
	CVD	Healthier	1.00 (ref)		2975	1.00 (ref)		1086
		Middle	1.10 (0.87, 1.38)	0.42		1.36 (0.94, 1.96)	0.10	
		Unhealth	1.15 (0.91, 1.44)	0.23		1.42 (0.97, 2.08)	0.07	
MCCS	Obesity	Healthier	1.00 (ref)		7941	1.00 (ref)		12691
		Middle	1.23 (1.07, 1.42)	0.01		1.30 (1.18, 1.43)	<0.001	
		Unhealth	1.27 (1.11, 1.46)	0.001		1.34 (1.22, 1.49)	<0.001	
	Diabetes	Healthier	1.00 (ref)		6582	1.00 (ref)		10595
		Middle	0.86 (0.70, 1.05)	0.15		1.07 (0.90, 1.28)	0.43	
		Unhealth	0.80 (0.66, 0.98)	0.03		0.87 (0.71, 1.05)	0.14	
	Hypertension	Healthier	1.00 (ref)		6961	1.00 (ref)		10968
		Middle	1.00 (0.87, 1.13)	0.94		1.14 (1.04, 1.26)	0.01	
		Unhealth	1.13 (1.00, 1.28)	0.06		1.26 (1.14, 1.40)	<0.001	
	CVD	Healthier	1.00 (ref)		8042	1.00 (ref)		12841
		Middle	0.75 (0.60, 0.95)	0.02		1.10 (0.84, 1.43)	0.49	
		Unhealth	0.86 (0.70, 1.07)	0.18		1.21 (0.93, 1.58)	0.16	
CoLaus	Obesity	Healthier	1.00 (ref)		1487	1.00 (ref)		1722
		Middle	1.37 (0.97, 1.95)	0.08		1.38 (1.00, 1.92)	0.05	
		Unhealth	1.22 (0.86, 1.72)	0.260		1.93 (1.38, 2.70)	<0.001	
	Diabetes	Healthier	1.00 (ref)		1499	1.00 (ref)		1735
		Middle	1.03 (0.73, 1.46)	0.85		0.92 (0.58, 1.46)	0.72	
		Unhealth	0.59 (0.42, 0.84)	<0.001		1.10 (0.69, 1.77)	0.69	
	Hypertension	Healthier	1.00 (ref)		1501	1.00 (ref)		1734
		Middle	1.24 (0.92, 1.66)	0.15		1.18 (0.92, 1.52)	0.20	
		Unhealth	1.41 (1.06, 1.87)	0.02		1.25 (0.95, 1.64)	0.11	
	CVD	Healthier	1.00 (ref)		1484	1.00 (ref)		1728
		Middle	1.10 (0.76, 1.58)	0.62		0.83 (0.61, 1.14)	0.26	
		Unhealth	1.10 (0.77, 1.57)	0.60		1.30 (0.94, 1.78)	0.11	
EpiPorto	Obesity	Healthier	1.00 (ref)		569	1.00 (ref)		929
		Middle	0.63 (0.33, 1.19)	0.15		1.44 (1.03, 2.03)	0.03	
		Unhealth	0.97 (0.56, 1.70)	0.92		1.45 (0.99, 2.12)	0.06	
	Diabetes	Healthier	1.00 (ref)		567	1.00 (ref)		920
		Middle	1.08 (0.58, 2.03)	0.80		1.28 (0.79, 2.08)	0.32	
		Unhealth	1.28 (0.71, 2.32)	0.42		1.94 (1.17, 3.22)	0.01	
	Hypertension	Healthier	1.00 (ref)		569	1.00 (ref)		931
		Middle	0.79 (0.49, 1.27)	0.33		1.17 (0.83, 1.66)	0.36	

		Unhealth	1.28 (0.82, 2.01)	0.27		1.61 (1.10, 2.38)	0.02	
	CVD	Healthier	1.00 (ref)		570	1.00 (ref)		929
		Middle	1.10 (0.66, 1.84)	0.71		1.04 (0.73, 1.50)	0.81	
		Unhealth	0.99 (0.60, 1.61)	0.96		1.12 (0.75, 1.67)	0.59	
Constances	Obesity	Healthier	1.00 (ref)		23885	1.00 (ref)		26831
		Middle	1.34 (1.21, 1.49)	<0.001		1.20 (1.09, 1.32)	<0.001	
		Unhealth	1.46 (1.31, 1.62)	<0.001		1.32 (1.19, 1.46)	<0.001	
	Diabetes	Healthier	1.00 (ref)		24131	1.00 (ref)		27103
		Middle	0.92 (0.80, 1.07)	0.29		1.09 (0.88, 1.34)	0.44	
		Unhealth	0.93 (0.80, 1.08)	0.32		1.08 (0.85, 1.39)	0.52	
	Hypertension	Healthier	1.00 (ref)		23849	1.00 (ref)		26705
		Middle	1.19 (1.11, 1.28)	<0.001		1.11 (1.03, 1.20)	0.01	
		Unhealth	1.39 (1.28, 1.49)	<0.001		1.23 (1.13, 1.35)	<0.001	
	CVD	Healthier	1.00 (ref)		23935	1.00 (ref)		26902
		Middle	0.99 (0.88, 1.12)	0.93		1.04 (0.92, 1.17)	0.57	
		Unhealth	1.12 (0.99, 1.26)	0.08		1.00 (0.87, 1.15)	0.99	
EPIC Italy	Obesity	Healthier	1.00 (ref)		11074	1.00 (ref)		21986
		Middle	0.95 (0.83, 1.09)	0.48		0.98 (0.90, 1.07)	0.66	
		Unhealth	0.94 (0.82, 1.07)	0.34		1.03 (0.95, 1.13)	0.46	
	Diabetes	Healthier	1.00 (ref)		11210	1.00 (ref)		22087
		Middle	1.02 (0.83, 1.24)	0.86		1.11 (0.95, 1.29)	0.19	
		Unhealth	0.91 (0.75, 1.12)	0.38		1.03 (0.88, 1.21)	0.72	
	Hypertension	Healthier	1.00 (ref)		10864	1.00 (ref)		21815
		Middle	1.02 (0.92, 1.13)	0.68		0.96 (0.90, 1.04)	0.32	
		Unhealth	1.19 (1.08, 1.32)	0.002		1.03 (0.96, 1.11)	0.43	
	CVD	Healthier	1.00 (ref)		11210	1.00 (ref)		22087
		Middle	0.97 (0.79, 1.18)	0.74		1.20 (0.99, 1.45)	0.06	
		Unhealth	1.06 (0.87, 1.28)	0.57		1.35 (1.12, 1.63)	0.00	
E3N	Obesity	Healthier				1.00 (ref)		45646
		Middle				1.28 (1.10, 1.49)	<0.001	
		Unhealth				1.41 (1.21, 1.63)	<0.001	
	Hypertension	Healthier				1.00 (ref)		28084
		Middle				1.02 (0.96, 1.09)	0.57	
		Unhealth				1.08 (1.02, 1.16)	0.01	
	CVD	Healthier				1.00 (ref)		46142
		Middle				0.99 (0.92, 1.06)	0.77	
		Unhealth				1.00 (0.93, 1.07)	0.92	

mAHEI, modified alternate healthy eating index; CVD, cardiovascular disease.

[a] Odds ratio and 95% confidence intervals for the association of cardiometabolic disorders with tertiles of the mAHEI (unhealthier versus healthier tertile, and middle versus healthier tertile), from multinomial logistic regression model, with the effect size adjusted for age, sedentary behavior, and smoking.

Supplementary figure 1. Participant inclusion flowchart



Chapter 8 General discussion

Summary of main results and comparison to the literature

The findings presented in this thesis provide important additions to the literature in social and nutritional epidemiology. In Chapter 2, we conducted a systematic review and meta-analysis and we found that a majority of reported associations between sodium intake and socioeconomic indicators specified higher sodium intake among more disadvantaged individuals. In the meta-analysis, we confirmed this inverse association, showing that people of lower SES tended to consume about 14% more sodium (approximately 503 milligrams) per day compared with more advantaged individuals. This difference likely contributes to the increased risk of hypertension and CVD observed in disadvantaged populations. These results expand the extensive body of evidence linking socioeconomic disadvantage to poorer diet quality in populations of HICs (1-4).

In Chapters 3 to 5, we focused on the Swiss population and we explored barriers to healthy eating. We found that a substantial proportion of participants in the 2012 Swiss Health Survey, ranging from 20% to more than half the sample, identified price, daily habits, taste, time constraints, and lack of willpower as barriers that prevented them from attaining and maintaining healthy eating behaviors. These results largely reflected those reported in a Pan-European study, except that the prevalence of price as a barrier was much higher in Switzerland (5). Importantly, the prevalence of all the barriers followed sociodemographic patterns, likely reflecting the broader social, cultural, economic, and environmental factors that shape people's dietary behaviors (6-13). Women, for instance, were more likely to report time constraint than men, which may be due to the challenges that women continue to face in balancing employment and family expectations (14). Additionally, participants with lower education were more likely to identify taste as a barrier, which may reflect a misinformed perception of healthy foods as lacking in taste. This is more likely, however, due to chronic exposure to an obesogenic environment—common in disadvantaged neighborhoods—that promotes and facilitates the consumption of unhealthier foods (6, 8, 10, 15-17). Taking into account these findings, we proposed a series of multisectoral measures that could reduce the prevalence of barriers to healthy eating in the population.

We then extended this work on barriers to healthy eating by examining trends over time (fifteen years), using data from the Swiss Health Surveys conducted in 1997, 2002, 2007, and 2012. We found that between 1997 and 2012, the prevalence of barriers to healthy eating (daily habits, price, time, willpower, and lack of healthy food options) was consistently high (above 20%). Importantly, similar sociodemographic differences were present in all survey years. Notably, we observed that the prevalence of price as a barrier closely resembled the fluctuations of the Swiss consumer price index for healthy foods across the same period; this indicates that the population may indeed respond to changing prices of healthy foods, and consequently adapt their dietary behavior (4, 6). To date, our study remains the sole secular trends analysis of barriers to healthy eating in any population, which prevents a comparison to the literature.

In chapter 5, using data from the 2012 Swiss Health Survey, we examined whether the highly prevalent barriers to healthy eating were associated with adherence to the Swiss dietary guidelines for several food groups. Our analysis revealed a complex pattern of association between barriers and adherence to dietary guidelines. As expected, participants who reported daily habits as a barrier were less likely to adhere to the guidelines for fruits, fish, meat, and drinks; these findings concur with those from the two other studies that investigated the same barriers-guidelines adherence associations (18, 19). Surprisingly, however, participants who reported price, lack of options in restaurants, and lack of options in food markets as barriers were more likely to adhere to the guidelines for fruits, vegetables, fish, and meat; these findings contradicted previous research (18). A possible explanation for this apparent paradox could be that participants who devote more time to searching, selecting and purchasing healthy foods may simply be more aware of their higher price and of the lack of healthy options in food markets and restaurants.

In the last part of this thesis, we explored the contribution of diet quality to social inequalities in cardiometabolic disorders. We assessed the mediation of diet quality in the association between educational level and four obesity indicators in the adult Swiss population, using data from the national nutrition survey menuCH. Our findings showed that participants with less than a university degree were more than twice more likely to be obese regardless of the obesity marker—results in line with the literature (10,

11, 20). We found that participants with less education were also more than twice more likely to have poorer quality diets, also in agreement with extensive evidence in other populations (1, 3, 21). In turn, participants with poorer quality diets were over twice more likely to be obese across all obesity markers, as reported in the literature (20, 22, 23). The counterfactual mediation analysis revealed that diet quality substantially contributed (between 22% and 36%) to the educational inequalities in obesity. To our knowledge, this is the first study to utilize a comprehensive dietary index to assess the mediation of diet quality in the SES-obesity association, as well as the first do so using four objectively measured obesity markers. Our findings are in line with previous reports that have found diet quality—albeit measured less comprehensively—to be an important contributor to inequalities in obesity (as defined by BMI) (24-27). These findings emphasize the need to empower socioeconomically disadvantaged individuals to improve their diets in order to reduce health inequities and the overall burden of rising obesity in the population.

Finally, we applied the above mediation analysis to examine the contribution of diet quality to educational inequalities in four cardiometabolic outcomes: obesity, diabetes, hypertension, and CVD. For this study, we used a large pooled sample from seven cohorts that form part of the LIFEPATH consortium. We observed a strong and consistent educational gradient in all four cardiometabolic outcomes—participants with less education were more likely to be obese, as well as to have diabetes, hypertension, and CVD. These findings are in line with a large and consistent body of evidence on socioeconomic inequalities in chronic disease (28-31). We also found that lower education was associated with poorer quality diets, also in agreement with extensive evidence (1-3). In turn, a poorer quality diet was associated with higher likelihood of obesity, hypertension, and CVD, in line with findings from a recent systematic review of the link between several dietary quality indices and cardiometabolic outcomes (32). Among women, we observed that diet quality contributed little to the educational inequalities in obesity and hypertension, but substantially to the educational inequalities in CVD. Among men, we found that diet contributed moderately to educational inequalities in hypertension and CVD.

Previous studies examining the contribution of diet quality to socioeconomic inequalities in cardiometabolic outcomes have reported a wide range of findings. Recently, a systematic review identified 31 studies that investigated the mediation of diet in socioeconomic inequalities in health; of these, 14 studies found that diet appeared to explain between 2% and 50% of social inequalities in cardiovascular disorders and 10% of metabolic disorders (29). Notably, the included studies exhibited considerable heterogeneity in terms of the socioeconomic indicators used, the measurement of outcomes, the confounders accounted for in the models, the mediation analysis technique, and the assessment of diet (29). Importantly, the latter differed considerably, with diet quality being assessed using total energy intake (33), total calories from fats (34), consumption of specific food groups (35, 36), take-away and fast foods (25, 27), or dozens of macro and micronutrients (37). In light of these methodological differences, we exert caution in comparing our mediation results to the literature.

One cross-sectional study that measured diet quality using food groups (consumption of bread, fats, milk, meat, and fruits and vegetables) also found little to no contribution of diet in the educational inequalities in obesity and hypertension among women (35). However, another cross-sectional study that measured diet quality using several macro and micronutrients found that diet explained between 34% and 41% of the educational inequalities in hypertension (37). Studies that have cross-sectionally examined the combined mediation of diet and other health behaviors—primarily smoking, alcohol consumption, and physical activity—have found these behaviors explained up to 64% of the socioeconomic inequalities in cardiometabolic outcomes (including all-cause mortality) (29). To our knowledge, no other study has assessed cross-sectionally the contribution of diet to social inequalities in health using a diet quality index such as the AHEI and the counterfactual mediation method.

Strengths and limitations

The studies conducted in this thesis had several strengths. Namely, the systematic review and meta-analysis, the secular trends analysis, and the two mediation studies are, to our knowledge, novel. We were able to use large sample sizes in our analyses. The meta-analysis included study-specific effect estimates from a total of 42'555 participants from nine countries. The analyses of barriers to healthy eating benefitted from the large population-based representative samples of the adult Swiss population across four cross-sectional Swiss Health Surveys. The large sample size provided sufficient statistical power to disaggregate the analysis by sex and other sociodemographic variables, and to check for interactions. Similarly, our multi-cohort study benefitted from a large pooled sample (N=160'916) of adults from Australia, France, Italy, Portugal, Switzerland, and the UK. Furthermore, the menuCH survey included two 24h dietary recalls (38), which provided more accurate daily food intake compared with only one 24h dietary recall or FFQs (39, 40), and four obesity markers that were objectively measured and are known predictors of chronic disease risk (41-43).

Notwithstanding, these studies also presented several important limitations. Most importantly, all the analyses were cross-sectional, which precludes any inference of causality and introduces the possibility of reverse causality (44-46). This may help explain the lack of association among women, and positive association among men, between diet quality and diabetes in our multi-cohort study. The emphasis on nutrition in the management of diabetes may explain this (47), although the evidence is inconsistent regarding the quality of diet among diabetic patients (48-51). Similar to our findings, a recent cross-sectional study also found a positive association between diet quality—a score measuring adherence to the Mediterranean diet—and diabetes (52). Nevertheless, extensive evidence from large prospective studies, including with repeated measures of diet quality, indicates that a poorer quality diet is indeed associated with higher risk of diabetes (53, 54). The cross-sectional nature of our analysis may also help explain the fact that we found only modest, little or no mediation of diet in the SES-obesity and SES-hypertension in the multi-cohort study. Indeed, longitudinal assessments stand to better capture the contribution of diet to inequalities in chronic disease (29). One such longitudinal analysis using a large UK sample found that an

unhealthy diet—measured via the AHEI—explained around 9% of social inequalities in diabetes incidence (55). Another study, using a large Australian sample, found that diet quality—measured using consumption of several food groups—explained between 15% and 20% of educational inequalities in BMI increases over a 13-year period (24). Yet another study using a large Dutch sample found that diet explained between 48% and 67% of educational inequalities in coronary heart disease and stroke incidence (56).

Related to the above, another important limitation is the period when the cross-sectional data collections took place, which ranged between 1993 and 2014 across the LIFEPATH cohorts, and between 1997 and 2016 in the meta-analysis. This may be relevant given that populations vary in regard to the stages of the epidemiological and nutrition transitions (57, 58). We focused on HICs in the review and the multi-cohort study, which made it less likely that the sample populations would differ significantly in their stages of the epidemiological and nutrition transitions. Nevertheless, we observed considerable heterogeneity in both analyses, likely due to important demographic, social and cultural characteristics that are specific to each sampled population. For instance, evidence has shown that the socioeconomic pattern of health behaviors and risk factors differs considerably across European countries (59-61).

The self-reported nature of the data represents another important limitation in our analyses, especially regarding barriers to healthy eating and food intakes. Exploring the association of the barriers to healthy eating with adherence to the Swiss dietary guidelines provided some validation as to whether these perceived barriers indeed prevented individuals from following a healthy diet. Our results indicated that at least some perceived barriers may in fact not be preventing participants from following the dietary guidelines. Over-reporting of healthier foods and underreporting of unhealthier foods are common in self-reported diet information, with obese and socioeconomically disadvantaged people more likely to misreport (62-64). The latter are also less likely to accurately recall past foods or estimate frequency of consumption (62, 64).

Another limitation is the small number of socioeconomic indicators used to assess socioeconomic disadvantage in the mediation analyses. While in the analyses on barriers to healthy eating and adherence to the dietary guidelines we were able to use

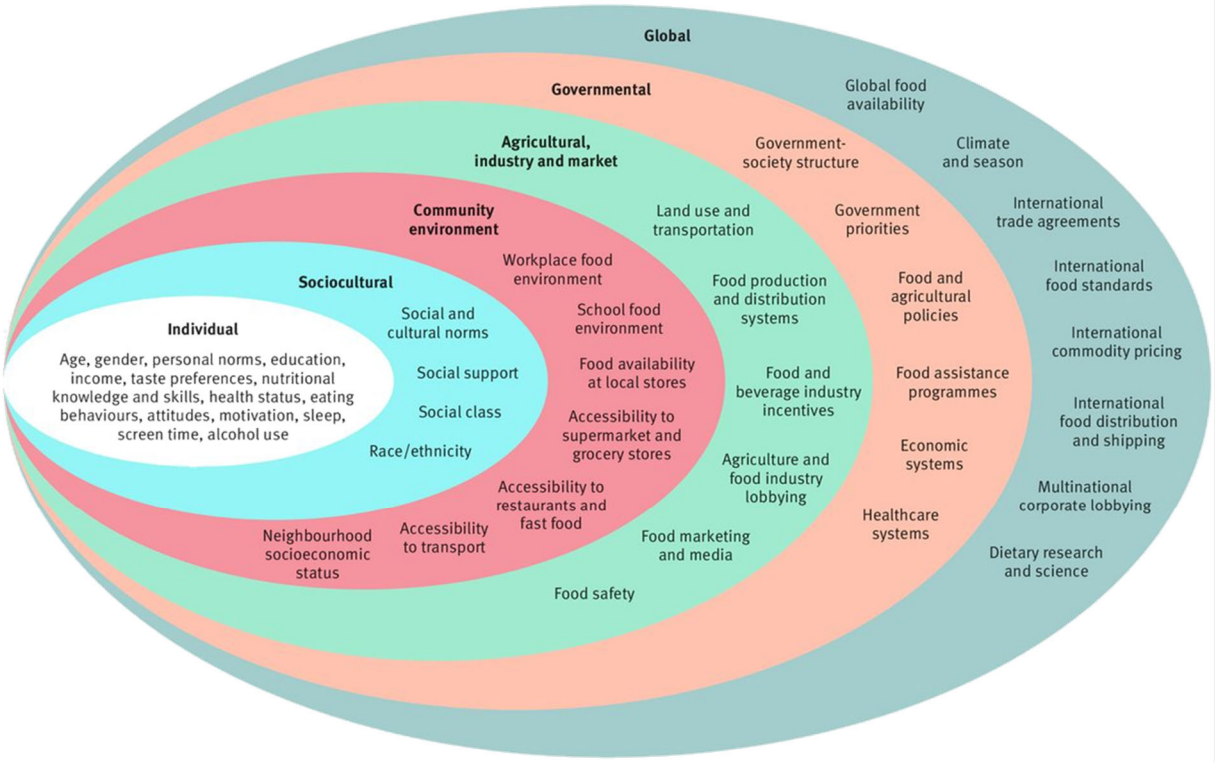
education, income, and occupation, we could only use education in the two different mediation analyses. As previously discussed, socioeconomic inequalities are best assessed with several different indicators that each capture different and independent aspects of socioeconomic conditions and disadvantage. Further, these indicators might be differently associated with diet. Indeed, in our analyses of barriers to healthy eating, reporting of barriers was differently associated with different indicators. Given the importance of income (and price) as a barrier to healthy eating in the Swiss population, assessing the inequalities in diet quality by income level is needed.

Finally, another limitation is the type of instruments applied to collect the dietary data we used in our analyses. Importantly, most of the associations reported in the systematic review originated from suboptimal measurements of sodium intake relying on several different dietary questionnaires. Importantly, in the meta-analysis, we only considered associations from urine-based methods, which provide more accurate sodium estimates. The data originating from the 24h dietary recalls used in the menuCH and the FFQs in the LIFEPATH cohorts are limited due to recall bias, social desirability bias, and interviewer bias. Furthermore, there were differences across cohorts in the number of food items measured in each FFQ. Additionally, only four cohorts had complete data for the ten mAHEI food groups, while the remaining included seven food groups. The missing food groups were whole grains, the ratio of saturated to unsaturated fats, and sodium intake—the absence of these in the mAHEI may have affected the estimation of effect size in the exposure-mediator and mediator-outcome associations.

Implications for public health

Placing our findings in the context of established knowledge in epidemiology and public health draws attention to the importance of the social determinants of health (44, 65). These are the social, cultural, economic, political and environmental factors that influence and shape the manner in which individuals are born, grow, eat, learn, behave, and age (65). An extensive and growing body of evidence demonstrates that dietary behaviors result from a complex interaction of multiple factors that lie outside an individual's sphere of control (9, 12, 66). At the background of dietary behavior lies the fundamental fact that, as part of the human species, individuals have an innate affinity towards flavorful foods, especially sugars, that is reinforced by a strong biological rewards system (67-69). This rewards system evolved over the course of human evolution and contributed to survival in environments with limited and inconsistent foods source, which stands in sharp contrast to the current obesogenic environments (69). Figure 1 shows the multiple factors that influence and drive dietary behavior and patterns in modern life.

Figure 1. Factors that influence dietary behaviors, reproduced from (66)



As shown in the figure, individual level factors of dietary behavior are influenced by sociocultural aspects around food, which in turn are shaped by the community food environment (66)—this thesis explored several of these factors. However, important factors at the food industry and market level also profoundly affect dietary behavior. Similarly, governments and global food policies shape dietary behavior, albeit less obviously. To illustrate, without providing the full historical account that it merits, several societal, technological, economic and political processes occurred during the nutrition transition in HICs that shaped the current food environments. Government policies at the turn of the 20th century began subsidizing the large-scale production of staple grains and their sugar derivatives (66, 70). The main reason for this was to tackle the high prevalence of undernutrition at the time (66, 70). The enormous amount of excess grains eventually contributed to the development of the intensive animal farming and modern sugar industries (71, 72). Facilitated by the innate human craving for sugary and fatty foods, these industries successfully spread to diverse food environments using strategic marketing and advertisement that sought to shape sociocultural norms, attitudes, and beliefs about foods. Notably, evidence indicates that unhealthy food advertisements disproportionally target socioeconomically disadvantaged people (73).

Unsurprisingly, the proportion of animal and highly processed foods in the diet increased steadily for decades (74). The food industry also introduced progressively larger portion sizes (75) and influenced government policy that enabled it to promote its products in schools, workplaces, and government-funded food assistance programs (13, 76). The latter particularly may have contributed to socioeconomic inequalities in diet; programs such as the Supplemental Nutrition Assistance Program (SNAP) in the US, intended for socioeconomically disadvantaged individuals, appear to facilitate consumption of unhealthier foods (77-79). Importantly, as evidence began to emerge of the deleterious health effects of their most profitable food products, the food industry sought to influence nutritional and epidemiological research, dissemination of findings, and public health messages (13, 80). At the same time, socioeconomically advantaged individuals, with greater capacity to discern and resources to respond to the growing knowledge on the effect of diet and other health behaviors, began to choose healthier diets and lifestyles (1, 81, 82). These processes took place primarily within the US, but

other HICs countries have also experienced similar processes (83-85). Unsurprisingly, the growth in size and influence of the food industry correlated with the expansion of obesity, diabetes, and other chronic diseases in the population (7, 13).

Therefore, powerful factors that have little to do with individual factors determine the current food environments—aptly labeled obesogenic environments—in which people choose their foods (86, 87). In these environments, healthier foods tend to cost more, and in many socioeconomically deprived areas, healthier foods may not be readily available (17, 88, 89). Today most individuals devote little time to food preparation, averaging 33 minutes per day in the US (90) and 39 minutes per day in France (91). Individuals with higher income devote more time to food preparation and cooking in the US (90). In France, while it is the more educated individuals who spend less time in food preparation, they compensate this with overall healthier food purchases and eating patterns (91). Most individuals purchase their foods in supermarkets, where evidence indicates the most advertised foods tend to be the unhealthier kinds (84, 92, 93), especially in more deprived neighborhoods (78, 88). At the same time, fast food or "junk food" chain outlets have proliferated, often strategically placing themselves in areas of greater socioeconomic disadvantage (78, 88, 94-96). Clearly, most people today simply do not live in food environments that are conducive and supportive of healthy dietary behaviors, and this is situation worsens the greater the socioeconomic deprivation of the individual.

In the midst of the prevailing obesogenic environments, nutritional epidemiologists have for quite some time known what constitutes a healthy diet—roughly, one that is rich and diverse in fruits and vegetable, whole grains, nuts and seeds, and legumes and lean meats, and has little or no amount of highly processed foods, simple sugars, processed meats, and sweetened beverages (97, 98). Yet government policies across wealthy countries continue to subsidize the sugar, meat, and dairy industries (66, 70, 99), and as public health experts argue, current global food systems place no importance in meeting the nutritional needs of the population, but rather in maximizing profits (13, 76). To counteract the epidemic of obesity and chronic diseases, current government policies emphasize personal liberty, choice, and responsibility (7, 13, 66), an approach that creates or exacerbates socioeconomic inequalities in diet and

health as more privileged individuals have greater capacity for and access to health-promoting resources (66, 100). Critically, this emphasis on personal responsibility and choice, coupled with the mass media promotion of a specific ideal body shape and size, has contributed to enormous stigmatization of obese individuals, including from the medical community (101, 102). Extensive evidence indicates that stigmatization leads to several serious and consequential mental health problems, and further exacerbates the obesity epidemic (101, 103, 104).

Thus, systemic interventions at the government level are urgently needed to transform the current obesogenic food environments so that they promote, facilitate, and sustain healthy eating behaviors. In recent years, public health experts have repeatedly called for such systemic interventions, under various policy frameworks that incorporate governments, the food industry, retailers, schools and work places, and the individual (11, 12, 66, 79, 99, 105). Such interventions call for government policies that subsidize the production of healthy foods, which would increase their availability and affordability; restrict the establishment of junk food outlets in poorer neighborhoods, and instead incentivize food markets to enter these socioeconomically deprived areas, which would eradicate food deserts and increase access to healthy foods among poorer individuals; legislate to outlaw junk food outlets within a certain distance of schools, parks and playgrounds that children frequent; restrict marketing of unhealthy foods, especially to children, which would reduce the enormous amount of advertisement in socioeconomically deprived neighborhoods; and tax unhealthy foods (11, 12, 66, 99, 106). They also call for the food industry to reformulate foods—voluntarily or mandated by law—to maximize healthy ingredients and minimize unhealthy ones, and for food retailers to increase visibility and shelf space for healthy foods, and minimize unhealthy options, all of which can facilitate healthy food choices, and reduce social inequalities in diet (10, 12, 66, 105, 106). Importantly, interventions at the school level include early education and promotion of healthy eating habits, knowledge, and skills, including serving of only healthy meals. These interventions show promise to transform current food environments and empower individuals to achieve and maintain healthy eating habits, thus reducing inequalities in healthy eating and preventing chronic disease development (11, 12, 66, 99, 105, 106). In the face of unrelenting growth of the obesity

and diabetes epidemic, the urgency of such systemic and multisectoral interventions cannot be overstated.

Future research

To better assess the association between barriers and dietary intake, several changes and additions could be introduced to existing studies. For instance, studies such as menuCH, CoLaus, or Bus Santé should incorporate questions about barriers to healthy eating, particularly since these studies include a better assessment of diet compared to the Swiss Health Survey. At the same time, the Swiss Health Survey could improve the measurement of diet and maintain consistency across surveys. Notably, we were unable to examine adherence to dietary guidelines across time because the diet-specific questions varied between surveys and could not be harmonized.

Most saliently, our mediation findings warrant a longitudinal assessment of the contribution of diet quality to socioeconomic inequalities in cardiometabolic disorders. Unfortunately, this is not possible in the menuCH sample. However, among the seven LIFEPATH cohorts included in our cross-sectional analysis, six have longitudinal data available, and we will include these in a future project. We hypothesize that the associations between socioeconomic indicators and cardiometabolic disorders, those between diet quality and cardiometabolic disorders will be stronger than those found in this thesis. Consequently, we also hypothesize that a stronger contribution of dietary quality will emerge.

To gain greater insight into the role of diet in socioeconomic inequalities in health, there is a need for studies to examine diet with a lifecourse approach. Ideally, this would involve a cohort study that, at baseline, measures the dietary quality of pregnant women and, in subsequent follow-up waves, measures the dietary quality of the child as well as the elements of the food environment. This approach would enable an examination of potential diet-related epigenetic programming in utero, early life exposures, and how these contribute to socioeconomic inequalities in health.

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