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Gender Differences in Socioeconomic Inequalities in Body Mass Index and Health-Related Mediators

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Abstract:

Introduction: Socioeconomic differences in body mass index (BMI) are well established, but less is known about gender differences in them, and about the behavioral pathways underlying these inequalities. This thesis examined gender differences in the association between socioeconomic position (SEP) and BMI, and whether dietary factors and physical activity mediated this association similarly in both women and men.

Methods: Survey data from the employees of the City of Helsinki aged 19–39 collected in 2017 (n = 4,400, 80% women) were used in the main analysis, with follow-up data from 2022 (n = 2,581). SEP was measured by highest educational attainment, and the examined mediators were consumption of fruit and vegetables, red and processed meat, sweets and confectionery and alcohol as well as leisure-time vigorous physical activity (VPA) and sedentary time. Gender-specific multiple mediation analyses using structural equation modeling were conducted, both cross-sectionally and longitudinally.

Results: Mean BMI was highest among those with low education and lowest among those with high education, ranging from 26.4 to 24.0 kg/m² in women and from 26.6 to 25.2 kg/m² in men. Lower SEP was associated with a lower consumption of fruit and vegetables, a higher consumption of red and processed meat and lower VPA in both genders. Compared to men, women consumed more fruit and vegetables and sweets, but less red and processed meat and alcohol, as well as engaged in less VPA. The strongest SEP–BMI mediator among women was VPA (indirect effect: 0.35, 95% confidence interval (CI) 0.26, 0.44), meaning that differences in VPA accounted for 0.35 kg/m² of the BMI difference between women with low and high education. Other significant mediators in women were fruit and vegetable (0.15, 95% CI 0.08, 0.23) and red and processed meat consumption (0.06, 95% CI 0.02, 0.11). Among men, significant mediators were red and processed meat consumption (0.12, 95% CI 0.03, 0.23), sedentary time (0.11, 95% CI 0.01, 0.24), and VPA (0.10, 95% CI 0.02, 0.21). The longitudinal model showed that follow-up BMI was largely explained by prior BMI rather than by subsequent BMI change explained by the mediators.

Conclusions: Socioeconomic inequalities in BMI were stronger among women and were partly explained by different behavioral pathways in women and men, suggesting that gender-specific approaches may be beneficial in reducing weight-related inequalities. However, since only part of the SEP–BMI association was explained by the examined mediators, more research is needed on the psychological, social, and environmental factors that are likely to play an important role in maintaining weight-related inequalities.

Tiivistelmä:

Johdanto: Sosioekonomiset erot painoindeksissä (BMI) tunnetaan hyvin, mutta vähemmän tiedetään yhteyden sukupuolieroista ja tekijöistä, jotka selittävät sosioekonomisen aseman (SEP) ja painon yhteyttä. Tutkielmassa tarkasteltiin sukupuolieroja SEP:n ja BMI:n välisessä yhteydessä sekä sitä, välittävätkö ruokavaliotekijät ja fyysinen aktiivisuus yhteyttä samalla tavoin naisilla ja miehillä.

Menetelmät: Tutkielmassa käytettiin Helsingin kaupungin työntekijöiltä (19–39 v.) kerättyä kyselyaineistoa vuodelta 2017 (n = 4400, 80 % naisia) sekä vuonna 2022 toteutettua seurantakyselyä lisäanalyyseissa (n = 2581). Sosioekonomista asemaa mitattiin korkeimmalla koulutustasolla, ja välittävinä tekijöinä tarkasteltiin hedelmien ja kasvisten, punaisen ja prosessoidun lihan, makeisten ja leivonnaisten ja alkoholin käyttöä sekä vapaa-ajan rasittavaa fyysistä aktiivisuutta (VPA) ja istumisaikaa. Menetelmänä käytettiin sukupuolittain eroteltua rakenneyhtälömallinnusta (SEM) sekä poikkileikkausasetelmassa että pitkittäisasetelmassa.

Tulokset: Keskimääräinen BMI oli korkeampi vastaajilla, joilla on matala koulutus verrattuna vastaajiin, joilla on korkea koulutus (naisilla 26,4 kg/m² verrattuna 24,0 kg/m²:iin ja miehillä 26,6 kg/m² verrattuna 25,2 kg/m²:iin). Matalampi SEP oli yhteydessä pienempään hedelmien ja kasvisten käyttöön, suurempaan punaisen ja prosessoidun lihan käyttöön sekä pienempään VPA:han molemmilla sukupuolilla. Miehiin verrattuna naiset käyttivät enemmän hedelmiä ja kasviksia sekä makeisia, sekä vähemmän punaista ja prosessoitua lihaa ja alkoholia, ja heidän VPA:nsa oli pienempää. Naisilla vahvin SEP:n ja BMI:n yhteyden välittäjä oli VPA (epäsuora vaikutus: 0,35, 95 %:n luottamusväli (LV) 0,26–0,44). Tämä tarkoittaa, että koulutusryhmien väliset erot VPA:ssa selittivät 0,35 kg/m² BMI-erosta matalimmin ja korkeimmin koulutettujen naisten välillä. Naisilla tilastollisesti merkitseviä välittäjiä olivat lisäksi hedelmien ja kasvisten käyttö (0,15, 95 % LV 0,08–0,23) sekä punaisen ja prosessoidun lihan käyttö (0,06, 95 % LV 0,02–0,11). Miehillä tilastollisesti merkitseviä välittäjiä olivat punaisen ja prosessoidun lihan käyttö (0,12, 95 % LV 0,03–0,23), istumisaika (0,11, 95 % LV 0,01–0,24) ja VPA (0,10, 95 % LV 0,02–0,21). Pitkittäisasetelma osoitti, että seurannan korkeampi BMI selittyi aiemmalla BMI:llä eikä välittäjien selittämällä BMI:n muutoksella.

Johtopäätökset: Sosioekonomiset erot BMI:ssä näyttävät olevan voimakkaampia naisilla, ja eroja muovaavat osittain erilaiset mekanismit sukupuolten välillä. Siispä sukupuolen huomioivat lähestymistavat voivat olla hyödyllisiä sosioekonomisten terveyserojen kaventamisessa. Koska tarkastellut tekijät selittivät vain osan SEP:n ja BMI:n yhteydestä, jatkossa on tärkeä tutkia sitä, mikä merkitys psyykkisillä, sosiaalisilla ja ympäristöön liittyvillä tekijöillä on painoon liittyvien sosioekonomisten erojen ylläpitämisessä.

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This master's thesis is part of the Helsinki Health Study, which examines the health and well-being of employees of the City of Helsinki. I was not involved in data collection but worked with the pseudonymized data. I was responsible for data cleaning and variable construction for the variables used for the purposes of this thesis. I also searched the literature, identified the research gap, and formulated the research questions. In addition, I designed and conducted all statistical analyses according to the research questions and was responsible for tabulating, reporting, and interpreting the results. My supervisors helped with the selection of the main analytical approach, helped to interpret the results and commented on the manuscript. I want to express my gratitude to my supervisors, Tea Lallukka and Morris Viitanen. I want to also thank Lari Järvensivu and Ossi Rahkonen from the research group for their advice and encouraging support. I want to also thank the City of Helsinki, Finland, and all participating employees. This master's thesis will be used as the basis for a scientific article intended for publication.

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List of abbreviations

CI = confidence interval

BMI = body mass index

M = men

MET = metabolic equivalent

MICE = multiple imputation by chained equations

SD = standard deviation

SEP = socioeconomic position

VPA = vigorous physical activity

W = women

1 Introduction

Overweight and obesity are rising globally and in Finland, and in high-income countries, higher body weights are increasingly concentrated in lower socioeconomic groups [1]. According to the World Health Organization, in 2022 the global prevalence of overweight and obesity among adults aged 18 years and older was 43% and 16%, respectively [2]. In Finland, the prevalence of obesity has increased substantially between 2000 and 2023, rising from 21% to 30% among men and from 22% to 30% among women, with the most pronounced increases seen among adults aged 30–44 years [3]. However, recent trends suggest that in high-income countries, such as Finland, the rise in obesity is plateauing for instance, due to better affordability of healthier foods compared to low- and middle-income countries [4].

Socioeconomic position (SEP) refers to social and economic differences within society that arise from educational, occupational, economic, and cultural resources [5]. Education is a widely used indicator of SEP because it is established relatively early in adulthood and captures resources that may shape health knowledge, working conditions, material circumstances, and health-related behaviors [6]. In high-income countries, body mass index (BMI) generally shows an inverse socioeconomic gradient, although the strength of this association differs by gender [7]. Previous studies have often reported stronger and more consistent inverse associations between SEP and obesity among women than among men [8,9]. This pattern was already identified in the Finnish population in the 20th century [10] and has since been replicated in later national and international studies [8,11].

Dietary behaviors are among the most plausible mediators linking SEP to later BMI. Lower SEP is linked to consuming fewer fruit and vegetables, and more red and processed meats [12,13]. Fruit and vegetable consumption can support weight regulation through lower energy density, higher fiber content and greater satiety, and previous research suggests a higher consumption is associated with reduced obesity [14]. By contrast, red and processed meats are often energy dense and embedded in dietary patterns associated with greater adiposity but have also been independently

associated with weight gain [15]. Sweets and confectionery are plausible mediators, although the strongest evidence linking sugar to obesity concerns sugar-sweetened beverages [16]. Alcohol should also be considered, since it can contribute to excess energy intake directly or indirectly by weakening dietary restraint [17]. However, no clear socioeconomic differences have been observed in sweets and confectionery or alcohol consumption, although the gender pattern suggests that women consume more sweets, whereas men consume more alcohol [12].

In addition to diet including alcohol consumption, moderate-to-vigorous physical activity as well as sedentary time are potential mediators since they are socioeconomically patterned and consistently linked to weight management [18–20]. However, the evidence is unclear whether increased sedentary time leads to increased BMI or whether the associations are due to reverse causation [21–23]. Physical activity and less sedentary time may influence body weight not only through energy expenditure but also through improved appetite regulation and satiety signaling [24]. Physical activity is socially patterned, but these patterns vary by domain and intensity: higher socioeconomic groups tend to be more active during leisure time and to accumulate more high-intensity physical activity, whereas lower socioeconomic groups tend to accumulate more occupational and light-intensity physical activity [19,20,25]. Socioeconomic differences in sedentary time vary by domain, with higher SEP groups tending to report more occupational sitting, while lower SEP groups tend to report more leisure-time sitting [26].

Despite extensive research on socioeconomic differences in obesity, gender interactions in the associations are less explored. The mechanisms through which SEP contributes to the development of obesity, and whether these mechanisms differ by gender, remain insufficiently understood. I hypothesize that lower SEP is linked to a higher BMI partly through dietary factors and physical activity and that the absolute effects of the mediators are larger among women because the SEP–obesity gradient is steeper in women. In this thesis, I first examined gender differences in the association between SEP and BMI. Second, I examined whether dietary factors and physical activity mediate this association similarly in men and women.

2 Review of the literature

2.1 Definition of terms

2.1.1 Socioeconomic position

Socioeconomic inequalities can be described with terms such as social class, social stratification, socioeconomic conditions, socioeconomic status or socioeconomic position (SEP). All of these are used to describe and measure differences within society that arise from economic, occupational, and cultural factors [5]. SEP includes both resource-based and prestige-based aspects: resource-based measures capture access to material and social resources, whereas prestige-based measures reflect social standing and the respect attached to a person's social position [27]. Because SEP cannot be measured directly, it is typically assessed through indicators that represent different aspects of social advantage and disadvantage. These indicators can be measured on the individual, household, or neighborhood level, and the most appropriate choice depends on the study population, the health outcome of interest, and the life stage under consideration [5,6].

Education is one of the most used indicators of SEP. It reflects knowledge, cognitive resources, and attitudes that may influence how individuals understand and use health information [6,28]. Education is relatively stable after young adulthood, easy to measure, and subject to little misclassification, which makes it useful in epidemiological research [27]. At the same time, it has limitations: it does not capture short-term changes in socioeconomic circumstances and may be less sensitive than income in reflecting material deprivation. Nevertheless, because it precedes many later-life socioeconomic outcomes, such as occupation and income, it is often considered an important upstream indicator of social inequalities in health [28].

In addition to education, the most commonly used indicators of SEP are income and occupation [5]. Income is the SEP indicator that most directly reflects material resources. It influences access to healthier foods, health care, housing, recreational opportunities, and other health-promoting conditions [5]. Income can be measured at the individual, household, or area level, but it may be difficult to collect accurately

because it is a sensitive topic and may fluctuate considerably over time [27,28]. Occupational status reflects employment-related resources, social standing, skill level, and working conditions, and is therefore linked to both material and prestige-based dimensions of SEP [6,27]. Occupation may also influence health through psychosocial pathways, such as job control, work demands, and exposure to physically or mentally strenuous conditions. However, occupational status excludes individuals outside the workforce, such as students, unemployed persons, retirees, or those on parental leave [27].

In addition to education, income, and occupation, other indicators capture different aspects of SEP. These include housing conditions, area-level deprivation, unemployment status, and subjective measures such as perceived social status or income adequacy [5,6]. Since SEP is multidimensional, no single indicator can fully represent it, and different indicators may be more relevant depending on the outcome of interest and the stage of the life course under consideration [5]. Although SEP indicators are correlated, they are not interchangeable, because each captures a distinct dimension of social inequality [6]. In this thesis, SEP is measured by highest educational attainment, as it is established early in adulthood, strongly associated with health behaviors, remains stable over time, and is less influenced by short-term changes in employment or income than other SEP indicators [27].

2.1.2 Gender

The term “gender” refers to socially determined characteristics of women and men shaped by psychosocial and cultural factors, whereas “sex” refers to biological differences based on anatomy, physiology, and reproductive biology [29]. Sex is typically used when discussing health from a biological standpoint, while gender is more appropriate when examining differences that arise from socially constructed roles, behaviors, and personal identities associated with being a man or a woman. Health behaviors are determined, in addition to biological needs, by broader factors such as norms related to body image and food preferences as well as the social meanings of food [30]. Because gender was obtained from survey responses or national registers, and because dietary choices, physical activity, and weight-related factors are strongly shaped

by social and cultural contexts, gender was considered the more appropriate term for this thesis.

2.1.3 Health behaviors

Health behaviors refer to actions and habits related to health maintenance, health restoration, and health improvement [31]. They include both health-enhancing and health-compromising behaviors. Commonly studied health behaviors include overall diet, individual dietary components, physical activity, smoking, alcohol consumption, and sedentary time. In this thesis, dietary factors, including consumption of fruit and vegetables, red and processed meats, sweets and confectionery and alcohol, and physical activity, including vigorous physical activity (VPA) and sedentary time, are the health behaviors investigated.

Health behavior patterns have changed substantially over time in high-income countries. Nutrition transition describes long-term shifts in diet and physical activity alongside economic development, urbanization, and demographic change [32]. Traditional diets high in cereals and fiber have increasingly been replaced by more Western dietary patterns rich in sugars, fats, and animal-source foods, while physically active lifestyles have become more sedentary. At the same time, in high-income countries, improved food availability and opportunities for exercise also provide greater possibilities for healthier and more sustainable lifestyles.

2.1.3.1 Recommended health behaviors

Health behavior recommendations are intended to translate scientific evidence into practical guidance for the public and health policy. Dietary guidelines summarize evidence on the relationships between foods, dietary patterns, and health, while also considering cultural context and feasibility [33]. In Finland, the most recent dietary guidelines were published in 2024 and integrate both health and environmental perspectives [34]. Similarly, Finnish physical activity recommendations, published in 2019, are based on international scientific evidence and emphasize not only moderate and vigorous activity but also light movement, breaking up sedentary time, and adequate sleep [35,36]. The following section describes the Finnish recommendations

related to each health behavior examined in this thesis, including their relevance to common chronic diseases [37].

Fruit and vegetable consumption

The Finnish recommendation is to consume vegetables, berries, and fruit in a varied way at least 500–800 g per day, with roughly half coming from vegetables and root vegetables and the other half from berries and fruit [37]. Fruit and vegetables should be eaten in different forms, including fresh, cooked, and as part of meals, while salted or sweetened products are not recommended. According to the recommendations, high intake is associated with a lower risk of several cancers, cardiovascular disease, and mortality [37].

Red and processed meat consumption

The recommendation for red meat is to consume no more than 350 g of cooked beef, pork, or lamb per week, corresponding to about 500 g of raw meat, and to keep processed red meat consumption as low as possible [37]. According to the recommendations, both unprocessed and processed red meat are identified as risk factors for colorectal cancer, and high consumption has also been linked to a higher risk of cardiovascular disease [37].

Sweets and confectionery consumption

For sweets and confectionery, there is no specific gram-based recommendation, but the guidelines state that foods high in free sugars should be consumed as little as possible and the proportion of energy coming from free sugars should be less than 10% of total energy [37]. A high consumption of these foods is associated with poorer overall diet quality and lower nutrient density. According to the recommendations, sugar-sweetened beverages have been linked to the risk of obesity and type 2 diabetes [37].

Alcohol consumption

The Finnish recommendation is that alcohol is not recommended, because no safe limit of use can be established [37]. If alcohol is consumed, the amount should be as small as possible. Children, adolescents, pregnant and breastfeeding women, and older adults are advised not to consume alcohol at all. According to the recommendations, alcohol

consumption has been linked to several cancers, especially breast cancer and cancers of the digestive tract, and long-term heavy use may lead to liver cirrhosis and increased mortality [37].

Physical activity

According to the Finnish national physical activity guidelines for adults aged 18–64 years, the recommendation is at least 2 hours and 30 minutes of moderate-intensity aerobic activity per week, or 1 hour and 15 minutes of vigorous-intensity activity, or an equivalent combination of both together with muscle-strengthening exercise at least twice a week [36]. Moderate intensity refers to any movement that elevates heart rate, such as brisk walking, swimming, or dancing. Vigorous intensity refers to more intense forms of physical activity, such as running, cycling, or skiing. In addition to structured exercise, the guidelines emphasize light everyday movement, such as walking, active breaks, and physically active daily tasks. Physical activity is associated with improvements in a wide array of health outcomes such as better cardiovascular, metabolic and mental health [36].

Sedentary time

According to the guidance of the Ministry of Social Affairs and Health, sedentary time should be minimized (Ministry of Social Affairs and Health, 2015). This is also emphasized in the Finnish national physical activity guidelines for adults [36]. Both guidelines stress the importance of avoiding long uninterrupted periods of sitting, breaking them up regularly, and replacing sitting with light movement whenever possible. Practical recommendations include walking or cycling for short distances, using stairs instead of elevators, varying working postures, standing during routine tasks, and getting up regularly from the sofa or desk. Although neither guideline gives a specific daily limit for sitting among working-age adults, the Ministry of Social Affairs and Health notes that sitting for more than seven hours per day is associated with a higher mortality risk [38].

2.1.3.2 Measuring health behaviors

Health behaviors can be measured using either subjective or objective methods [39]. Subjective methods rely on self-reported questionnaires, recalls, or diaries, whereas objective methods use devices or direct measurements to record behavior. The choice of the method depends on the research question, the level of precision required, and the size and feasibility of the study. Subjective measures are often practical and cost-effective in large epidemiological studies, although they are affected by recall bias and misreporting; objective measures may provide more precise estimates for certain behaviors, but they are often more expensive, burdensome, and less able to capture behavioral context [39].

The concept of diet quality is widely used in scientific literature to describe the extent to which an individual's diet aligns with dietary recommendations, although there is no single agreed definition or universally accepted indicator [40]. Various dietary indices have been developed to capture different dimensions of diet quality, but individual food groups, such as fruit and vegetable consumption, are also commonly used as indicators of healthy eating patterns [40]. Dietary behavior can be measured in several ways, including food records, 24-hour dietary recalls, and food frequency questionnaires (FFQs) [41]. Dietary intake may be examined at the level of nutrients, foods, food groups, or broader dietary patterns. For assessing habitual or longer-term dietary behaviors in population studies, FFQs that measure dietary habits on a food or food-group level are especially useful [39].

Physical activity and sedentary time can likewise be measured using both objective and subjective approaches [42]. Objective methods include device-based tools such as accelerometers and heart-rate monitors, whereas subjective methods include self-reported questionnaires and activity diaries. Self-reported measures are practical and inexpensive and can provide information on the type, context, frequency, and setting of activity, but they depend on participants' recall and are therefore subject to bias. Device-based methods are better suited to capturing movement patterns and activity intensity, but they are often more costly and less feasible in large population studies [42]. In some settings, combining different methods may provide the most comprehensive picture. In

this thesis, health behaviors were measured using questionnaire data: dietary factors were assessed using a food-group-level FFQ, and physical activity was assessed using questionnaire items covering both activity type and intensity. This approach was appropriate because the focus is on associations and patterns rather than on precise estimates of dietary intake or activity levels.

2.1.4 Body weight

Body weight refers to an individual's mass and is commonly expressed in kilograms or pounds. It is influenced by a wide range of factors, some of which are beyond individual control and others potentially modifiable [43]. Obesity has traditionally been described as a chronic imbalance between energy intake and energy expenditure. Although this is true from a physiological perspective, it ignores the complex drivers that influence both energy intake and expenditure. Body weight regulation is governed by complex interactions between metabolic, endocrine, and neural systems [44]. The brain integrates internal signals related to energy needs with external environmental cues. Adipose tissue functions as an active endocrine organ that secretes hormones such as leptin, which are involved in appetite regulation, energy expenditure, and metabolic processes.

Genetic factors are estimated to account for about 30–70% of the variation in obesity [45]. Individuals differ considerably in how their body weight and body fat respond to changes in energy balance. However, much of this genetic susceptibility is thought to operate through behaviors such as dietary intake and physical activity, as genetic variation influences appetite regulation and food and activity preferences. At the same time, these behaviors are shaped by social and environmental conditions. The widespread availability of energy-dense foods and other features of the modern environment can interact with the intrinsic mechanisms and support positive energy balance and the development of obesity [46]. Obesity should therefore be viewed as a multifactorial condition in which health behaviors are shaped by genetic susceptibility as well as social and environmental influences.

2.1.4.1 Measuring body weight

Monitoring changes in body weight over time is important in both clinical and public health contexts: in pediatric populations to ensure appropriate growth and development, and in adults to assess disease risk. Body size can be assessed using various anthropometric measurements, including height, weight, and different circumferences such as head, waist, hip, and arm [47]. To facilitate interpretation, indices such as the body mass index (BMI) are calculated. BMI is a height-adjusted measure of body mass that is widely used in population studies to classify individuals according to relative weight status and to estimate adiposity, primarily because it is simple to calculate and easily standardized across large samples [48]. It is calculated as body weight in kilograms divided by height in meters squared. In adults, BMI cut-off values for underweight (<18.5 kg/m²), overweight (≥25 kg/m²), and obesity (≥30 kg/m²) are based on associations with adverse health outcomes and increased mortality risk [45].

Although BMI is currently the most widely used indicator for defining underweight, overweight, and obesity in both adults and children, additional measures such as waist circumference are also used, as the accumulation of abdominal visceral fat is associated with a higher cardiometabolic risk than overall excess body fat alone [49]. Additional measures are important since BMI has limitations as an indicator of body fatness. It does not distinguish between fat mass and lean mass, nor does it provide information about the distribution of adipose tissue, both of which are relevant for disease risk [48]. Moreover, lean mass varies considerably among individuals of the same height, and the validity of BMI changes with age due to age-related losses of muscle mass in some older adults.

BMI is frequently obtained through self-reported height and weight in epidemiological studies because of its practicality, particularly in large-scale surveys. However, this approach introduces the potential for reporting bias. Evidence suggests that women tend to underreport their weight, whereas men often overreport their height [50]. It has also limited sensitivity for detecting excess body fat. A meta-analysis demonstrated that while a high BMI correctly identifies many individuals with obesity, approximately half

of those with elevated body fat percentage may be misclassified as non-obese when BMI is used as the only measurement [51]. Despite these limitations, BMI performs reasonably well as an indicator of absolute fat mass in young and middle-aged adults, and the agreement between self-reported and measured height and weight is generally good [52,53]. BMI derived from self-reported weight and height is generally considered sufficiently accurate for epidemiological research and is widely used as an estimate for body weight. Therefore, BMI, calculated from self-reported height and weight, will be used as the estimate of weight in this thesis.

2.1.4.2 Health behaviors and body weight

Body weight changes naturally across the life course. In adulthood further weight gain is no longer part of normal development and may have adverse health consequences, including higher all-cause and cardiovascular mortality [54]. However, weight gain during adulthood is common, and approximately two thirds of adult obesity begin after adolescence [45]. Therefore, preventing further weight gain and promoting weight reduction are important public health goals as even modest weight loss of 5% can substantially reduce disease risk. The effects of individual components are generally small, but influencing several factors simultaneously may have great potential to affect long-term weight development. In this section, I will describe how each health behavior examined in this thesis is associated with weight.

<u>Fruit and vegetable consumption and body weight</u>

Adequate consumption of fruit and vegetables is associated with less weight gain, which may be due to their low energy density and high fiber and micronutrient content [16]. Fruit and vegetable consumption can also be an indicator of an overall healthy diet, which makes causal interpretation more difficult. An umbrella review including data from over 166 thousand participants, found that high consumption of fruit, vegetables and legumes was associated with a reduced risk of overweight and obesity [14]. Another review found that a higher consumption of vegetables and fruit was linked to a lower risk of weight gain [16].

Red and processed meat consumption and body weight

Meat consumption has been positively associated with weight gain, although the effect sizes are relatively small. Meats, especially processed meats, are high in energy and fat content, and high meat consumption can be an indicator of an overall unhealthy dietary pattern. One added serving of processed meat per day has been associated with a 0.26 kg increase in weight and 0.14 cm increase in waist circumference per year [15]. In a large European cohort including almost 400 thousand participants total meat, including processed meats, red meats and poultry, was associated with weight gain in men and women and in those with normal weight and overweight [55]. The researchers calculated that an increase in meat consumption of 250 grams per day would lead to a 2 kg higher weight gain in 5 years. When looking at different meats separately, there seems to be evidence for increased risk for weight gain only with red and processed meats [14,16].

Sweets and confectionery consumption and body weight

Sugary foods, such as sweets and confectionery, are associated with weight gain, although the most consistent associations have been observed for sugar-sweetened beverages [14,16]. These may increase the risk of obesity due to their high energy content and low satiety effect due to liquid form [56]. However, refined grains, sweets, and desserts are also associated with greater weight gain [16,57]. Across carbohydrate-containing foods, the source matters: carbohydrates coming from whole grains, fruit, and non-starchy vegetables have been linked to less weight gain, while carbohydrates from refined grains have been linked to greater weight gain [58]. High consumption of sweets and confectionery may also increase the energy density of the diet, which has been associated with obesity [59].

Alcohol consumption and body weight

Alcohol consumption, especially heavy drinking, has been linked to weight gain, but the evidence between moderate consumption and weight gain is inconclusive. A meta-analysis of 127 studies found that alcohol consumption, especially heavy drinking, was associated with higher odds of overweight, obesity, and abdominal obesity in cross-sectional studies [60]. However, a systematic review of 31 studies found inconsistent

evidence across both cross-sectional and prospective studies, with positive associations mainly observed in studies examining higher levels of alcohol consumption [17]. Light-to-moderate consumption, particularly wine, was less strongly associated with weight gain or even protective, whereas spirits were linked to greater weight gain. Alcohol may influence weight gain directly through contributing to total energy intake or indirectly by weakening dietary restraint. A review suggested that adults do not compensate appropriately for alcohol energy by eating less, which may indirectly result in weight gain [61].

Physical activity and body weight

Physical activity is widely recognized as beneficial for not only weight-related outcomes but also for its beneficial effects on cardiovascular, metabolic, musculoskeletal, and mental health [36]. Physical activity may facilitate weight regulation by increasing energy expenditure and contributing to better satiety signaling [24]. In a systematic review of 40 studies, the authors found strong evidence of physical activity being associated with prevention of weight gain in adults [18]. There was evidence of a dose-response relationship and the prevention of weight gain when moderate-to-vigorous intensity physical activity was above 150 minutes per week, but this relationship could not be determined for light-intensity activity. For those with overweight or obesity, a systematic review suggested that exercise alone has only modest effects on body weight, but clearer benefits for body fat, visceral fat, and body composition [62,63].

Sedentary time and body weight

Sedentary time is increasingly recognized as a distinct behavioral factor relevant to body weight regulation, rather than simply the absence of physical activity. It may contribute to weight gain by lowering daily energy expenditure and by clustering with other obesogenic behaviors [24]. At the same time, sedentary time and physical inactivity are closely related, which makes their independent effects difficult to separate. Review evidence suggests that sedentary time is positively associated with both general and abdominal obesity, but the direction of this relationship remains unclear [21–23]. Reverse causation is possible, meaning that a higher body weight leads to a more sedentary lifestyle. The overall evidence in adults seems only weakly supportive of an

association between sedentary time and obesity, and the studies reporting significant associations have generally found small effect sizes [22]. In contrast, the obesogenic role of sedentary time appears to be more clearly established in children and adolescents [64].

2.2 Socioeconomic and gender differences in health behaviors

2.2.1 Socioeconomic differences in health behaviors

Socioeconomic differences in health behaviors are well established: individuals in more disadvantaged positions tend to have poorer dietary patterns and engage in less physical activity. The differences arise from a myriad of factors, including but not limited to material resources, knowledge and motivation as well as social and physical environment [46]. Social norms around food and activity, shaped by peers, family practices, and local culture, vary and may normalize different eating patterns and activity habits across socioeconomic groups. Socioeconomic disadvantage often accumulates, with economic hardship, poorer neighborhood conditions, limited access to healthy options, and adverse living circumstances reinforcing one another over time [65]. For this reason, reducing socioeconomic differences in health behaviors requires not only individual behavior change but also structural action, such as food pricing policies, subsidies for healthier foods, regulation of food marketing, and environments that better support healthy everyday choices [66]. Next, I will give an overview of the socioeconomic patterning of each health behavior examined in this thesis.

Fruit and vegetable consumption

Fruit and vegetable consumption follows a clear socioeconomic gradient in high-income countries, with those in the highest SEP consuming more of them. Individuals with higher educational attainment tend to consume more fruit and vegetables compared to those with lower education, both in Finland and in other high-income countries [12,67]. Similar findings have been reported in an earlier meta-analysis, which showed that in Europe, higher socioeconomic status was associated with a greater consumption of both fruit and vegetables regardless of whether education or occupation was used as the SEP

indicator [13]. A systematic review also found clear socioeconomic differences in fruit and vegetable consumption among European adults, with particularly clear differences for vegetables [68]. Examining income and education together adds nuance: a Finnish study reported that individuals with low education, but high-income consumed more fruit and vegetables than highly educated individuals with low income [69].

Red and processed meat consumption

Lower SEP is generally associated with a higher consumption of red and processed meat. A review found that in high-income countries, individuals with lower education consumed more red and processed meats than those with higher education [67], which is also seen in Finnish studies [12]. Similarly, lower-SEP groups tend to consume more refined and energy-dense foods, including processed meat [12]. However, not all findings are fully linear. Among US adults, participants in both the lowest and highest SEP categories have reported to have better adherence to red and processed meat recommendations than those in middle-income groups [66]. Combining red and processed meat into a single category may obscure relevant differences, as consumption patterns could vary by SEP. For example, individuals with lower SEP may consume proportionally more processed meats because they are often cheaper, whereas individuals with higher SEP may consume more high-quality meat products [67].

Sweets and confectionery consumption

There is less evidence of the socioeconomic patterning of sweets and confectionery consumption compared to that of fruit and vegetables or red and processed meat, although it leans towards a higher consumption among those with higher SEP. In the Finnish national diet survey, both women and men with higher education reported higher consumption of sweets and confectionery than those with lower educational attainment [12]. In a review concerning high-income countries, higher socioeconomic groups consumed more candy and pastries whereas lower socioeconomic groups consumed more sugar and cake [70]. Other authors note that not all dietary outcomes show clear socioeconomic gradients, and findings for some sugary products, such as sugar-sweetened beverages, are modest, mixed, or country-specific [67].

Alcohol consumption

Alcohol appears to be commonly consumed across all socioeconomic groups, but beverage types differ by SEP. Some studies suggest that in high-income countries lower-SEP groups tend to prefer beer, whereas higher-SEP groups are more likely to consume wine [70]. Finnish data show that women with higher education report higher alcohol consumption than women with lower education, whereas among men, socioeconomic differences in total alcohol consumption are less clear [12]. In another Finnish study, socioeconomic differences in the average amount of alcohol consumed were small, but drinking patterns differed by SEP: binge drinking was more common among individuals with lower SEP, whereas frequent drinking was more common among those with higher SEP [71]. Therefore, the small differences in total alcohol consumption can be explained by differences in beverage choices and drinking patterns across SEP.

Physical activity

The socioeconomic differences in physical activity are particularly evident in leisure-time sports and exercise participation [25]. Nearly half of European adults report no participation in sports or exercise with participation being strongly associated with SEP [72]. On the other hand, those with lower SEP accumulate more occupational and light-intensity physical activity. Therefore, total physical activity may obscure important socioeconomic differences in type, intensity, and context. The trends are similar in Finland with people with the lowest SEP having less leisure-time and commuting physical activity compared to those with higher SEP [19,73].

Sedentary time

The socioeconomic patterning of sedentary time seems inconsistent since differences vary by domain, with higher SEP groups reporting more occupational sitting, and lower SEP groups more leisure-time sitting in Europe [26]. Finnish evidence is similar: SEP is associated with total sedentary time, and these differences are largest during working hours, where higher education and income are associated with more sedentary time [20]. This likely reflects the nature of the different occupations in those with higher and lower SEP. In contrast, lower SEP is associated with more sedentary time at home in front of a television or computer and in vehicles [20]. However, individuals with higher SEP, although having a lot of sedentary time, often report higher levels of physical

activity, highlighting that high sedentary time should not be interpreted as indicative of an overall inactive lifestyle [19,73].

2.2.2 Gender differences in health behaviors

There are clear gender differences in health behaviors, in both diet quality and physical activity patterns. In high-income countries, men generally have poorer dietary quality and show less engagement in health-related behaviors than women [12,74–77]. Gender differences in health behaviors arise mainly from social, psychological, and cultural factors, even though biological influences may also play a role [78]. Women generally show greater interest in health, nutrition, and preventive behaviors, and are more likely to perceive foods recommended in dietary guidelines as beneficial for health [79]. Differences in body image and eating behavior may also contribute: women are more likely to engage in dieting, restrictive eating, and emotionally driven eating, whereas men often describe their relationship with food as more straightforward and guided by pleasure or functionality [80,81]. In many Western societies, foods such as salads, fruit, and vegetables are often associated with femininity, whereas red meat, alcohol, and energy-dense meals are more commonly linked to masculinity [30]. Also, food choice motives differ between genders: women more often emphasize health, freshness, price, and family preferences, while men more often identify taste as the main determinant of food choice [82]. Next, I will give an overview of the gender differences in each health behavior examined in this thesis.

Fruit and vegetable consumption

Women generally consume more fruit and vegetables than men, a pattern that has been consistently observed in high-income countries and is also evident in Finland [11,12,74,77]. Gender differences are also observed in attitudes toward preferences for plant-based foods [83]. Across Western societies, women are approximately twice as likely as men to identify as vegetarian or vegan [84].

Red and processed meat consumption

Men generally consume more red and processed meat than women. The Finnish national diet survey showed that women consumed less red and processed meat than

men, and similar patterns have been reported in other high-income countries [11,74,75,77]. Meat consumption is also culturally associated with masculinity, and men tend to report more favorable attitudes toward meat than women [83].

Sweets and confectionery consumption

In Finland, women report higher consumption of sweets and confectionery than men after adjustment for total energy intake, despite having better overall diet quality. The Finnish national diet survey showed that women had a higher energy-adjusted consumption of sugary treats and a higher proportion of total energy from added sugars [12]. However, findings from other countries appear less consistent [74,75,77]. Women also report cravings for sugary foods more often than men and are more likely to report guilt after consuming them [79]. One additional explanation for this gender difference is that emotional eating is more common among women [80].

Alcohol consumption

Men generally consume more alcohol than women. The Finnish national diet survey showed that men had higher absolute alcohol consumption and a higher proportion of total energy intake from alcohol than women [12]. Similar patterns have been observed in several high-income countries, where men tend to consume more alcoholic beverages, including beer, wine and spirits, whereas women generally report lower alcohol consumption [77,79]. There are also differences in drinking patterns, with men traditionally reporting more binge drinking. However, this gender difference seems to have declined, and women report more binge drinking than before [85].

Physical activity

Gender differences in physical activity vary by activity type and intensity. In Europe, men are more likely than women to meet physical activity guidelines, and this overall gender gap has been relatively stable between 2005 and 2022 [86]. Men seem to participate in sport and exercise more often than women, whereas no consistent gender differences are observed for walking. Another study showed that women, middle-aged and older adults, and unemployed persons were less likely to participate in sports and exercise, indicating that gender differences in physical activity may intersect with socioeconomic circumstances [72]. Finnish studies similarly suggest that boys and men

continue to engage in physical activity more actively than girls and women, although the form of participation differs: men are more active in sport clubs, whereas women more often use private sports and fitness services [87].

Sedentary time

Evidence on gender differences in sedentary time is mixed, and differences appear to depend more on the type of sedentary time than on total sedentary time. In Finnish studies, total sedentary time has been broadly similar among women and men [19,20]. Similarly, previous evidence has shown that gender differences are more apparent in specific sedentary domains than in total sitting time: boys and young men tend to report more video and computer game use, whereas girls and young women report more leisure-time reading [88]. European evidence suggests that women may be less likely than men to sit for more than 7.5 hours per day, although other studies have reported inconsistent findings, with some showing no gender differences in general sitting behaviors [89]. A large US population study found that men reported slightly more sedentary time than women [90].

2.3 Socioeconomic and gender differences in obesity

2.3.1 Socioeconomic differences in obesity

In high-income countries, there is a negative association between SEP and obesity, meaning that individuals with lower SEP have higher body weights and those with higher SEP have lower body weights [9]. Although the thesis focuses on Finland, it is important to highlight the broader global pattern. Since the 1980s, studies have consistently shown a socioeconomic gradient in obesity whereby obesity is more common among higher socioeconomic groups in low-income countries but less common among higher socioeconomic groups in high-income countries [9,91]. Thus, as national wealth increases, the burden of obesity tends to shift toward socioeconomically disadvantaged populations. Consequently, when moving from high- to medium- to low-income countries, positive associations between SEP and obesity increase, while negative associations become less common [9,92,93]. Recent trends suggest that in

high-income countries, the rise in obesity is plateauing for instance, due to better affordability of different foods compared to low- and middle-income countries [4].

Finland, being a high-income country, follows the global pattern in which higher SEP is associated with lower body weight. This pattern was already identified in the Finnish population in the 20th century [10] and has since been replicated in later studies [11]. In Finland, BMI has increased among men and women across all educational and income groups, but the most pronounced increases are seen among adults aged 30–44 years [3]. In a recent 22-year follow-up study, BMI was found to increase across all educational groups, and both genders, with BMI trajectories being quite similar across educational groups [94]. These differences tended to widen until late midlife and then stabilize. Younger participants showed the steepest increases in BMI over time, while educational differences narrowed slightly.

2.3.2 Gender differences in obesity

According to the World Health Organization, in 2022 approximately 2.5 billion adults aged 18 years and older had overweight, including 890 million who had obesity [2]. This corresponds to about 43% of adults worldwide having overweight, with similar proportions among men (43%) and women (44%). However, some studies report that the obesity prevalence is slightly higher among women than among men [95]. The magnitude of the difference varies across regions. In low and middle-income countries, particularly in the Middle East and North Africa, gender disparities in obesity tend to be larger, with women experiencing substantially higher prevalence than men. In 2012 it was reported that across 68 countries there were approximately three obese women for every two obese men, and that this excess female obesity was negatively associated with indicators of national wealth and gender inequality [96]. There was a positive association between obesity and national income among men, suggesting that the gap in obesity prevalence between men and women tends to narrow as the country's national income rises. Consequently, in high-income countries the prevalence of overweight is generally similar between genders [95].

In Finland, obesity prevalence has increased in both genders over the past decades. Between 2000 and 2023, the prevalence of obesity rose from 21% to 30% among men and from 22% to 30% among women, with similar trends in abdominal obesity [3]. In 2000, men had a slightly higher mean BMI than women (27.1 kg/m² vs. 26.4 kg/m²), and in 2023 this difference remained similar (28.4 kg/m² vs. 27.9 kg/m²). The most substantial increases were observed in adults aged 30–44 years, where obesity prevalence rose from 15% to 26% among men and from 22% to 30% among women, indicating that there may be a gender difference in weight in this age group [3].

2.3.3 Gender differences in the association between socioeconomic position and BMI

The patterns of obesity across socioeconomic strata become more complex when gender differences are considered, as gender frequently acts as a moderator of the SEP–obesity relationship. Across studies, the socioeconomic gradient in weight appears steeper among women than among men [93,97]. Already in the late 1980s, both in Finland and internationally, researchers have reported a strong inverse relationship between socioeconomic status and obesity among women in high-income countries, whereas the association was inconsistent among men and children [10,98]. Later research has confirmed these findings.

Several reviews and meta-analyses focusing on high-income countries have confirmed the negative associations between SEP and different body weight outcomes, with the results being clearer among women than men [7–9,92,93]. Among men, the results seem more variable, with many reviews reporting either weak, non-significant, or curvilinear associations. The gender differences in the association are very similar regardless of whether adiposity is measured by self-reported variables, such as BMI or objective body composition indicators, such as skinfold measurements. Additionally, the same patterns are observed with several indicators, such as education, occupational status, area-level socioeconomic indicators, as well as composite measures. In general, women tend to show more consistent associations despite the SEP indicator used [7–9,92,93,99,100].

Finnish studies show similar patterns in the gender differences of the SEP–BMI association, although there is little evidence from the 21st century. In a large Finnish cohort of over 50,000 participants, BMI in general increased across all educational and income groups during the 25-year follow-up, but the socioeconomic pattern was more complex in men [11]. Among women, lower education and income were clearly associated with higher BMI, whereas among men educational differences were weaker. In another study examining multiple SEP indicators, nearly all indicators were associated with obesity among women, whereas among men only a few associations reached statistical significance [101]. Similarly, in a follow-up study of the same cohort, weight gain of 5 kg or more was associated with several SEP indicators among women, including education, economic difficulties, and housing status, whereas among men only frequent economic difficulties showed a significant association [102]. However, in these two studies, the lack of statistically significant associations may partly reflect the smaller number of men in the cohort.

2.4 Pathways explaining the association between socioeconomic position and weight

Socioeconomic inequalities in health arise from multiple factors and have proven to be persistent, both in Finland and internationally [103]. Several theoretical models provide a framework that proposes that SEP influences health through macroeconomic conditions and broader social factors, more immediate social environments, individual psychological and behavioral factors, and biological predisposition [104,105]. The pathways linking SEP to obesity are largely similar to those linking SEP to dietary quality or activity patterns, as they are both important determinants of weight [102]. Together, these models highlight that inequalities are not biologically inevitable but instead reflect the political, social, and economic environments in which people are born, grow, live, work, and age. The reasons underlying socioeconomic differences in obesity can be grouped into more distal factors, such as the broader cultural and environmental pathways, and more proximal factors related to the individual, which I will discuss below.

2.4.1 Environmental and social pathways

Environmental factors are closely linked to SEP and may contribute to weight gain. Areas with many outlets selling unhealthy and ultra-processed foods are associated with higher obesity levels, whereas better access to fruit, vegetables, supermarkets, and physical activity facilities is linked to lower obesity levels [106,107]. Material deprivation is considered a central explanation for the SEP–obesity association, as limited financial resources may restrict the ability to maintain healthy behaviors [106]. As countries become wealthier, energy-dense foods become widely available while higher-SEP groups may adopt health information and healthier behaviors more rapidly [108]. Residents of disadvantaged areas are less likely to have access to nearby supermarkets and affordable healthy foods, while often being more exposed to fast-food outlets and convenience stores [109]. However, the extent of these inequalities varies considerably across countries. For example, in the United States, neighborhood socioeconomic inequalities in access to healthy food retailers are well documented, particularly in areas with high poverty and racial segregation [110]. In contrast, although socioeconomic differences in dietary habits are also observed in Finland, they are less likely to arise from the availability of food retailers because healthy food is generally widely available throughout the country.

In Finland, the country-specific factors contributing to socioeconomic inequalities in health include cardiovascular diseases, alcohol-related problems, and accidental injuries, all of which are proportionally more common among lower socioeconomic groups than among higher socioeconomic groups [103]. Although income equality in Finland is globally on a good level, the socioeconomic inequalities in self-rated health have been around the European average. Socioeconomic inequalities in mortality, on the other hand, have been relatively large in Finland compared with other European countries, particularly among men, and have also increased among women [103]. Although the increase in these differences has slowed since the 2010s, they remain considerable.

Gendered social expectations may further shape the SEP–obesity association, particularly among women. Thinness norms appear strongest among higher-SEP

women, while larger body size in women is often stigmatized more strongly than in men, for whom larger size may be associated with strength, power, or dominance [111]. The desire for thinness tends to increase with SEP among adolescent girls and continues into adulthood [98]. Because higher-SEP women may internalize thinness ideals more strongly, they may invest more effort in weight control, whereas lower-SEP women may be less influenced by these norms or face greater barriers to pursuing them. In some low-income countries, larger female body size may be culturally valued as a sign of fertility, health, or prosperity, although these norms often change with westernization [95].

Although social and physical environments play an important role in socioeconomic inequalities, these inequalities cannot be explained by a single factor. The association is better understood as multifactorial, involving unequal access to broader resources needed for healthy living, including money, time, safe neighborhoods, supportive food systems, and opportunities for physical activity. Additional mechanisms, such as social media use and air pollution exposure, may also be relevant but remain less well understood [9].

2.4.2 Individual and behavioral pathways

As described previously, individuals with higher SEP are more likely to engage in health-promoting behaviors, including healthier diets and greater leisure-time physical activity [67, 112]. Lower SEP is also associated with poorer sleep health, including short and non-optimal sleep [113]. These behaviors may also reinforce one another, as poor sleep can reduce diet quality and increase the risk of weight gain [114]. Health literacy may further contribute to these differences, since higher education can improve access to health information, nutrition knowledge, and the ability to apply health advice, although knowledge alone does not necessarily lead to behavior change [9,115].

Differences in physical activity may be particularly relevant for gendered SEP gradients in obesity. Women's overall activity levels are generally lower than men's, which may contribute to differences in body weight between genders [95]. Men with lower SEP may have higher occupational physical activity because they are more likely to work in

manual jobs, although this pattern may weaken in more equal labor markets [7]. These gender differences may further shape the socioeconomic gradients. Lower SEP may more strongly restrict women's opportunities for leisure-time physical activity and healthy eating due to family-related factors such as time constraints, caregiving responsibilities, and financial barriers. Job insecurity and unemployment may contribute more strongly to inequality among men [97].

Stress and psychosocial strain are also important mechanisms that link lower SEP to higher body weight. Socioeconomically disadvantaged groups are more exposed to chronic stress related to financial insecurity, low social status, and stigma, which may influence obesity through behavioral and biological pathways [106]. Prolonged stress may alter cortisol regulation, increase preference for energy-dense foods, promote emotional eating, and contribute to abdominal fat accumulation and metabolic disturbances [9]. However, empirical evidence remains mixed, and a review notes that fewer than half of studies examining stress as a mediator of the SEP–obesity association have found clear support for it [106]. Psychosocial stress may nevertheless be more relevant among women, as stress, depression, adverse childhood experiences, and life-course socioeconomic disadvantage appear to show stronger associations with BMI or obesity risk in women than in men [106,116].

2.4.3 Life-course accumulation of socioeconomic disadvantage

The factors underlying the association between SEP and obesity accumulate across the life course, as health inequalities reflect long-term exposure to different material and psychosocial environments. This is particularly important because obesity often persists from childhood to adulthood. Children and adolescents with obesity have an approximately fivefold higher risk of obesity in adulthood [117]. Childhood socioeconomic disadvantage may influence later obesity risk through family diet, parental behaviors, early nutrition, stress exposure, and the accumulation of disadvantage over time [118]. Family background is especially important, since dietary habits and physical activity patterns often persist into adulthood [67].

Gender and socioeconomic disadvantage may also reinforce one another across the life course: women appear to be vulnerable to the obesogenic effects of socioeconomic disadvantage compared to men [119]. In addition, reproductive and hormonal transitions, such as pregnancy and menopause, may further shape women's fat accumulation and weight gain [120]. Higher body weight may in turn increase further socioeconomic disadvantage [119]. For example, a higher weight may contribute to SEP through lower wages and reduced employment opportunities [108]. This suggests that the relationship between obesity and SEP is bidirectional, and reverse causation may partly explain the stronger income–obesity association among women.

Health behaviors that contribute to socioeconomic differences in BMI tend to cluster together [121]. A life-course perspective suggests that these factors do not operate independently but reinforce one another over time: physical activity may motivate individuals to eat more healthfully, while both healthy eating and regular exercise may alleviate stress and make individuals more likely to maintain a healthy lifestyle. Biological mechanisms are likely to interact with behavioral and environmental factors in shaping obesity risk [9]. For example, lower SEP may lead to greater financial stress, which can impair sleep and worsen insulin sensitivity. Reduced insulin sensitivity may promote weight gain, while obesity-related stigma may further increase stress. In this way, socioeconomic disadvantages, biological responses, and health behaviors may form a reinforcing cycle over time during the life course.

2.4.4 The mediating role of health behaviors in the association

At present, only seven observational studies have examined whether health behaviors mediate the association between SEP and BMI or obesity, and even fewer compare the gender differences [121–127]. The characteristics and main findings of the studies are summarized in Table 1. Although the evidence remains heterogeneous, existing studies suggest that dietary factors and physical activity may partly explain socioeconomic inequalities in BMI, although the strength of mediated proportion varies by mediator, SEP indicator, outcome measure, study design, and gender. The following section discusses the evidence related to the variables of interest in this thesis: fruit and

vegetable, red and processed meat, sweets and confectionery and alcohol consumption as well as leisure-time and commuting-related VPA and sedentary time

Among dietary factors, consumption of fruit and vegetables is the most studied mediator of the SEP–BMI relationship, although the evidence is mixed. A Canadian cross-sectional study found that consumption of fruit and vegetables was a marginally significant mediator of the association between education and high-risk adiposity among women, but not among men [122]. In contrast, a similar Australian study found that meeting fruit and vegetable recommendations did not mediate educational inequalities in BMI in either gender [123]. In a follow-up study on the same population, fruit and vegetable consumption did not significantly mediate educational differences in 13-year BMI gain [124]. A Swedish study found the economic strain was associated with BMI partly through inadequate fruit and vegetable consumption [127]. However, broader measures of diet quality appear more consistent. In a Finnish study, diet, including fruit and vegetable consumption and self-rated diet quality, was one of the strongest mediators of the SEP–BMI association in both women and men [121]. A Swiss study also found that overall diet quality, measured using the Alternate Healthy Eating Index, mediated 22–36% of the association between education or income and obesity, depending on the obesity indicator used [125].

Evidence on meat, sweets, and confectionery is more limited because most studies do not examine these food groups separately. Unhealthy savory foods, including processed meats, were among the most important mediators of educational differences in BMI in both women and men in the previously discussed Australian cross-sectional study [123]. Similarly, high red and processed meat consumption was included in another study in a broader dietary risk score, which mediated the education–adiposity association among women [126]. Findings for sweets and confectionery are also inconsistent. In the Australian cross-sectional study, snacks did not explain socioeconomic inequalities in BMI in the expected direction [123], and in the follow-up study, discretionary foods, including sweets and confectionery, did not mediate educational differences in BMI gain [124]. Regarding alcohol, the evidence suggests that its role may be gender-specific. In the Australian cross-sectional study alcohol contributed to the mediation of educational differences in BMI among women, but not among men [123]. The Finnish study

similarly found an indirect pathway from income to BMI through alcohol consumption among women [121]. In the Czech study alcohol consumption was also a significant mediator among women, whereas no mediation was observed among men [126].

Physical activity has shown relatively consistent evidence as a mediator. In the Australian cross-sectional study, leisure-time physical activity contributed substantially to educational differences in BMI in both women and men [123]. In a prospective study of the same cohort, leisure-time physical activity mediated 10.2% of the association between education and 13-year BMI gain among women [124]. Among men, mediation of BMI gain was not estimated because the total association between education and BMI gain was not significant, although physical activity contributed to educational differences in incident obesity. A Swedish study found the economic strain is associated with BMI in both women and men partly through inadequate physical activity [127]. In the Finnish study, leisure-time physical activity was an important mediator among women, while its role among men was weaker [121]. Sedentary behavior, although being less studied, appears to be relatively important. The Finnish study found that sitting time was one of the strongest and most consistent mediators of the SEP–BMI association in both women and men [121]. The Czech study found that sedentary behavior mediated educational differences in adiposity in both genders: among men, it was the only significant mediator in the multiple mediation model, whereas among women it was one of several significant mediators [126].

Overall, the literature suggests that health behaviors explain part, but not all, of the SEP–BMI association. Broader dietary quality, leisure-time physical activity, and sedentary behavior show the most consistent evidence as mediators, whereas consumption of fruit and vegetables, sweets and confectionery, and red meat show less consistent evidence [121–127]. Alcohol may be relevant particularly among women [123]. Across studies, mediation effects often appear stronger or more varied among women, which may partly explain why socioeconomic gradients in BMI are often steeper in women than in men. However, none of the abovementioned studies statistically tested gender differences in the mediators.

Table 1. Summary of previous cross-sectional and prospective studies including at least one behavioral mediator of the association between socioeconomic position and weight outcomes

Study	Country	Design	Time	Sample size	Gender distribution	Sample characteristics	SEP measure (exposure)	Mediators	Outcome	Method	Gender differences *	Main results
Barto-skova Polcrova et al. (2024) [126]	Czechia	Cross-sectio-nal	Survey in 2013.	n= 2,154	Women 54.6%, men 45.4%.	Mean age: men 46.74 years; women 47.77 years. Measured BMI: men mean 26.86; women mean 25.51.	Education classified into high, middle, and low.	Dietary score from questionnaire, alcohol consumption, smoking, sedentary behavior, equivalized household income, mental health	Adiposity based on body fat percen-tage, BMI, waist circum-ference, and visceral fat area.	Age-adjusted gender-specific simple and multiple mediation models.	Men showed a narrower mediation pattern, while women showed multiple significant mediator pathways.	The direct effect of education on adiposity was significant in both sexes. In multiple mediation models, sedentary behavior significantly mediated the association in men. In women, significant mediators were dietary risk, alcohol consumption, sedentary behavior, income, and mental health. Total mediated proportion in women was 30.5%.
Boro-dulin et al. (2012) [121]	Finland	Cross-sectio-nal	2002, FINRISK	n= 3,995	Women 58.7%, men 41.3%.	Ages from 25-64, BMI: men mean 26.9 (SD 4.0); women mean 25.9 (SD 4.9).	Education in years and household income.	Fruit, fresh vegetables, root crops, salads, and self-rated dietary quality, leisure-time physical activity, smoking, alcohol, sedentary time	Measured BMI, continu-ous	Gender-stratified structural equation modeling adjusted for age	Physical activity and alcohol-related pathways were more evident among women, smoking-mediated pathway was found among men.	The strongest and most consistent mediators were diet and sitting in both sexes. Significant pathways also included education-smoking-BMI among men and education-income-BMI, income-alcohol-BMI, and education-income-alcohol-BMI among women. Direct associations of education and income with BMI were observed among women only.

Table 1. *continued*

Study	Country	Design	Time	Sample size	Gender distribution	Sample characteristics	SEP measure (exposure)	Mediators	Outcome	Method	Gender differences	Main results
de Mestral et al. (2019) [125]	Switzer-land	Cross-sectio-nal	2014-2015	n= 1,860.	Women 54.2%, men 45.8%.	Mean age 49.2 years, obesity prevalence by marker: BMI 10.6%, waist circumference 18.8%, waist-to-hip ratio 30.0%, waist-to-height ratio 43.0%.	Dichotomized education and income	Diet quality measured with the Alternate Healthy Eating Index 2010 (AHEI) from two 24-hour dietary recalls	Obesity, defined by BMI, waist circum-ference, waist-to-hip ratio and waist-to-height ratio	Counter-factual mediation modeling adjusted for age, gender, physical activity, total energy intake, and smoking	Main analyses combined women and men, the authors tested whether socioeconomic inequalities in obesity differed by gender and did not find evidence of gender differences	Lower education was associated with higher odds of obesity across all markers. Diet quality mediated 22.1% of the education-obesity association using BMI, 26.6% using waist circumference, 31.4% using waist-to-height ratio, and 35.8% using waist-to-hip ratio. Similar findings were observed for income.
Gearon et al. (2013) [123]	Australia	Cross-sectio-nal	1990-1994, Mel-bourne Colla-borative Cohort Study	n= 30,630	Women 60.4%, men 39.6%.	Mean age: men 57.4 low vs 54.1 high education, women 56.8 low vs 52.9 high education. Mean BMI: men 27.3 low vs 26.3 high education, women 26.5 low vs 25.3 high education.	Highest educational attainment, dichotomized as completed high school vs not completed high school	Leisure-time physical activity, alcohol, diet soft drink, regular soft drink, healthy snacks, healthy savory items, meeting fruit and vegetable guidelines, sweet snacks, unhealthy savory items	Self-reported BMI, continu-ous	Gender-stratified mediation, adjusted for age and smoking	Total mediation was larger among women. Alcohol and diet soft drink were important mediators in women, whereas alcohol did not significantly mediate the SEP-BMI association in men.	Lower education was associated with about 1 kg/m² higher BMI. Meeting fruit and vegetable guidelines was not associated with SEP inequalities in BMI, sweet snacks showed inverse mediation. Diet and physical activity together explained 27% of the educational difference in BMI among men and 48% among women.

Table 1. *continued*

Study	Country	Design	Time	Sample size	Gender distribution	Sample characteristics	SEP measure (exposure)	Mediators	Outcome	Method	Gender differences	Main results
Gearon et al. (2018) [124]	Australia	Prospective cohort (Melbourne Collaborative Cohort Study)	Baseline 1990-1994, follow-up 2003-2007, approximately 13 years.	n= 7,894	Women 60.7%, men 39.3%.	Baseline age 40-69 years, baseline BMI: women mean 24.7 (SD 4.0), men mean 26.1 (SD 3.2). Mean 13-year BMI gain: women 2.0 kg/m² (SD 2.2), men 1.3 kg/m² (SD 1.6).	Highest educational attainment, dichotomized as completed high school vs not completed high school	Leisure-time physical activity, diet soft drink, regular soft drink, nutrient-rich foods, fruit and vegetables, discretionary foods.	13-year BMI gain, continuous	Gender-specific multiple mediation analysis	Among women, higher education was associated with 0.27 kg/m² less 13-year BMI gain. Mediation of BMI gain was found among women only. In sensitivity analysis, incident obesity was the only outcome with significant mediation among men.	In women, physical activity, diet soft drink consumption, and nutrient-rich foods mediated the association, explaining 10.2%, 20.1%, and 14.7%, respectively. Together they explained 45.0%. Among men, no total effect was found for BMI gain, incident obesity analyses suggested mediation through physical activity (5%), nutrient-rich foods (12%), and diet soft drink (7%).
Moreno-Llamas et al. (2024) [127]	Sweden	Cross-sectional	Survey years 2016, 2018, 2020, and 2021. (four pooled surveys)	n= 44,177	Women 52.19%, men 47.81%.	Mean age 53.41 years (SD 18.39). Mean BMI 26.01 kg/m² (SD 4.44). Normal weight/ underweight 45.82%; overweight/ obesity 54.18%.	12 strata by gender, educational level (high, medium, low), and migration status (native or immigrant)	Economic strain, unhealthy lifestyle defined as not meeting both physical activity and fruit/vegetable consumption recommendations	Self-reported BMI, continuous outcome	Intersectional mediation analysis using generalized linear models, adjusted for age, survey year, tobacco use, alcohol use, social support, physical limitations.	Patterns differed across strata and gender: compared with high-educated native men, BMI was higher among lower-educated men, while high-educated women had lower BMI. Highest BMI and lifestyle risk occurred among low- and middle-educated men.	Disadvantaged strata had more economic strain, which was linked to poorer lifestyle and higher BMI. The pathway through economic strain and unhealthy lifestyle to BMI was consistent across groups. The direct impact of economic strain was stronger in some strata, particularly low-educated women.

Table 1. *continued*

Study	Country	Design	Time	Sample size	Gender distribution	Sample characteristics	SEP measure (exposure)	Mediators	Outcome	Method	Gender differences	Main results
Ward et al. (2007) [122]	Canada	Cross-sectio-nal	1997–1998 (Ontario Food Survey)	n= 1,087	Women 57.0%, men 43.0%.	Ages 18-75, Adiposity risk categories: men 28% least risk, 39% increased risk, 33% high risk; women 42% least risk, 22% increased risk, 36% high risk.	Education and household income	Leisure-time physical activity, fruit and vegetable consumption, smoking status	Increased-risk and high-risk adiposity groups based on BMI and waist circum-ference	Gender-stratified structural equation modeling adjusted for age, education and income models run separately	SEP-adiposity associations appeared among women but not men. Fruit and vegetable consumption marginally mediated education-high-risk adiposity only among women.	In women, high-risk adiposity was directly associated with education and income. Increased-risk adiposity was not associated with education or income in either sex. No clear mediating pathways were found among men.

Abbreviations. BMI = Body mass index , SD = standard deviation, SEP = socioeconomic position.

*none of the studies statistically tested the gender difference.

2.5 Summary of current evidence and research gaps

2.5.1 What is well established in the literature

Several findings are well established in the literature on SEP, health behaviors, gender, and BMI. First, SEP is a multidimensional concept that captures differences in material resources, social status, knowledge, opportunities, and living conditions. Education, income, and occupational status are the most used indicators, but they are not interchangeable, as each reflects a different aspect of socioeconomic advantage or disadvantage [5,6,27]. Therefore, studies using different SEP indicators may produce partly different findings.

Second, both dietary factors and physical activity patterns are socially patterned. In high-income countries, individuals with higher SEP generally have healthier diets and engage in more physical activity than those in lower SEP. Higher SEP is associated with a higher consumption of fruit and vegetables and lower consumption of red and processed meats. With sweets and total alcohol, there are no clear socioeconomic differences [13,67,68]. For physical activity and sedentary time, the patterns vary by domain: higher SEP is generally associated with more leisure-time physical activity and occupational sitting, whereas lower SEP may be associated with more occupational physical activity and passive leisure-time sitting [20,25,26,73].

Third, there are clear gender differences in health behaviors. Women generally have better dietary quality than men, including higher consumption of fruit and vegetables and lower consumption of red and processed meat, but higher consumption of sweets and confectionery [12,79]. Men generally consume more alcohol and are more likely to participate in some forms of sports and exercise. Consequently, men have higher levels of VPA, whereas there are no clear gender differences in light physical activity [72,86,95].

Fourth, the negative association between SEP and body weight is well established in high-income countries including Finland, and the association is particularly consistent among women [7–9,92,93]. Although weight has increased across all socioeconomic groups over time, the socioeconomic differences have persisted [11,94,101].

Fifth, body weight is determined by multiple factors, many of which are beyond individual control [43]. Although health behaviors such as diet quality, alcohol consumption, physical activity, and sedentary time directly contribute to weight development through energy balance, they are shaped by broader environmental, material, and social conditions. Socioeconomic differences in weight therefore reflect resources, norms, and opportunities that influence people's ability to engage in health-promoting behaviors.

2.5.2 Limitations of existing studies and need for further research

Overall, there is limited evidence on the behavioral mediators of the SEP–BMI association. There are many proposed explanations for the SEP–BMI association, but there is a need for quantitative analysis to investigate them. Although some studies suggest that dietary factors and physical activity may partly explain the SEP–BMI association, other studies have found no mediation by these components [121–127]. Studies should examine multiple behaviors simultaneously, since they often cluster together and may reinforce one another over the life course [9,121].

Gender-specific evidence on mediators of the SEP-obesity association is limited. Although many studies and reviews show that the SEP–obesity association is stronger among women, few studies examine statistically whether the mediating pathways differ by gender. At the same time, some studies indicate that the gender differences are inconsistent [122,123]. Approaches where gender and SEP are examined together are needed to understand how these factors together shape health behaviors and BMI.

The methodological quality of mediation studies examining pathways between SEP and weight outcomes is often weak [106]. Much of the evidence is based on cross-sectional studies, which cannot establish temporal order. In other words, reverse causation cannot be fully ruled out since it is possible that a higher BMI may result in an unhealthier behavioral profile and not the other way around. These can also occur simultaneously: socioeconomic disadvantage may increase obesity risk, while higher body weight may also contribute to socioeconomic disadvantage through stigma, discrimination, lower wages, and reduced employment opportunities [108,119].

Longitudinal studies are needed since at present, there is only one study that examines whether behavioral factors mediate the association between SEP and BMI gain [124].

Lastly, Finnish evidence on the SEP–BMI association and its gender differences is weak, and the existing evidence is relatively old [10]. Only one Finnish study has examined mediators of the SEP–BMI association using gender-stratified analyses. By examining whether dietary factors and physical activity mediate the association between SEP and BMI, and whether these pathways differ by gender, this thesis contributes to these gaps and helps to clarify which behavioral pathways are most relevant for understanding socioeconomic inequalities in BMI. With evidence on the specific health behaviors that mediate the relationship between SEP and BMI, it could be possible to create effective gender-specific interventions targeting factors that might play a role in the association.

2.6 Research objectives

The aims of this thesis were to 1) investigate gender differences in the SEP–BMI association and 2) determine whether dietary factors and physical activity mediate the associations similarly in women and men. SEP was measured using the highest educational attainment, and the potential mediators included consumption of fruit and vegetables, red and processed meat, sweets and confectionery, and alcohol, as well as leisure-time VPA and sedentary time. The thesis was based on the hypothesis that lower SEP is linked to a higher BMI partly through dietary factors and physical activity and that the absolute effects of the mediators are larger among women because the SEP–obesity gradient is steeper in women.

The specific research questions were:

1) How do socioeconomic differences in BMI differ between women and men among young and early midlife Finnish employees?

2) Do dietary factors (fruit and vegetable, red and processed meat, sweets and confectionery and alcohol consumption) and physical activity (VPA and sedentary time) mediate the association between SEP and BMI similarly in women and men?

3 Methods

3.1 Data and study population

This thesis was part of the Helsinki Health Study, which examines the health and well-being of employees of the City of Helsinki, the largest employer in Finland with approximately 38,000 employees across diverse occupational sectors [128,129]. The target population consisted of 11,459 employees born in 1978 or later (aged 19–39 years) who had been employed for at least four months with a contract of at least 50% regular working hours. Data collection occurred in autumn 2017 (Phase 1) via online and mailed questionnaires, supplemented by shorter telephone interviews for non-responders.

The initial response rate was 51.5% (n = 5,897). While non-response analysis indicated slightly higher participation among those with higher SEP, the sample was found to reasonably represent the target population [128]. I excluded telephone interviewees (n = 787) because the interviews did not include all variables of interest needed for this thesis. I also excluded those with missing data on education, BMI or one or more of the mediators, as shown in Figure 1. Gender had no missing values. Outliers in physical activity and sedentary time were identified as values more than three standard deviations from the mean, following previous studies [20]. The final analytical sample included 4,400 participants of whom 80% were women, reflecting the gender distribution of both the City of Helsinki and the broader Finnish municipal sector.

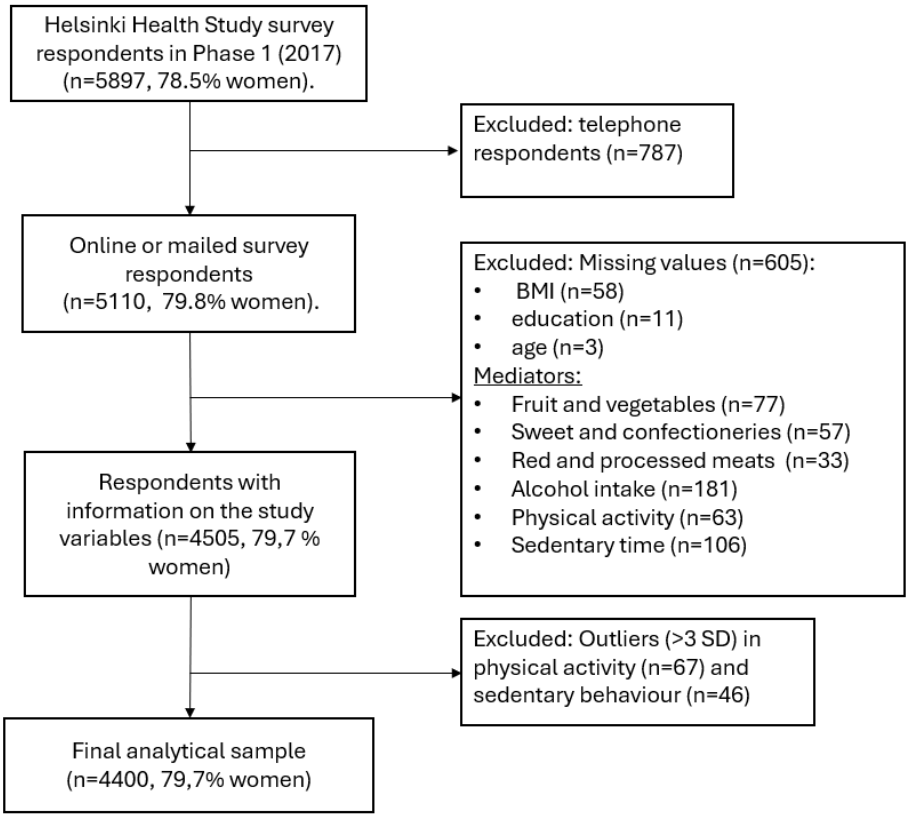


Figure 1. Flowchart of the exclusions leading to the final analytical sample. SD = Standard deviation

3.2 Measures

3.2.1 Gender, socioeconomic position and weight

Gender (man/woman) was obtained from national registers for participants who had given consent. For participants without consent, gender was based on the survey response. All other variables used in this thesis were obtained from the surveys. SEP was measured using the highest educational attainment, categorized into three groups: upper secondary or vocational education or lower, bachelor's degree, and master's degree or higher. BMI (kg/m²) was computed from height and weight by dividing weight in kilograms by height in meters squared. Age was obtained from surveys and was categorized as 19–29 years and 30–39 years for descriptive analyses and treated as a continuous variable in mediation models, following previous studies [20].

3.2.2 Dietary factors and physical activity

Six health behaviors were included, four related to diet: fruit and vegetable consumption, red and processed meat consumption, sweets and confectionery consumption, alcohol consumption, and two activity-related behaviors during leisure time: VPA and sedentary time. These mediators were chosen because they are directly related to body weight through energy intake or energy expenditure.

Food consumption was assessed using a 14-item FFQ covering the previous 4 weeks. Consumption of fruit and vegetables was calculated by summing four items: fresh vegetables, fresh fruit, cooked vegetables, and berries. Red and processed meat consumption was based on one questionnaire item, and sweets and confectionery consumption was calculated by summing two items, one on candy and chocolate and the other on coffee pastries and baked goods (biscuits/cookies, doughnuts, and other pastries). The variables were divided by four to obtain weekly servings. Alcohol consumption was assessed from participants' reported frequency of consuming three beverage types: beer, cider, long drink and similar beverages; wine and other low-alcohol beverages; and spirits or other strong alcoholic beverages. Weekly alcohol consumption was calculated by summing the reported consumption frequencies across beverage types. One unit of alcohol refers to 12 grams of pure ethanol.

Participants reported their leisure-time and commuting physical activity during the past 12 months by classifying activities according to perceived intensity and estimating the average weekly duration at each intensity level. Intensity was converted to metabolic equivalents (METs) and multiplied by the duration of each intensity [130]. Only VPA (> 10 METs) was investigated as a mediator in the main analysis and total physical activity (sum of all the domains) in sensitivity analyses. Sedentary time was assessed as self-reported daily sitting time across four domains: at home while watching television or using a computer, at home while reading, during transport, and elsewhere. These were summed up and multiplied by seven to obtain time sitting per week. If a participant reported physical activity, sedentary time or alcohol consumption for some domain but left one domain blank, the missing value for that domain was set to zero, following prior studies conducted with the same data [19,20].

3.3 Statistical methods

Background characteristics of the participants were described by gender and SEP. Continuous variables were presented as means and categorical variables as counts and percentages. Differences in dietary factors and physical activity across gender and SEP groups were examined descriptively and visualized using bar plots. The association between SEP and BMI was first examined visually and then tested using linear regression models. Interaction terms between SEP and gender were used to assess whether educational differences in BMI differed between women and men. Model assumptions, including the normality of residuals and heteroscedasticity, were assessed.

The mediating role of dietary factors and physical activity in the association between SEP and BMI was examined using multiple parallel mediation models within a structural equation modeling framework in accordance with the conceptual model shown in Figure 2 [131]. All analyses were stratified by gender and adjusted for age. A three-category SEP variable (upper secondary or vocational education or lower/bachelor's degree/master's degree or higher) was created for men and women, with the highest education being the reference group. In each mediation model, SEP was specified as the exposure, BMI as the outcome, and dietary factors and physical activity as simultaneous mediators. All mediators were treated as continuous variables.

The mediation analyses were conducted using structural equation modeling and followed the standard path-analytic approach [131]. First, the total association (c-path) between SEP and BMI was estimated. Second, the associations between SEP and each mediator were estimated as a-paths. Third, the associations between each mediator and BMI, adjusted for SEP and all other mediators, were estimated as b-paths. The direct effect (c'-path) represented the association between SEP and BMI after adjustment for all mediators. Mediator-specific indirect effects were calculated as the product of the corresponding a- and b-paths. The indirect effect tells how much of the association between SEP and BMI is statistically explained by each mediator, while accounting for the other mediators in the model [131]. The total indirect effect was calculated as the sum of all mediator-specific indirect effects, and it tells how much of the association between SEP and BMI is statistically explained by the mediators together.

The proportion mediated was calculated by dividing the indirect effect by the total effect. Indirect effects and confidence intervals (CI) were estimated using bootstrapped standard errors with 5,000 replications. Model parameters are presented as non-standardized regression coefficients. Non-standardized estimates were used to allow more direct comparison between women and men, as the focus was on gender differences rather than comparisons between mediators within genders. Standardized estimates depend on variable variances, which may differ by gender. Results are reported separately for women and men as total effects, direct effects, total indirect effects and mediator-specific indirect effects. Gender differences in mediation were tested by estimating the difference between the indirect effects in women and men (women – men), with 95% bootstrap CI used to assess statistical significance. Results were considered statistically significant, when the CI did not include zero or when the p-value was less than 0.05. Models were fitted using the lavaan package in R (version 4.5.3, 2026-03-11).

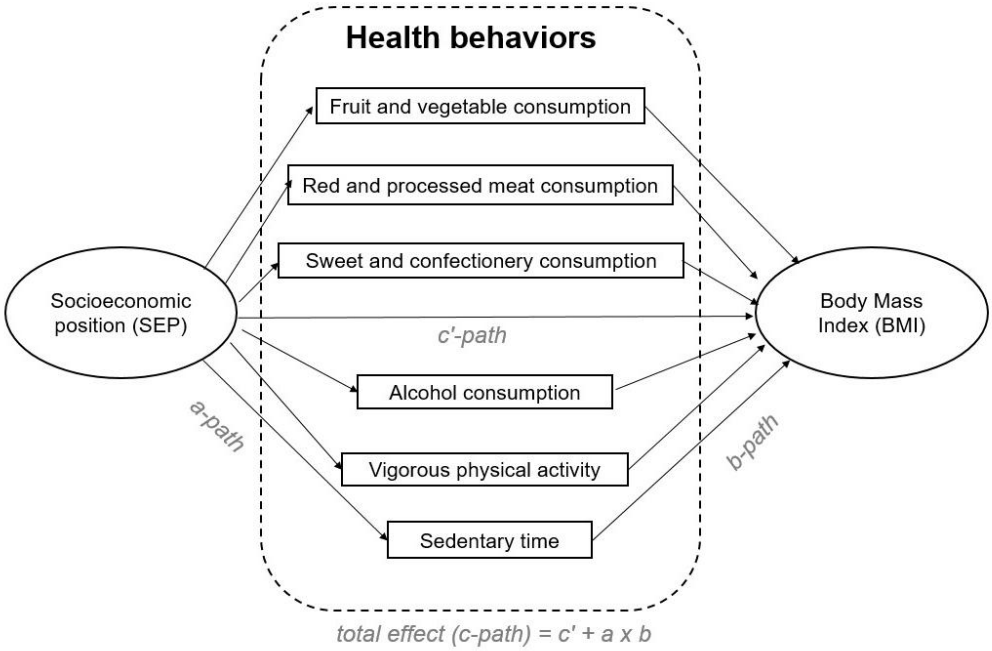


Figure 2. Conceptual mediation model of the association between socioeconomic position (SEP) and body mass index (BMI) through dietary factors and physical activity in the Helsinki Health Study cohort (n = 4,400) in Phase 1 (2017). The a-path represents the association between SEP and each mediator, the b-path represents the association between each mediator and BMI adjusted for SEP and the other mediators, the c-path represents the total association, and the c'-path represents the direct association after adjustment for mediators.

3.4 Additional follow-up analyses

To assess whether the observed mediation reflected socioeconomic differences in BMI already present at Phase 1, a secondary longitudinal analysis among those who had responded to the Phase 2 survey five years later in 2022 (n = 2,581, 80% women) was conducted. The cross-sectional analysis was chosen as the main analysis to maximize statistical power, as 40% of participants were lost to follow-up between Phases 1 and 2. In the longitudinal model, Phase 2 BMI was used as the outcome variable, and the models were additionally adjusted for Phase 1 BMI. Education was taken from Phase 2 to consider new completed education between Phase 1 and 2.

3.5 Ethical considerations

This thesis used existing Helsinki Health Study survey data. The Helsinki Health Study follows good scientific practice as defined by the Finnish National Board on Research Integrity and adheres to the Declaration of Helsinki and the General Data Protection Regulation (GDPR) [132–134]. The protocol has received ethical approval from the Research Ethics Committee of the Faculty of Medicine, University of Helsinki, as well as approval from the relevant authorities of the City of Helsinki. For the data used in this thesis, the Faculty of Medicine gave a positive ethical statement on 14 February 2017, and the City of Helsinki granted permission on 16 April 2017. Participation was voluntary, and participants were informed about the study purpose, confidentiality, data use and processing, and their right to withdraw without consequences.

The data are securely stored in a network folder within an environment designed for sensitive data, and access is restricted to authorized researchers within the research group. For this thesis, the data were shared from the secure storage environment to an authorized researcher's personal folder administered by the University of Helsinki. The shared data were pseudonymized, and only the variables necessary for the research questions were used. Due to GDPR requirements and the sensitive nature of the data, the dataset is not openly accessible to other researchers, and the ownership of the data remains with the data controller. The data protection statement is available on the Helsinki Health Study website (helsinki.fi/hhs_dataprotectionstatement).

4 Results

4.1 Descriptive statistics

As shown in Table 2, two-thirds of the participants were aged 30–39 years, and one-third were 19–29 years. Those with higher education were generally older than those in lower education groups. Mean BMI in the total sample was 25.2 kg/m² and increased with decreasing educational level in both women and men. Normal weight was most common in those with highest education, whereas overweight and obesity were more prevalent in the lower education groups, with overweight being more common among men.

Table 2. Descriptive characteristics of the Helsinki Health Study participants in Phase 1 (2017).

		All	**Women** (n=3506, 79.7%)			**Men** (n=894, 20.3%)			**P-value***
Education			High	Middle	Low	High	Middle	Low	
Total		4400	1062 (24.1)	1361 (30.9)	1083 (24.6)	257 (5.7)	267 (6.1)	370 (8.4)	
Age (n (%))	19–29 years	1378 (31.3)	178 (16.8)	482 (35.4)	475 (43.9)	40 (15.6)	69 (25.8)	132 (35.7)	<0.001
	30–39 years	3022 (68.7)	882 (83.2)	879 (64.6)	608 (56.1)	217 (84.4)	198 (74.2)	238 (64.3)	
BMI, kg/m² (mean (SD))		25.2 (5.2)	24.0 (4.5)	24.7 (4.8)	26.4 (6.6)	25.2 (3.7)	26.0 (3.7)	26.6 (4.7)	<0.001
BMI (categorized) (n (%))	Normal weight and under-weight	2615 (59.4)	756 (71.2)	884 (65.0)	557 (51.4)	139 (54.1)	120 (44.9)	159 (43.0)	<0.001
	Overweight	1147 (26.1)	210 (19.8)	302 (22.2)	289 (26.7)	96 (37.4)	110 (41.2)	140 (37.8)	
	Obesity	638 (14.5)	96 (9.0)	175 (12.9)	237 (21.9)	22 (8.6)	37 (13.9)	71 (19.2)	

* P-values were calculated using χ^2 test for categorical variables and a t-test for mean BMI
High education = master's degree or higher, middle education = bachelor's degree, low education = upper secondary or vocational school or lower, BMI = body mass index (body weight in kilograms divided by height in meters squared, kg/m²), SD = standard deviation,

Figure 3 shows clear differences in dietary factors and physical activity across gender and SEP. Women reported a higher consumption of fruit and vegetables than men in all education groups, and in both genders, consumption decreased with lower education. In

contrast, red and processed meat consumption increased with decreasing education and was consistently higher among men than women. Sweets and confectionery consumption was also higher among women than men, whereas alcohol consumption was higher among men across all education groups, with little difference by education. VPA was higher among men than women and declined with decreasing education in both genders. Sedentary time showed the opposite educational pattern, tending to be higher in the lower education groups, particularly among men.

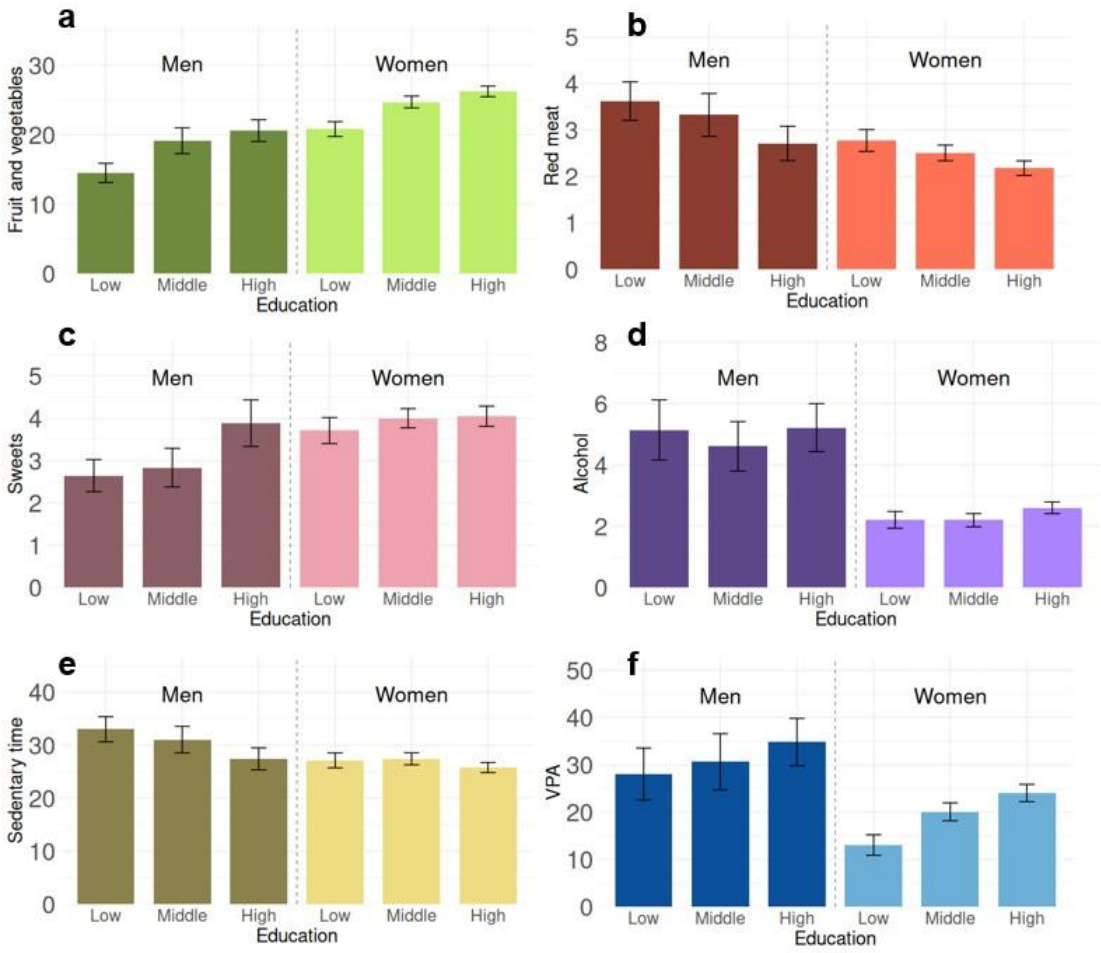


Figure 3. Differences in dietary factors and physical activity across gender and educational groups in the Helsinki Health Study cohort (n = 4,400) in Phase 1 (2017). Bars represent means and error bars represent their 95% confidence intervals. Panels show a) fruit and vegetable consumption (servings/week), b) red and processed meat consumption (servings/week), c) sweets and confectionery consumption (servings/week), d) total alcohol consumption from different beverage types (servings/week, one serving equivalent to 12 grams of pure ethanol), e) sedentary time (hours/week), and f) vigorous physical activity (MET-hours/week). High education = master's degree or higher, middle education = bachelor's degree, low education = upper secondary or vocational school or lower, MET = metabolic equivalent, VPA = vigorous physical activity

4.2 Gender difference in the association between body mass index and socioeconomic position

Figure 4 shows an inverse association between SEP and BMI in both genders. The gradient was steeper among women although men had a higher mean BMI overall. Consequently, men had a higher BMI than women in the two higher education groups, but this gender difference narrowed in the lowest education group. Statistical testing showed that both educational level and gender were associated with BMI ($p < 0.001$), and the education × gender interaction was statistically significant ($p = 0.037$), suggesting a gender difference in the association between SEP and BMI.

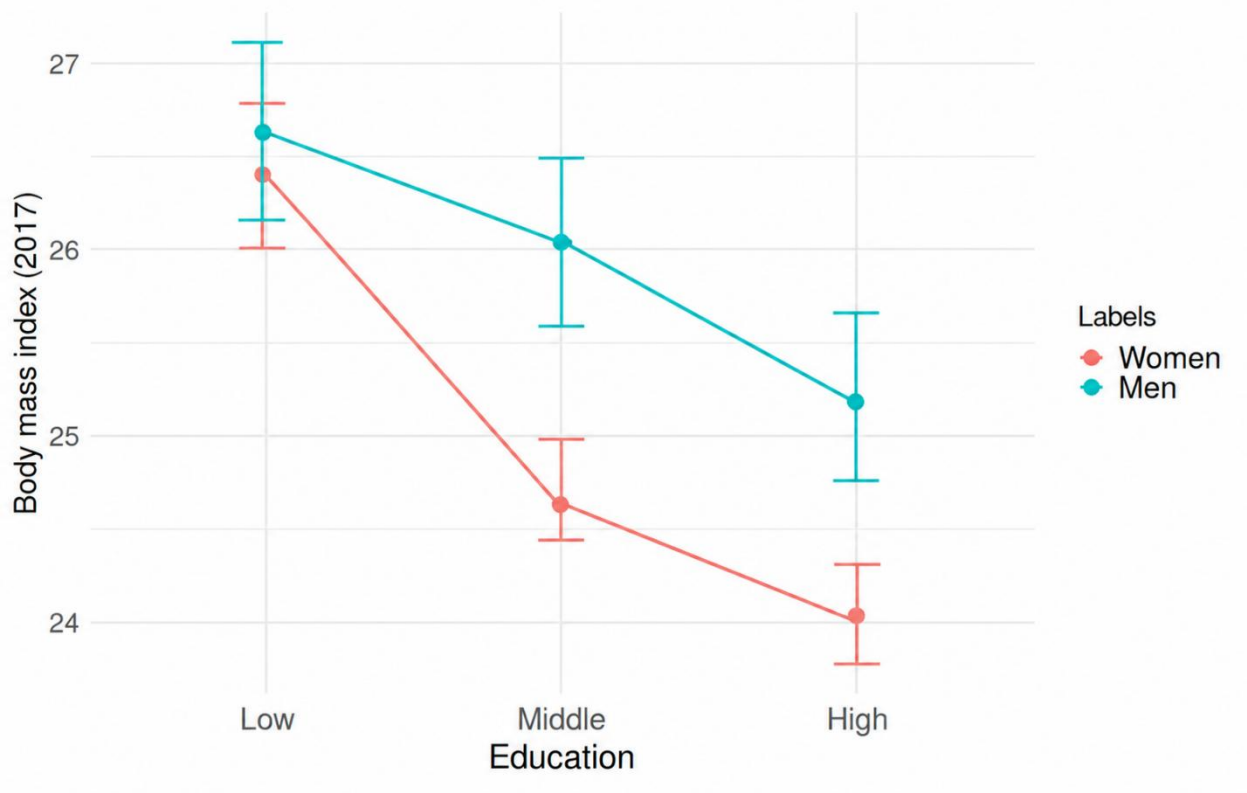


Figure 4. Gender differences in the association between socioeconomic position and body mass index in the Helsinki Health Study Cohort (n = 4,400, 80% women) in Phase 1 (2017). Points represent means and error bars represent their 95% confidence intervals. High education = master's degree or higher, middle education = bachelor's degree, low education = upper secondary or vocational school or lower, BMI = body mass index (body weight in kilograms divided by height in meters squared, kg/m²)

4.3 The mediating role of dietary factors and physical activity

4.3.1 Total effect of socioeconomic position on BMI

Compared to participants with high education, the total effect of middle education, meaning the estimated BMI difference between the groups, was similar in women and men, at 0.98 (95% confidence interval (CI) 0.61, 1.37) and 0.97 (95% CI 0.33, 1.61), respectively. The difference was stronger among participants with low education, particularly among women: compared with high education, the total effect of low education on BMI was 2.84 (95% CI 2.34, 3.35) in women and 1.67 (95% CI 0.99, 2.34) in men.

4.3.2 Exposure–mediator relationship (a-path)

Among women, both middle and low education were associated with lower fruit and vegetable consumption, higher red and processed meat consumption, lower VPA, and lower alcohol consumption, as shown by the a-paths in Table 3. Among men, low education was associated with lower fruit and vegetable consumption, higher red and processed meat consumption, and lower VPA, while both middle and low education were associated with lower sweets and confectionery consumption and higher sedentary time.

4.3.3 Mediator–outcome relationship (b-path)

Higher consumption of fruit and vegetables was associated with lower BMI only among women, whereas higher VPA was associated with lower BMI in both genders, shown as the b-paths in Table 3. In contrast, higher red and processed meat consumption and greater sedentary time were associated with higher BMI among both women and men. The associations of VPA and sedentary time with BMI were stronger among women, whereas the association between red and processed meat and BMI was stronger among men. Sweets and confectionery and alcohol consumption were not significantly associated with BMI in either gender.

4.3.4 Indirect effects through dietary factors and physical activity

Among women, VPA showed the largest indirect effect, both for middle versus high education (0.18, 95% CI 0.11, 0.26; 18.6% mediated) and low versus high education (0.35, 95% CI 0.26, 0.44; 12.1% mediated), as shown in Table 3. Thus, among women, VPA accounted for 0.35 kg/m² of the BMI difference between the low and high education groups, and 0.18 kg/m² of the BMI difference between the middle and high education groups. Smaller indirect effects were observed through consumption of fruit and vegetables among women (middle vs high: 0.05, 95% CI 0.01, 0.09; 4.8% mediated; low vs high: 0.15, 95% CI 0.08, 0.23; 5.4% mediated) and through red and processed meat consumption in both women (middle vs high: 0.04, 95% CI 0.01, 0.07; 3.9% mediated; low vs high: 0.06, 95% CI 0.02, 0.11; 2.1% mediated) and men (middle vs high: 0.09, 95% CI 0.01, 0.19; 9.2% mediated; low vs high: 0.12, 95% CI 0.03, 0.23; 7.2% mediated). VPA in men was a significant mediator in the low-high comparison (0.10, 95% CI 0.02, 0.21, 5.8% mediated). Among men, an additional significant indirect pathway was observed through sedentary time (middle vs high: 0.09, 95% CI 0.01, 0.22; 9.3% mediated; low vs high: 0.11, 95% CI 0.01, 0.24; 6.3% mediated). No clear indirect effects were observed for sweets and confectionery consumption or alcohol consumption in either gender.

Statistical testing of gender differences showed that only the indirect effect through VPA differed significantly between women and men. The indirect effect through VPA was larger among women for both middle versus high education (difference = 0.16, 95% CI 0.05, 0.27; $p = .003$) and low versus high education (difference = 0.25, 95% CI 0.11, 0.36; $p < .001$). Although fruit and vegetable consumption showed a significant indirect effect only among women and sedentary time only among men, the corresponding indirect effects did not differ statistically significantly between genders. The complete results of the gender differences in the indirect effects are shown in Appendix 1.

Taken together, all mediators explained 29.0% of the education–BMI association among women in the middle versus high education comparison and 20.1% in the low versus high comparison; among men, the corresponding proportions were 26.8% and 25.3%, respectively. The total indirect effect did not differ significantly between women and

men for either middle versus high education (difference = 0.02, 95% CI −0.24, 0.30; p = .855) or low versus high education (difference = 0.15, 95% CI −0.14, 0.43; p = .302). This means that, although the relative importance of individual mediators differed between women and men, there was no evidence that the total indirect effect including all of the mediators differed between genders.

Table 3. The mediating role of dietary factors and physical activity in the age-adjusted education–BMI association among women and men

			Association between education and mediator	Association between mediator and BMI*	Mediated effect (indirect effect)	
Mediator	**Education** (Ref: High education)	**Gender**	**a-path (95% CI)**	**b-path (95% CI)**	**a x b (95% CI)**	**Proportion mediated**
Fruit and vegetables	Middle	W	-1.37 (-2.30, -0.45)	-0.03 (-0.05, -0.02)	0.05 (0.01, 0.09)	4.8%
		M	-1.38 (-3.21, 0.43)	-0.01 (-0.04, 0.02)	0.02 (-0.03, 0.08)	1.7%
	Low	W	-4.44 (-5.45, -3.40)	-0.03 (-0.05, -0.02)	0.15 (0.08, 0.23)	5.4%
		M	-5.67 (-7.36, -3.99)	-0.01 (-0.04, 0.02)	0.07 (-0.09, 0.23)	4.0%
Red and processed meat	Middle	W	0.36 (0.16, 0.55)	0.11 (0.04, 0.18)	0.04 (0.01, 0.07)	3.9%
		M	0.62 (0.16, 1.08)	0.14 (0.04, 0.25)	0.09 (0.01, 0.19)	9.2%
	Low	W	0.56 (0.35, 0.78)	0.11 (0.04, 0.18)	0.06 (0.02, 0.11)	2.1%
		M	0.83 (0.40, 1.25)	0.14 (0.04, 0.25)	0.12 (0.03, 0.23)	7.2%
Sweets and confectionery	Middle	W	-0.13 (-0.40, 0.15)	-0.03 (-0.08, 0.02)	0.00 (-0.01, 0.02)	0.3%
		M	-1.16 (-1.71, -0.64)	-0.03 (-0.15, 0.09)	0.04 (-0.12, 0.18)	3.6%
	Low	W	-0.26 (-0.56, 0.03)	-0.03 (-0.08, 0.02)	0.01 (-0.01, 0.03)	0.2%
		M	-0.88 (-1.44, -0.32)	-0.03 (-0.15, 0.09)	0.03 (-0.09, 0.15)	1.6%

Table 3. *Continued*

			Association between education and mediator	Association between mediator and BMI*	Mediated effect (indirect effect)	
Mediator	**Education** (Ref: High education)	**Gender**	**a-path (95% CI)**	**b-path (95% CI)**	**a x b (95% CI)**	**Proportion mediated**
Alcohol	Middle	W	-0.24 (-0.46, -0.02)	0.04 (-0.01, 0.1)	-0.01 (-0.03, 0.00)	-1.1%
		M	0.51 (-0.41, 1.50)	0.02 (-0.04, 0.09)	0.01 (-0.03, 0.08)	1.2%
	Low	W	-0.33 (-0.58, -0.08)	0.04 (-0.01, 0.1)	-0.02 (-0.04, 0.00)	-0.5%
		M	0.41 (-0.50, 1.38)	0.02 (-0.04, 0.09)	0.01 (-0.03, 0.07)	0.5%
Vigorous physical activity	Middle	W	-5.77 (-7.99, -3.56)	-0.03 (-0.04, -0.03)	0.18 (0.11, 0.26)	18.6%
		M	-1.46 (-7.83, 4.52)	-0.01 (-0.02, -0.01)	0.02 (-0.06, 0.11)	1.9%
	Low	W	-10.89 (-13.19, -8.44)	-0.03 (-0.04, -0.03)	0.35 (0.26, 0.44)	12.1%
		M	-7.78 (-13.71, -1.95)	-0.01 (-0.02, -0.01)	0.10 (0.02, 0.21)	5.8%
Sedentary time	Middle	W	0.1 (-0.06, 0.26)	0.22 (0.14, 0.30)	0.02 (-0.01, 0.06)	2.3%
		M	0.63 (0.24, 1.02)	0.14 (0.01, 0.28)	0.09 (0.01, 0.22)	9.3%
	Low	W	0.1 (-0.09, 0.29)	0.22 (0.14, 0.30)	0.02 (-0.02, 0.07)	0.8%
		M	0.74 (0.38, 1.1)	0.14 (0.01, 0.28)	0.11 (0.01, 0.24)	6.3%
All mediators together	Middle	W	-	-	0.28 (0.18, 0.39)	29.0%
		M	-	-	0.26 (0.02, 0.51)	26.8%
	Low	W	-	-	0.57 (0.44, 0.72)	20.1%
		M	-	-	0.42 (0.18, 0.68)	25.3%

*adjusted for socioeconomic position and other mediators

High education = master's degree or higher, middle education = bachelor's degree, low education = upper secondary or vocational school or lower, BMI = body mass index (body weight in kilograms divided by height in meters squared, kg/m^2), CI = confidence interval, M=men, W=women

4.4 Additional follow-up analysis with adjustment for baseline BMI

4.4.1 Descriptive statistics

After excluding those who had not responded to the follow-up survey, the number of participants was 2,581. The gender distribution remained almost unchanged, but the follow-up sample was somewhat older and more highly educated. The socioeconomic gradient in BMI remained clearly visible in Phase 2. Among women, mean BMI increased by 1.1 kg/m² in the high education group, 1.3 kg/m² in the middle education group, and 1.3 kg/m² in the low education group, reaching 25.4 kg/m², 26.0 kg/m², and 28.5 kg/m² in 2022, respectively. Among men, mean BMI increased by 0.7 kg/m² in the high education group, 0.9 kg/m² in the middle education group, and 0.9 kg/m² in the low education group, reaching 26.0 kg/m², 27.3 kg/m², and 28.0 kg/m² in 2022, respectively. Thus, BMI increased over follow-up in all education groups, but the highest BMI levels were consistently observed in the low education group, and the increase was more pronounced among women. The categorical BMI distribution showed a similar development, with the proportion of overweight and obesity increasing and normal weight decreasing. The complete characteristics of the follow-up sample are presented in Table 4.

Table 4. Descriptive characteristics of the Helsinki Health Study participants who responded in both Phases 1 (2017) and 2 (2022).

		All	**Women** (n=2070, 80.2%)			**Men** (n=511, 19.8%)			**P-value***
Education			High	Middle	Low	High	Middle	Low	
Total		2581	835 (32.4)	754 (29.2)	481 (18.6)	182 (7.1)	151 (5.9)	178 (6.7)	
Age (n (%))	19–29 years	725 (28.0)	158 (19.0)	268 (35.5)	173 (36.0)	25 (13.7)	46 (30.5)	53 (29.8)	<0.001
	30–39 years	1856 (72.0)	675 (81.0)	486 (64.5)	308 (64.0)	157 (86.3)	105 (69.5)	125 (70.2)	
BMI, kg/m² (Phase 1) (mean (SD))		25.34 (5.32)	24.26 (4.47)	24.72 (5.04)	27.18 (6.98)	25.38 (4.08)	26.41 (3.80)	27.14 (5.30)	<0.001
BMI categorized (Phase 1) (n (%))	Normal weight and underweight	1511 (58.5)	569 (68.1)	494 (65.5)	220 (45.7)	97 (53.3)	60 (39.7)	71 (39.9)	<0.001
	Overweight	672 (26.0)	182 (21.8)	161 (21.4)	132 (27.4)	66 (36.3)	62 (41.1)	69 (38.8)	
	Obesity	398 (15.4)	84 (10.1)	99 (13.1)	129 (26.8)	19 (10.4)	29 (19.2)	38 (21.3)	
BMI, kg/m² (Phase 2) (mean (SD))		26.47 (5.77)	25.36 (5.05)	25.99 (5.61)	28.51 (7.17)	26.03 (4.60)	27.26 (4.26)	28.01 (5.88)	<0.001
BMI categorized (Phase 2) (n (%))	Normal weight and underweight	1259 (48.8)	480 (57.5)	407 (54.0)	180 (37.4)	85 (46.7)	49 (32.5)	58 (32.6)	<0.001
	Overweight	787 (30.5)	237 (28.4)	203 (26.9)	134 (27.9)	73 (40.1)	70 (46.4)	70 (39.3)	
	Obesity	535 (20.7)	118 (14.1)	144 (19.1)	167 (34.7)	24 (13.2)	32 (21.2)	50 (28.1)	

* P-values were calculated using χ^2 test for categorical variables and a t-test for mean BMI

High education = master's degree or higher, middle education = bachelor's degree, low education = upper secondary or vocational school or lower, BMI = body mass index (body weight in kilograms divided by height in meters squared, kg/m²), SD = standard deviation

4.4.2 Gender difference in the association

The gender interaction in the SEP–BMI association in Phases 1 and 2 among those who had responded to the follow-up survey (n = 2,581) is shown in Figure 5. By 2022, mean BMI had increased in all education groups, but the inverse gradient remained. The gender differences had narrowed, meaning that weight gain was more pronounced in women. At follow-up, education remained strongly associated with BMI ($p < 0.001$), whereas gender-BMI association no longer reached statistical significance ($p = 0.085$). However, the education × gender interaction remained significant ($p = 0.040$), meaning that the gender difference in the association between SEP and BMI remained.

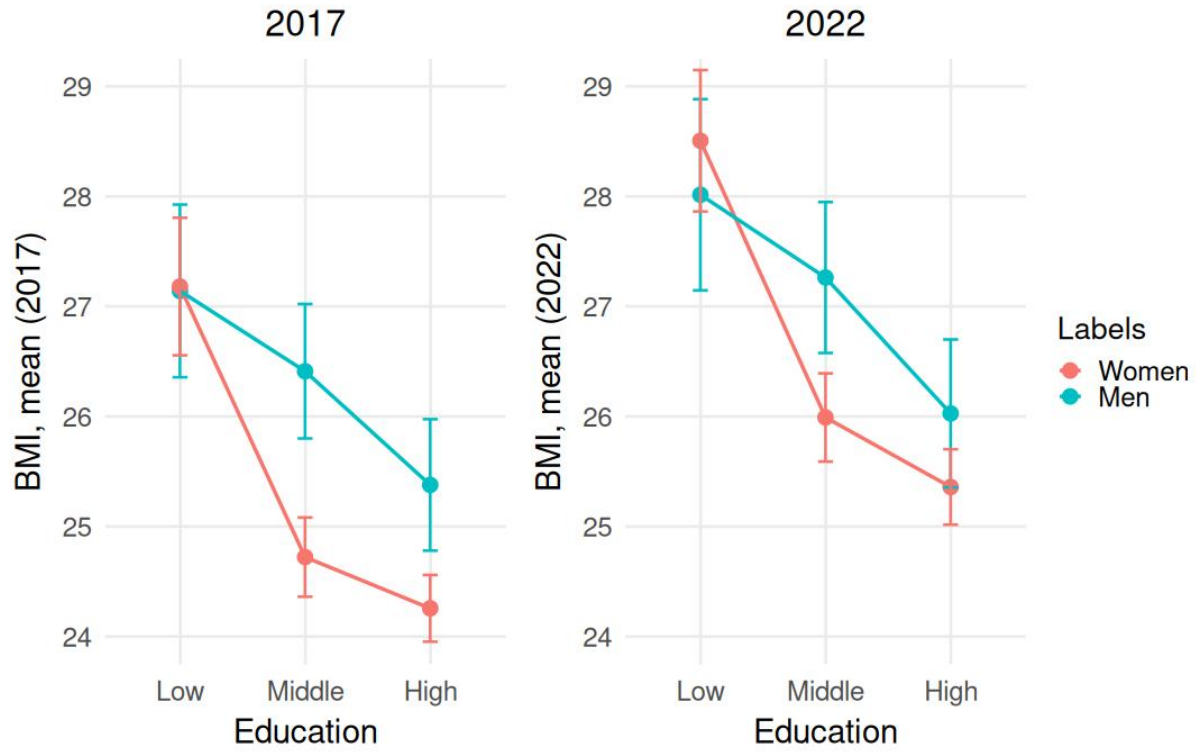


Figure 5. Gender differences in the association between socioeconomic position and body mass index in the Helsinki Health Study Cohort (n = 2,581) in Phases 1 (2017) and 2 (2022). Points represent means and error bars represent their 95% confidence intervals. High education = master's degree or higher, middle education = bachelor's degree, low education = upper secondary or vocational school or lower, BMI = body mass index (body weight in kilograms divided by height in meters squared, kg/m²)

4.4.3 The mediating role of dietary factors and physical activity

4.4.3.1 Total effect of socioeconomic position on follow-up BMI

After adjustment for age and baseline BMI, the total effects of SEP on follow-up BMI were small and not statistically significant in either gender (Table 5). Compared with participants with high education, the total effect of middle education on follow-up BMI was 0.11 (95% CI −0.13, 0.34) among women and 0.13 (95% CI −0.27, 0.54) among men. The corresponding total effects for low versus high education were 0.23 (95% CI −0.12, 0.56) among women and 0.13 (95% CI −0.32, 0.56) among men.

4.4.3.2 Exposure–mediator relationship (a-path)

The associations between educational attainment and the mediators were broadly similar to those observed in the cross-sectional analyses (Table 5). In both women and men, compared with participants with high education, those with middle and low education had lower consumption of fruit and vegetables, higher consumption of red and processed meat, and lower VPA. In addition, lower education was associated with lower alcohol consumption among women, whereas among men it was associated with lower consumption of sweets and confectionery and greater sedentary time.

4.4.3.3 Mediator–outcome relationship (b-path)

After adjustment for baseline BMI, the associations between the mediators and follow-up BMI were substantially attenuated compared with the cross-sectional analyses (Table 5). Among women, only higher consumption of red and processed meat remained statistically significant and positively associated with follow-up BMI (b = 0.06, 95% CI 0.01, 0.10). Among men, the statistically significant b-paths were higher consumption of sweets and confectionery, which was positively associated with follow-up BMI (b = 0.09, 95% CI 0.03, 0.15), and higher consumption of fruit and vegetables, which was associated with lower follow-up BMI (b = -0.02, 95% CI -0.04, -0.01).

4.4.3.4 Indirect effect of socioeconomic position on follow-up BMI through dietary factors and physical activity

The indirect effects of SEP on follow-up BMI were generally small (Table 5). Among women, significant indirect effects were observed through red and processed meat consumption for both the middle versus high education (0.02, 95% CI 0.003, 0.04) and the low versus high education (0.03, 95% CI 0.005, 0.07). VPA also showed significant indirect effects among women (middle vs high: 0.02, 95% CI 0.002, 0.04; low vs high: 0.04, 95% CI 0.006, 0.09). Among men, significant indirect effects were observed through fruit and vegetable consumption for the low versus high education (0.14, 95% CI 0.03, 0.27) and through sweets and confectionery consumption for both the middle versus high (−0.09, 95% CI −0.19, −0.02) and the low versus high (−0.10, 95% CI −0.20, −0.03) education comparisons. No significant indirect effects were observed through alcohol consumption or sedentary time in either gender.

The summed indirect effects across all mediators were not statistically significant in any group (women: middle vs high 0.03, 95% CI −0.01, 0.07; low vs high 0.06, 95% CI 0.00, 0.14; men: middle vs high −0.09, 95% CI −0.26, 0.05; low vs high −0.02, 95% CI −0.20, 0.15). Because the total effects were small and close to zero after adjustment for baseline BMI, mediated proportions were not calculated. Additionally, since the results were largely attenuated compared to the cross-sectional model, no statistical testing for gender differences was done. The longitudinal model adjusting for baseline BMI suggests that the educational differences in BMI were present already at Phase 1 and that Phase 2 BMI was largely explained by prior BMI rather than by subsequent BMI change explained by the mediators.

Table 5. The mediating role of dietary factors and physical activity in the association between SEP and follow-up BMI among women and men adjusted for age and baseline BMI

			Association between education and mediator	Association between mediator and BMI*	Mediated effect (indirect effect)	The total effect of education on BMI
Mediator	**Education** (Ref. High education)	**Gender**	**a-path (95% CI)**	**b-path (95% CI)**	**a x b (95% CI)**	**total (95% CI)**
Fruit and vegetable	Middle	W	-1.12 (-2.29, 0.04)	0 (-0.01, 0.01)	0 (-0.01, 0.02)	0.11 (-0.13, 0.34)
		M	-1.09 (-3.55, 1.35)	-0.02 (-0.04, -0.01)	0.03 (-0.03, 0.10)	0.13 (-0.27, 0.54)
	Low	W	-4.32 (-5.67, -2.99)	0 (-0.01, 0.01)	0.01 (-0.03, 0.06)	0.23 (-0.12, 0.56)
		M	-5.55 (-7.72, -3.46)	-0.02 (-0.04, -0.01)	0.14 (0.03, 0.27)	0.13 (-0.32, 0.56)
Red and processed meat	Middle	W	0.33 (0.10, 0.56)	0.06 (0.01, 0.10)	0.02 (0.003, 0.04)	0.11 (-0.13, 0.34)
		M	0.55 (-0.11, 1.17)	-0.02 (-0.10, 0.05)	-0.01 (-0.08, 0.03)	0.13 (-0.27, 0.54)
	Low	W	0.54 (0.24, 0.84)	0.06 (0.01, 0.10)	0.03 (0.005, 0.07)	0.23 (-0.12, 0.56)
		M	0.80 (0.19, 1.39)	-0.02 (-0.10, 0.05)	-0.02 (-0.10, 0.04)	0.13 (-0.32, 0.56)
Sweets and confectionery	Middle	W	0.02 (-0.31, 0.35)	0.01 (-0.03, 0.05)	0 (-0.01, 0.01)	0.11 (-0.13, 0.34)
		M	-0.98 (-1.70, -0.26)	0.09 (0.03, 0.15)	-0.09 (-0.19, -0.02)	0.13 (-0.27, 0.54)
	Low	W	-0.30 (-0.71, 0.10)	0.01 (-0.03, 0.05)	0 (-0.02, 0.01)	0.23 (-0.12, 0.56)
		M	-1.14 (-1.84, -0.42)	0.09 (0.03, 0.15)	-0.10 (-0.20, -0.03)	0.13 (-0.32, 0.56)
Alcohol	Middle	W	-0.45 (-0.74, -0.15)	0.04 (0, 0.07)	-0.02 (-0.04, 0)	0.11 (-0.13, 0.34)
		M	-0.73 (-1.84, 0.38)	-0.01 (-0.05, 0.03)	0 (-0.03, 0.05)	0.13 (-0.27, 0.54)
	Low	W	-0.51 (-0.84, -0.17)	0.04 (0, 0.07)	-0.02 (-0.05, 0)	0.23 (-0.12, 0.56)
		M	-0.28 (-1.51, 0.95)	-0.01 (-0.05, 0.03)	0 (-0.02, 0.05)	0.13 (-0.32, 0.56)

Table 5. *Continued*

			Association between education and mediator	Association between mediator and BMI*	Mediated effect (indirect effect)	The total effect of education on BMI
Mediator	**Education** (Ref. High education)	**Gender**	**a-path (95% CI)**	**b-path (95% CI)**	**a x b (95% CI)**	**total (95% CI)**
Vigorous physical activity	Middle	W	-4.11 (-6.69, -1.49)	-0.003 (-0.01, 0)	0.02 (0.002, 0.04)	0.11 (-0.13, 0.34)
		M	-2.86 (-10.39, 4.80)	0 (0, 0)	0 (-0.02, 0.02)	0.13 (-0.27, 0.54)
	Low	W	-9.16 (-12.05, -6.30)	-0.002 (-0.01, 0)	0.04 (0.006, 0.09)	0.23 (-0.12, 0.56)
		M	-4.50 (-11.93, 2.91)	0 (0, 0)	0 (-0.03, 0.03)	0.13 (-0.32, 0.56)
Sedentary time	Middle	W	0.15 (-0.06, 0.36)	0.04 (-0.02, 0.09)	0 (-0.01, 0.02)	0.11 (-0.13, 0.34)
		M	0.40 (-0.08, 0.87)	-0.06 (-0.19, 0.05)	-0.03 (-0.10, 0.02)	0.13 (-0.27, 0.54)
	Low	W	-0.01 (-0.26, 0.25)	0.04 (-0.02, 0.09)	0 (-0.01, 0.01)	0.23 (-0.12, 0.56)
		M	0.62 (0.18, 1.07)	-0.06 (-0.19, 0.05)	-0.04 (-0.15, 0.03)	0.13 (-0.32, 0.56)
Total	Middle	W	-	-	0.03 (-0.01, 0.07)	
		M	-	-	-0.09 (-0.26, 0.05)	
	Low	W	-	-	0.06 (0, 0.14)	
		M	-	-	-0.02 (-0.20, 0.15)	

*adjusted for education and other mediators

High education = master's degree or higher, middle education = bachelor's degree, low education = upper secondary or vocational school or lower, BMI = body mass index (body weight in kilograms divided by height in meters squared, kg/m^2), CI = confidence interval, M=men, W=women

5 Discussion

5.1 Main findings

This thesis was set to examine gender differences in the SEP–BMI association and to determine whether mediation of dietary factors and physical activity in the SEP–BMI association differs between women and men. The main finding was that the association between SEP and BMI was stronger among women than among men, and that the difference was partly explained by dietary factors and physical activity.

VPA and red and processed meat consumption were significant mediators in both genders, although VPA explained a larger part of the SEP–BMI association among women. Additional statistically significant mediators were consumption of fruit and vegetables among women and sedentary time in men, while alcohol and sweets and confectionery consumption did not mediate the SEP–BMI association in either gender. The only statistically significant gender difference in the mediated effect was found for VPA. Additional follow-up analyses with 5-year follow-up BMI as the outcome, adjusting for baseline BMI, suggested that educational differences in follow-up BMI were largely explained by baseline BMI instead of the mediators.

5.2 Comparison to previous literature

First, I wanted to find out whether socioeconomic differences in BMI differed between men and women, and the results suggested that the negative SEP–BMI association is more pronounced among women. Thus, this part of the hypothesis was supported, and it is also in line with previous research. The steeper SEP–BMI gradient has been shown in the Finnish population and internationally [8,11]. SEP tends to be associated with obesity regardless of the indicator used, but in studies examining multiple SEP indicators, the associations with body weight have generally been more consistent among women and more variable among men [99–102].

Lower SEP was associated with a less favorable behavioral profile in both genders, including lower consumption of fruit and vegetables, higher red and processed meat consumption, and lower VPA. The educational differences in diet quality were in line with the Finnish national dietary surveys [12] as well as international evidence, where the clearest support is seen for fruit and vegetable consumption [13,67]. Regarding physical activity and sedentary time, clear socioeconomic gradients were observed in VPA, which is consistent with previous literature [25,112]. Higher levels of VPA among the highly educated may reflect greater participation in organized sports. The pattern for sedentary time was less clear, although the socioeconomic gradient appeared somewhat stronger among men. These inconsistencies may be explained by differences between domains, which my thesis did not consider [20]. Because this thesis measured only leisure-time VPA, the observed socioeconomic patterning may reflect the possibility that lower educated individuals accumulate more occupational physical activity and less occupational sedentary time, whereas higher educated individuals engage more in leisure-time physical activity but may also have more sedentary work.

Gender differences related to dietary factors and physical activity were consistent with prior national and international evidence [12,87,135]. Overall, women had a better dietary quality. Women consumed more fruit and vegetables, less red and processed meats and less alcohol compared to men. However, women consumed a little more sweets and confectionery. These are strongly in line with the Finnish national dietary surveys [12]. Men, on the other hand, had higher levels of VPA but regarding sedentary time, there were no clear gender differences, both of which are in line with recent Finnish evidence [20,38].

Second, I wanted to examine the extent to which dietary factors (fruit and vegetable consumption, red and processed meat consumption, sweets and confectionery consumption, and alcohol consumption) and physical activity (VPA and sedentary time) mediate the association between SEP and BMI and whether the mediation pathways differ between men and women. I hypothesized that the mediated effects would be larger among women, and this was partly supported because the estimates tended to be larger among women. SEP–BMI mediation pathways differed by gender, which is largely in line with previous research. Despite the partly different behaviors included

across studies, the overall magnitudes of the individual mediators explaining the SEP–BMI association were broadly similar to my results [121–124].

The finding that fruit and vegetable consumption mediated the association among women is consistent with previous studies showing significant indirect effects through fruit and vegetable consumption [121,122,127]. It is possible that those with a high consumption of fruit and vegetables have a healthier dietary pattern in general, which means that the association may partly reflect broader diet quality rather than the independent effect of fruit and vegetable consumption. Similarly, the mediating role of VPA among women aligns with earlier findings [121,123,124,127]. The stronger mediating role of VPA among women may reflect larger socioeconomic differences in leisure-time physical activity. Women with lower SEP may face more social, financial, or time-related constraints to engaging in vigorous leisure-time activity, which could strengthen the role of VPA as a mediator. In contrast, sedentary time mediated the association only among men in the present thesis, whereas the Finnish study found sedentary time to be a mediator in both genders [121]. My results may reflect stronger socioeconomic patterning of sedentary time among men, possibly due to differences in occupational and leisure-time sitting across educational groups.

Alcohol consumption also differed from some previous findings, as it did not mediate the SEP–BMI association in either gender in this thesis, while earlier Finnish and Australian studies identified alcohol as a mediator among women [121,123]. Total frequency, which was used in this thesis, may not capture other aspects of alcohol use that may be relevant, such as binge drinking, beverage type, or drinking context. In this thesis, red and processed meat consumption mediated the association in both genders and proportion mediated appeared larger among men, although this was not confirmed statistically. Previous studies have not examined red and processed meat separately, but this result is partly comparable to the Australian cross-sectional study in which unhealthy savory foods were important mediators in both women and men [123]. Red and processed meat consumption could reflect a broader dietary pattern with higher energy density, which makes it a relevant indicator for higher BMI.

In the follow-up analysis, BMI increased in both genders and in all educational groups during the 5-year follow-up, which is in line with other Finnish studies [3]. However, there was a faster increase in BMI among women than among men, which has not yet been shown in prior studies. The gender differences and educational gradients remained visible, and previous research suggests that socioeconomic differences in body weight are relatively stable over time [136]. In additional mediation analyses with a 5-year follow-up BMI adjusted for baseline BMI, educational differences in BMI were largely explained by baseline BMI rather than by the mediators. In one longitudinal study BMI gain was partly explained by health behaviors [124]. However, that study had a 13-year follow-up, during which educational differences in BMI gain were detected. It is possible that the 5-year follow-up was too short to detect clear differences in BMI change.

5.3 Sensitivity analyses

Due to missing values, I conducted a sensitivity analysis using multiple imputations by chained equations (MICE) with a sample of size of 5,897 and 20 imputations. MICE is a statistical method used to fill in missing data in a dataset [137]. The complete results of MICE are shown in Appendix 2. In the method, several complete datasets are created by running a series of separate prediction models in cycles. The MICE results were broadly consistent with the complete-case analyses in terms of the direction of associations and the overall interpretation. However, because the imputed analyses used a larger analytic sample and therefore produced narrower CIs, several additional small indirect effects reached statistical significance, particularly among men where the initial sample size was smaller. Consumption of fruit and vegetables showed evidence of mediation in men contrary to the main model, whereas the estimates of sweets and confectionery and alcohol consumption remained very small in both genders. Sedentary time showed significant mediation in women, whereas before it did not. The MICE results therefore suggest that the gender differences in the mediators may be less clear than indicated by the complete-case analysis. However, VPA was clearly more prominent among women and red and processed meat consumption more prominent among men, while fruit and vegetables appeared similarly important in both genders.

Because not all mediators were normally distributed, I examined median values in the descriptive analysis. For all mediators except meat, socioeconomic gradients and gender differences were consistent with the mean-based results. For red and processed meat consumption, the differences disappeared, with a median consumption of 3 servings per week in all groups. This suggests that the distribution between groups differs, which was confirmed visually using histograms, although the differences were quite small (Appendix 3). Women and men with high education had relatively more observations in the lower range of consumption, whereas women and men with low education had relatively more observations in the higher range. The non-normality of some mediators was not a concern in the main analyses, because the normality assumption concerns the model residuals rather than the observed variables [138]. Visual residual plots did not indicate substantial deviations from normality. In addition, bootstrapped CIs were used for the indirect effects, which is recommended because the sampling distribution of indirect effects is often non-normal [131].

I also tested subjective sleep quality and total physical activity as additional mediators. These variables did not show statistically significant indirect effects and were therefore not included in the main mediation models. I decided to include dietary factors and physical activity because they are directly linked to weight through either energy intake or expenditure and are socioeconomically patterned.

5.4 Methodological considerations

This thesis has several strengths. It used a relatively large occupational cohort of young and early midlife employees in which socioeconomic inequalities in BMI were clearly seen. The analyses were gender-stratified and the differences in the mediators were additionally tested statistically, which allowed the mediating pathways to be compared between women and men. Multiple dietary and activity-related mediators were examined simultaneously, reducing the risk of overestimating the role of any single behavior. In addition, the analyses were in-depth with the complete-case results being compared with both a MICE-model and a follow-up model adjusted for baseline BMI.

Regarding the study population, this thesis used a large occupational cohort of young adults aged 19–39 years, including both manual and non-manual employees. Although the data may be generalized with caution to the working-age Finnish population, they cannot be directly generalized to the entire adult population because the cohort consisted only of employees of the City of Helsinki. However, there is no particular reason to assume that the results would be different among other Finnish working-age adults working in different municipalities. A healthy worker effect is likely, as the lowest SEP group in this thesis does not represent the most socioeconomically disadvantaged groups in society, such as the long-term unemployed [139]. I also excluded telephone interviewees, and prior studies have shown that those who responded via email or mail are often more highly educated [128].

Regarding measurements, all variables were based on self-report. Self-reported height and weight may introduce bias, although they are generally considered sufficiently accurate for epidemiological research [52,53]. Additionally, both predictors and outcomes were measured by a questionnaire, so common method bias is possible [140]. The dietary measure was based on a short FFQ that was not formally validated and did not include portion sizes, meaning that absolute consumption could not be estimated. However, short FFQs have been shown to be suitable for assessing group-level differences in frequently consumed foods [141,142] and portion-size questions may contribute relatively little to variance in consumption [143]. The similarity between my results and the national dietary survey, which uses a more precise data collection method, supports the FFQ's validity [12]. Similarly, the physical activity and sedentary time questionnaires were not validated in this cohort, although comparable measures have shown acceptable validity in epidemiological studies [144,145]. Gender was obtained from a national register for those with consent and for others, from the questionnaire. Thus, the measure mainly reflects legally registered gender, which does not fully capture gender as a social and cultural construct. Finally, education was used as the SEP indicator in this thesis, so it remains to be seen whether the observed gender differences in SEP–BMI association in this study population would be equally consistent if other SEP indicators were used.

Regarding statistical analysis, the statistical method used in this thesis, structural equation modeling, is built on the previous findings suggesting a relationship between SEP and BMI through less favorable health behaviors and is therefore a justified method for this research question. However, the main analytical approach was cross-sectional, which does not allow for causal conclusions. Because it is justified to assume that gender and SEP cannot be caused by health behaviors, measuring these variables at the same time point as the mediators is unlikely to disturb the assumed temporal ordering. With regard to health behaviors and BMI, temporal ordering is more important since in theory, a higher BMI could cause less favorable health behaviors, such as a decrease in VPA. In a well-designed mediation study, there should be three time points and mediators should be measured between the exposure and the outcome [131].

Despite the abovementioned reasons, the cross-sectional model was chosen as the main analysis to maximize statistical power and minimize participant loss to follow-up. Using Phase 2 BMI as the outcome without adjustment for Phase 1 BMI would have provided little additional information, because Phase 1 and Phase 2 BMI were strongly correlated ($r = 0.91$) and the smaller follow-up sample would have reduced statistical power. Although I also conducted a follow-up analysis, this did not fully overcome the limitations of the cross-sectional design because dietary factors and physical activity were still measured at the same time as SEP. In addition, the follow-up sample was smaller and more selective. However, the main interest of this thesis was to examine which health behaviors were associated with higher BMI and whether they mediated the SEP–BMI association, not the explanations for a 5-year change in BMI. When Phase 1 BMI was adjusted for, the indirect effects were largely attenuated, suggesting that five years may not be a sufficient follow-up period for differences in BMI trajectories to become visible.

An additional limitation was the small number of men. The sample was mostly women (80%), which reduced statistical power in the male subgroup and may partly explain why some associations among men were not statistically significant. This limitation was considered when interpreting the wider CIs observed among men. In the complete-case analysis women had three significant mediators (meat, VPA, fruit and vegetables), whereas men had two (meat, sedentary time) for both middle and low education

comparisons. VPA in men was significant for only the low-high comparison in the main model. After MICE analysis, several indirect effects among men became statistically significant. However, many of the newly significant effects were small, and the interpretation remained that the relative importance of certain mediators, such as red and processed meat consumption and VPA, differed by gender. Finally, mediation models were adjusted only for age, so some residual confounding may remain. This approach was chosen in line with previous studies and to maximize statistical power, as the sample size would not have necessarily been sufficient to adjust for several additional factors while already including six mediators in the model [11,123,124].

5.5 Implications and Future Directions

The results suggest that socioeconomic differences in BMI are not explained by a single behavioral pathway, but rather by a myriad of factors, with some mechanisms being gender-specific. For example, improving VPA may be relevant among women with lower SEP, whereas reducing red and processed meat consumption could be a target in both genders. The faster 5-year weight gain and stronger SEP–BMI gradient suggest that women, especially those with lower SEP, may be more vulnerable to weight gain, so health policies should focus on this group. Since my findings suggest that men and women differ in the types of health behaviors that mediate the SEP–BMI association, future studies should examine mediation pathways separately by gender and consider how gender intersects with other dimensions of social position, such as income, occupation, and migration background.

Because the six mediators explained only about one quarter of the SEP–BMI association, the findings indicate the importance of other mechanisms being potential mediators of the SEP–BMI association. Socioeconomic inequalities in BMI are produced through multiple interacting pathways, including psychosocial, material, environmental, occupational, and biological mechanisms. Future studies should therefore include mediators such as psychosocial stress, sleep, mental health, weight stigma, food environments, access to physical activity facilities and working conditions, to give a few

examples. Studies should also examine more complex sequential mediation pathways involving multiple mediators, such as whether lower SEP leads to greater financial strain, which may reduce fruit and vegetable consumption and contribute to a higher body weight. Future research should also pay more attention to gender-specific mechanisms, such as psychosocial stress, caregiving responsibilities, weight stigma and reproductive transitions, which may affect women more strongly.

Future studies would benefit from longitudinal designs with repeated measurements of both mediators and BMI over an adequate follow-up period, allowing changes and causal pathways to be examined more clearly. Longer follow-up times would also make it possible to study weight change and its determinants across SEP. This would help clarify whether socioeconomic differences in BMI are mainly explained by baseline differences in mediators, changes in mediators over time, or BMI trajectories that begin earlier in the life course. In addition, future studies should use multiple indicators of SEP to help clarify whether different dimensions operate through different mediating pathways. Finally, future research should move beyond identifying mediators toward understanding how these pathways could be modified. Effective prevention should focus on factors that support sustainable behavior change, such as improving access to affordable healthy foods and creating low-threshold opportunities for physical activity, while also considering gender-specific approaches.

6 Conclusions

Taken together, these findings suggest that different behavioral mechanisms may underlie socioeconomic differences in BMI in men and women. The association between SEP and BMI was stronger among women than among men. Fruit and vegetable consumption was a significant mediator of the SEP–BMI association in women and sedentary time in men. VPA and red and processed meat consumption acted as mediators in both genders, with VPA having a larger effect in women. The 5-year increase in BMI was more pronounced in women, and the highest BMI levels in follow-up were observed among women with low education. However, follow-up BMI was largely explained by prior BMI, not by the examined mediators. Although weight gain occurred across all SEP groups, socioeconomic disparities in BMI persisted, highlighting the long-standing nature of weight-related inequalities.

These results suggest that prevention of weight gain and the reduction of SEP-related health inequalities should focus on gender-specific approaches. At the same time, because only about one quarter of the SEP–BMI association was explained by the included dietary factors and physical activity patterns, psychological, social, and environmental factors are likely to play an important role in maintaining weight-related, and more broadly health-related, inequalities.

AI statement

ChatGPT (GPT-5.5 Thinking, OpenAI) was used for finding relevant literature, language editing and polishing and during data analysis to support coding, debugging, and the interpretation of the output. All AI-generated outputs were carefully reviewed and checked against the original sources. The content, analyses, interpretations, and conclusions of the thesis are my own.

7 References

1. Kagenaar E, Van Hemelrijck WMJ, Kunst AE, Janssen F. Long-Term Trends in Obesity Prevalence by Socio-Economic Group in Five European Countries and the USA: The Relevance of the Diffusion of Innovations Theory. Obes Facts. 2022;15(6):753–61. doi:10.1159/000527070
2. World Health Organization. Obesity and overweight [Internet]. Geneva: World Health Organization; 2025 [accessed October 5, 2026]. Available from: https://www.who.int/news-room/fact-sheets/detail/obesity-and-overweight
3. Lundqvist A, Jääskeläinen T, Lehtoranta L, Aspholm S, Vessari H, Ojanen A, et al. Age-specific changes in obesity and associated cardiometabolic risk factors: a two-decade study of the Finnish adults. Eur J Public Health. 2026 Feb 1;36(1):162–8. doi:10.1093/eurpub/ckaf186
4. NCD Risk Factor Collaboration (NCD-RisC), Zhou B, Phelps NH, Galeazzi A, O'Driscoll ON, Bennett JE, et al. Obesity rise plateaus in developed nations and accelerates in developing nations. Nature. 2026 May 14;653(8114):510–8. doi:10.1038/s41586-026-10383-0
5. Galobardes B, Lynch J, Smith GD. Measuring socioeconomic position in health research. Br Med Bull. 2007 Feb 6;81–82(1):21–37. doi:10.1093/bmb/ldm001
6. Braveman PA, Cubbin C, Egerter S, Chideya S, Marchi KS, Metzler M, et al. Socioeconomic Status in Health Research: One Size Does Not Fit All. JAMA. 2005 Dec 14;294(22):2879. doi:10.1001/jama.294.22.2879
7. Newton S, Braithwaite D, Akinyemiju TF. Socio-economic status over the life course and obesity: Systematic review and meta-analysis. PLOS ONE. 2017 May 16;12(5):e0177151. doi:10.1371/journal.pone.0177151
8. Witkam R, Gwinnutt JM, Humphreys J, Gandrup J, Cooper R, Verstappen SMM. Do associations between education and obesity vary depending on the measure of obesity used? A systematic literature review and meta-analysis. SSM Popul Health. 2021 Sep;15:100884. doi:10.1016/j.ssmph.2021.100884
9. Autret K, Bekelman TA. Socioeconomic Status and Obesity. J Endocr Soc. 2024 Sep 26;8(11):bvae176. doi:10.1210/jendso/bvae176
10. Lahti-Koski M. Body mass index and obesity among adults in Finland: trends and determinants [Doctoral dissertation] [Internet]. Helsinki: University of Helsinki; 2001 [accessed October 5, 2026]. Available from: http://hdl.handle.net/10138/20332

11. Prättälä R, Sippola R, Lahti-Koski M, Laaksonen MT, Mäkinen T, Roos E. Twenty-five year trends in body mass index by education and income in Finland. BMC Public Health. 2012 Dec;12(1):936. doi:10.1186/1471-2458-12-936

12. Finnish Institute for Health and Welfare. Ravitsemus Suomessa: FinRavinto 2017 -tutkimus [Internet]. Helsinki: Finnish Institute for Health and Welfare; 2018 [accessed October 5, 2026]. Available from: https://www.julkari.fi/handle/11111/31994

13. De Irala-Estévez J, Groth M, Johansson L, Oltersdorf U, Prättälä R, Martínez-González M. A systematic review of socio-economic differences in food habits in Europe: consumption of fruit and vegetables. Eur J Clin Nutr. 2000 Sep 1;54(9):706–14. doi:10.1038/sj.ejcn.1601080

14. Kristoffersen E, Hjort SL, Thomassen LM, Arjmand EJ, Perillo M, Balakrishna R, et al. Umbrella Review of Systematic Reviews and Meta-Analyses on the Consumption of Different Food Groups and the Risk of Overweight and Obesity. Nutrients. 2025 Feb 13;17(4):662. doi:10.3390/nu17040662

15. Händel MN, Rohde JF, Larsen SC, Sørensen TIA, Heitmann BL. Processed Meat Intake and Changes in Weight, Waist, Body Mass Index, and Fat Mass: Systematic Literature Review, Meta-Analysis, and GRADE Assessment of Cohort Studies of Adults. Nutr Rev. 2025 Oct 1;83(10):1827–42. doi:10.1093/nutrit/nuaf030

16. Schlesinger S, Neuenschwander M, Schwedhelm C, Hoffmann G, Bechthold A, Boeing H, et al. Food Groups and Risk of Overweight, Obesity, and Weight Gain: A Systematic Review and Dose-Response Meta-Analysis of Prospective Studies. Adv Nutr. 2019 Mar;10(2):205–18. doi:10.1093/advances/nmy092

17. Sayon-Orea C, Martinez-Gonzalez MA, Bes-Rastrollo M. Alcohol consumption and body weight: a systematic review. Nutr Rev. 2011 Aug;69(8):419–31. doi:10.1111/j.1753-4887.2011.00403.x

18. Jakicic JM, Powell KE, Campbell WW, Dipietro L, Pate RR, Pescatello LS, et al. Physical Activity and the Prevention of Weight Gain in Adults: A Systematic Review. Med Sci Sports Exerc. 2019 Jun;51(6):1262–9. doi:10.1249/MSS.0000000000001938

19. Päivärinne V, Salmela J, Lahti J, Pietiläinen O, Karjala A, Kouvonen A, et al. Life-course socioeconomic circumstances and changes in leisure-time physical activity among young and early midlife employees. Int J Equity Health. 2026 Jan 30;25(1):54. doi:10.1186/s12939-026-02769-3

20. Kekäläinen E, Rahkonen O, Päivärinne V, Nurminen H, Lallukka T. Childhood and current socioeconomic position as determinants of sedentary time among young and early midlife employees. Eur J Public Health. 2025 Oct 1;35(5):916–24. doi:10.1093/eurpub/ckaf152

21. Silveira EA, Mendonça CR, Delpino FM, Elias Souza GV, Pereira De Souza Rosa L, De Oliveira C, et al. Sedentary behavior, physical inactivity, abdominal obesity and obesity in adults and older adults: A systematic review and meta-analysis. Clin Nutr ESPEN. 2022 Aug;50:63–73. doi:10.1016/j.clnesp.2022.06.001

22. Biddle SJH, Bengoechea García E, Pedisic Z, Bennie J, Vergeer I, Wiesner G. Screen Time, Other Sedentary Behaviours, and Obesity Risk in Adults: A Review of Reviews. Curr Obes Rep. 2017 Jun;6(2):134–47. doi:10.1007/s13679-017-0256-9

23. Curran F, Davis ME, Murphy K, Tersigni N, King A, Ngo N, et al. Correlates of physical activity and sedentary behavior in adults living with overweight and obesity: A systematic review. Obes Rev. 2023 Nov;24(11):e13615. doi:10.1111/obr.13615

24. Beaulieu K, Hopkins M, Blundell J, Finlayson G. Homeostatic and non-homeostatic appetite control along the spectrum of physical activity levels: An updated perspective. Physiol Behav. 2018 Aug;192:23–9. doi:10.1016/j.physbeh.2017.12.032

25. Beenackers MA, Kamphuis CB, Giskes K, Brug J, Kunst AE, Burdorf A, et al. Socioeconomic inequalities in occupational, leisure-time, and transport related physical activity among European adults: A systematic review. Int J Behav Nutr Phys Act. 2012;9(1):116. doi:10.1186/1479-5868-9-116

26. Rodriguez Roca B, Tully MA, Sansano-Nadal O, Caserotti P, Coll-Planas L, Roqué M, et al. Is education level, as a proxy for socio-economic position, related to device-measured and self-reported sedentary behavior in European older adults? A cross-sectional study from the SITLESS project. Front Public Health. 2023 Dec 19;11:1296821. doi:10.3389/fpubh.2023.1296821

27. Krieger N, Williams DR, Moss NE. Measuring Social Class in US Public Health Research: Concepts, Methodologies, and Guidelines. Annu Rev Public Health. 1997 May;18(1):341–78. doi:10.1146/annurev.publhealth.18.1.341

28. O'Campo P, Burke J. Appendix C: Recommendations on the use of socioeconomic position indicators to better understand racial inequalities in health. In: Eliminating Health Disparities: Measurement and Data Needs [Internet]. Washington, DC: National Academies Press; 2004 [accessed October 10, 2026]. Available from: https://www.ncbi.nlm.nih.gov/books/NBK215756/

29. Kaufman M, Eschliman E, Sanchez Karver T. Differentiating sex and gender in health research to achieve gender equity. Bull World Health Organ. 2023 Oct 1;101(10):666–71. doi:10.2471/BLT.22.289310

30. Masella R, Malorni W. Gender-related differences in dietary habits. Clin Manag Issues. 2017 Jul 10;11(2). doi:10.7175/cmi.v11i2.1313

31. Gochman DS. Health behavior. In: Gochman DS, editor. Health Behavior [Internet]. Boston, MA: Springer US; 1988 [accessed October 5, 2026]. p. 3–17. Available from: http://link.springer.com/10.1007/978-1-4899-0833-9_1. doi:10.1007/978-1-4899-0833-9_1

32. Popkin BM. An overview on the nutrition transition and its health implications: the Bellagio meeting. Public Health Nutr. 2002 Feb;5(1a):93–103. doi:10.1079/PHN2001280

33. Herforth A, Arimond M, Álvarez-Sánchez C, Coates J, Christianson K, Muehlhoff E. A Global Review of Food-Based Dietary Guidelines. Adv Nutr. 2019 Jul;10(4):590–605. doi:10.1093/advances/nmy130

34. Erkkola M, Schwab U, Itkonen S, Lamberg-Allardt C, Männistö S. Miten ravitsemus- ja ruokasuosituksia laaditaan? Lääketieteellinen Aikakauskirja Duodecim [Internet]. 2023 [accessed October 5, 2026];139(18). Available from: https://www.duodecimlehti.fi/duo17852

35. DiPietro L, Buchner DM, Marquez DX, Pate RR, Pescatello LS, Whitt-Glover MC. New scientific basis for the 2018 U.S. Physical Activity Guidelines. J Sport Health Sci. 2019 May;8(3):197–200. doi:10.1016/j.jshs.2019.03.007

36. UKK Institute. Physical activity guidelines for adults [Internet]. Tampere: UKK Institute; 2019 [accessed October 5, 2026]. Available from: https://ukkinstituutti.fi/liikkuminen/liikkumisen-suositukset/aikuisten-liikkumisen-suositus/

37. National Nutrition Council, Finnish Institute for Health and Welfare. Kestävää terveyttä ruoasta: kansalliset ravitsemussuositukset 2024 [Internet]. Helsinki: Finnish Institute for Health and Welfare; 2024 [accessed October 5, 2026]. Available from: https://urn.fi/URN:ISBN:978-952-408-405-5

38. Ministry of Social Affairs and Health. Istu vähemmän – voi paremmin! Kansalliset suositukset istumisen vähentämiseen [Internet]. Helsinki: Ministry of Social Affairs and Health; 2015 [accessed October 5, 2026]. Available from: https://urn.fi/URN:ISBN:978-952-00-3726-0

39. Shaw PA, Deffner V, Keogh RH, Tooze JA, Dodd KW, Küchenhoff H, et al. Epidemiologic analyses with error-prone exposures: review of current practice and recommendations. Ann Epidemiol. 2018 Nov;28(11):821–8. doi:10.1016/j.annepidem.2018.09.001

40. Alkerwi A. Diet quality concept. Nutrition. 2014 Jun;30(6):613–8. doi:10.1016/j.nut.2013.10.001

41. Bailey RL. Overview of dietary assessment methods for measuring intakes of foods, beverages, and dietary supplements in research studies. Curr Opin Biotechnol. 2021 Aug;70:91–6. doi:10.1016/j.copbio.2021.02.007

42. Sylvia LG, Bernstein EE, Hubbard JL, Keating L, Anderson EJ. Practical Guide to Measuring Physical Activity. J Acad Nutr Diet. 2014 Feb;114(2):199–208. doi:10.1016/j.jand.2013.09.018

43. Masood B, Moorthy M. Causes of obesity: a review. Clin Med. 2023 Jul;23(4):284–91. doi:10.7861/clinmed.2023-0168

44. Hall KD, Farooqi IS, Friedman JM, Klein S, Loos RJ, Mangelsdorf DJ, et al. The energy balance model of obesity: beyond calories in, calories out. Am J Clin Nutr. 2022 May;115(5):1243–54. doi:10.1093/ajcn/nqac031

45. Obesity. Current Care Guidelines. Working group set up by the Finnish Society Duodecim, the Finnish Obesity researchers and the Finnish pediatric society. Helsinki: The Finnish Medical Society Duodecim. 2025 [accessed October 5, 2026]. Available online at: https://www.kaypahoito.fi/hoi50124

46. Fernqvist F, Spendrup S, Tellström R. Understanding food choice: A systematic review of reviews. Heliyon. 2024 Jun;10(12):e32492. doi:10.1016/j.heliyon.2024.e32492

47. Ulijaszek SJ, Kerr DA. Anthropometric measurement error and the assessment of nutritional status. Br J Nutr. 1999 Sep;82(3):165–77. doi:10.1017/S0007114599001348

48. Nuttall FQ. Body Mass Index: Obesity, BMI, and Health A Critical Review. Nutr Today. 2015 May;50(3):117–28. doi:10.1097/NT.0000000000000092

49. Ruiz-Castell M, Samouda H, Bocquet V, Fagherazzi G, Stranges S, Huiart L. Estimated visceral adiposity is associated with risk of cardiometabolic conditions in a population based study. Sci Rep. 2021 Apr 27;11(1):9121. doi:10.1038/s41598-021-88587-9

50. Fayyaz K, Bataineh MF, Ali HI, Al-Nawaiseh AM, Al-Rifai' RH, Shahbaz HM. Validity of Measured vs. Self-Reported Weight and Height and Practical Considerations for Enhancing

Reliability in Clinical and Epidemiological Studies: A Systematic Review. Nutrients. 2024 May 30;16(11):1704. doi:10.3390/nu16111704

51. Okorodudu DO, Jumean MF, Montori VM, Romero-Corral A, Somers VK, Erwin PJ, et al. Diagnostic performance of body mass index to identify obesity as defined by body adiposity: a systematic review and meta-analysis. Int J Obes. 2010 May;34(5):791–9. doi:10.1038/ijo.2010.5
52. Davies A, Wellard-Cole L, Rangan A, Allman-Farinelli M. Validity of self-reported weight and height for BMI classification: A cross-sectional study among young adults. Nutrition. 2020 Mar;71:110622. doi:10.1016/j.nut.2019.110622
53. Stommel M, Schoenborn CA. Accuracy and usefulness of BMI measures based on self-reported weight and height: findings from the NHANES & NHIS 2001-2006. BMC Public Health. 2009 Dec;9(1):421. doi:10.1186/1471-2458-9-421
54. Chen C, Ye Y, Zhang Y, Pan XF, Pan A. Weight change across adulthood in relation to all cause and cause specific mortality: prospective cohort study. BMJ. 2019 Oct 16;l5584. doi:10.1136/bmj.l5584
55. Vergnaud AC, Norat T, Romaguera D, Mouw T, May AM, Travier N, et al. Meat consumption and prospective weight change in participants of the EPIC-PANACEA study. Am J Clin Nutr. 2010 Aug;92(2):398–407. doi:10.3945/ajcn.2009.28713
56. Pan A, Hu FB. Effects of carbohydrates on satiety: differences between liquid and solid food. Curr Opin Clin Nutr Metab Care. 2011 Jul;14(4):385–90. doi:10.1097/MCO.0b013e328346df36
57. Fogelholm M, Anderssen S, Gunnarsdottir I, Lahti-Koski M. Dietary macronutrients and food consumption as determinants of long-term weight change in adult populations: a systematic literature review. Food Nutr Res. 2012 Jan;56(1):19103. doi:10.3402/fnr.v56i0.19103
58. Wan Y, Tobias DK, Dennis KK, Guasch-Ferré M, Sun Q, Rimm EB, et al. Association between changes in carbohydrate intake and long term weight changes: prospective cohort study. BMJ. 2023 Sep 27;382:e073939. doi:10.1136/bmj-2022-073939
59. Rouhani MH, Haghighatdoost F, Surkan PJ, Azadbakht L. Associations between dietary energy density and obesity: A systematic review and meta-analysis of observational studies. Nutrition. 2016 Oct;32(10):1037–47. doi:10.1016/j.nut.2016.03.017
60. Golzarand M, Salari-Moghaddam A, Mirmiran P. Association between alcohol intake and overweight and obesity: a systematic review and dose-response meta-analysis of 127 observational studies. Crit Rev Food Sci Nutr. 2022 Oct 17;62(29):8078–98. doi:10.1080/10408398.2021.1925221
61. Kwok A, Dordevic AL, Paton G, Page MJ, Truby H. Effect of alcohol consumption on food energy intake: a systematic review and meta-analysis. Br J Nutr. 2019 Mar 14;121(5):481–95. doi:10.1017/S0007114518003677
62. Bellicha A, Van Baak MA, Battista F, Beaulieu K, Blundell JE, Busetto L, et al. Effect of exercise training on weight loss, body composition changes, and weight maintenance in adults with overweight or obesity: An overview of 12 systematic reviews and 149 studies. Obes Rev. 2021 Jul;22(S4):e13256. doi:10.1111/obr.13256

63. Jayedi A, Soltani S, Emadi A, Zargar MS, Najafi A. Aerobic Exercise and Weight Loss in Adults: A Systematic Review and Dose-Response Meta-Analysis. JAMA Netw Open. 2024 Dec 26;7(12):e2452185. doi:10.1001/jamanetworkopen.2024.52185

64. Rezende LFMD, Rodrigues Lopes M, Rey-López JP, Matsudo VKR, Luiz ODC. Sedentary Behavior and Health Outcomes: An Overview of Systematic Reviews. PLoS ONE. 2014 Aug 21;9(8):e105620. doi:10.1371/journal.pone.0105620

65. Hagan K, Javed Z, Cainzos-Achirica M, Hyder AA, Mossialos E, Yahya T, et al. Cumulative social disadvantage and health-related quality of life: national health interview survey 2013–2017. BMC Public Health. 2023 Sep 4;23(1):1710. doi:10.1186/s12889-023-16168-8

66. McCullough ML, Chantaprasopsuk S, Islami F, Rees-Punia E, Um CY, Wang Y, et al. Association of Socioeconomic and Geographic Factors With Diet Quality in US Adults. JAMA Netw Open. 2022 Jun 9;5(6):e2216406. doi:10.1001/jamanetworkopen.2022.16406

67. Carrillo-Alvarez E, Rifà-Ros R, Salinas-Roca B, Costa-Tutusaus L, Lamas M, Rodriguez-Monforte M. Diet-Related Health Inequalities in High-Income Countries: A Scoping Review of Observational Studies. Adv Nutr. 2025 Jun;16(6):100439. doi:10.1016/j.advnut.2025.100439

68. Giskes K, Avendaňo M, Brug J, Kunst AE. A systematic review of studies on socioeconomic inequalities in dietary intakes associated with weight gain and overweight/obesity conducted among European adults. Obes Rev. 2010 Jun;11(6):413–29. doi:10.1111/j.1467-789X.2009.00658.x

69. Lallukka T, Pitkäniemi J, Rahkonen O, Roos E, Laaksonen M, Lahelma E. The association of income with fresh fruit and vegetable consumption at different levels of education. Eur J Clin Nutr. 2010 Mar;64(3):324–7. doi:10.1038/ejcn.2009.155

70. Darmon N, Drewnowski A. Does social class predict diet quality? Am J Clin Nutr. 2008 May;87(5):1107–17. doi:10.1093/ajcn/87.5.1107

71. Salonsalmi A, Lahelma E, Rahkonen O, Karjala A, Kouvonen A, Lallukka T. Associations between life course socioeconomic circumstances and drinking patterns among young and early midlife Finnish public sector employees. Alcohol Alcohol. 2026 Mar 17;61(3):agag023. doi:10.1093/alcalc/agag023

72. Memon AR, Rachele JN, Grgic J, Matolic T, Jurakic D, Kim Y, et al. Social disparities in sports and exercise participation in the European Union: a cross-sectional study in a population-representative sample of 25,434 adults. J Public Health. 2026 Mar 23. doi:10.1007/s10389-026-02734-y

73. Mäkinen T, Borodulin K, Laatikainen T, Fogelholm M, Prättälä R. Twenty-five year socioeconomic trends in leisure-time and commuting physical activity among employed Finns. Scand J Med Sci Sports. 2009 Apr;19(2):188–97. doi:10.1111/j.1600-0838.2007.00739.x

74. Fenton S, Ashton LM, Lee DCW, Collins CE. Gender differences in diet quality and the association between diet quality and BMI: an analysis in young Australian adults who completed the Healthy Eating Quiz. J Hum Nutr Diet. 2024 Aug;37(4):943–51. doi:10.1111/jhn.13309

75. Feraco A, Armani A, Amoah I, Guseva E, Camajani E, Gorini S, et al. Assessing gender differences in food preferences and physical activity: a population-based survey. Front Nutr. 2024 Feb 20;11:1348456. doi:10.3389/fnut.2024.1348456

76. Imamura F, Micha R, Khatibzadeh S, Fahimi S, Shi P, Powles J, et al. Dietary quality among men and women in 187 countries in 1990 and 2010: a systematic assessment. Lancet Glob Health. 2015 Mar;3(3):e132–42. doi:10.1016/S2214-109X(14)70381-X

77. Kang M, Park SY, Shvetsov YB, Wilkens LR, Marchand LL, Boushey CJ, et al. Sex differences in sociodemographic and lifestyle factors associated with diet quality in a multiethnic population. Nutrition. 2019 Oct;66:147–52. doi:10.1016/j.nut.2018.11.022

78. Lombardo M, Feraco A, Armani A, Camajani E, Gorini S, Strollo R, et al. Gender differences in body composition, dietary patterns, and physical activity: insights from a cross-sectional study. Front Nutr. 2024 Jul 11;11:1414217. doi:10.3389/fnut.2024.1414217

79. Arganini C, Saba A, Comitato R, Virgili F, Turrini A. Gender differences in food choice and dietary intake in modern Western societies. In: Maddock J, editor. Public Health - Social and Behavioral Health [Internet]. Rijeka: InTech; 2012 [accessed October 5, 2026]. Available from: https://www.intechopen.com/chapters/37886

80. Dube L, Lebel J, Lu J. Affect asymmetry and comfort food consumption. Physiol Behav. 2005 Nov 15;86(4):559–67. doi:10.1016/j.physbeh.2005.08.023

81. Kiefer I, Rathmanner T, Kunze M. Eating and dieting differences in men and women. J Mens Health Gend. 2005 Jun;2(2):194–201. doi:10.1016/j.jmhg.2005.04.010

82. Lennernäs M, Fjellström C, Becker W, Giachetti I, Schmitt A, Remaut de Winter A, et al. Influences on food choice perceived to be important by nationally-representative samples of adults in the European Union. Eur J Clin Nutr. 1997 Jun;51 Suppl 2:S8-15. PubMed PMID: 9222718.

83. Rozin P, Hormes JM, Faith MS, Wansink B. Is Meat Male? A Quantitative Multimethod Framework to Establish Metaphoric Relationships. J Consum Res. 2012 Oct 1;39(3):629–43. doi:10.1086/664970

84. Modlinska K, Adamczyk D, Maison D, Pisula W. Gender Differences in Attitudes to Vegans/Vegetarians and Their Food Preferences, and Their Implications for Promoting Sustainable Dietary Patterns–A Systematic Review. Sustainability. 2020 Aug 5;12(16):6292. doi:10.3390/su12166292

85. Wilsnack R. Gender Differences in Binge Drinking. Alcohol Res Curr Rev. 2018;39(1):57. doi:10.35946/arcr.v39.1.09

86. Owen KB, Corbett L, Ding D, Eime R, Bauman A. Gender differences in physical activity and sport participation in adults across 28 European countries between 2005 and 2022. Ann Epidemiol. 2025 Jan;101:52–7. doi:10.1016/j.annepidem.2024.12.011

87. Oja S, Hakamäki M, Syväoja H, Lehtonen K. Equality in sports and physical activity in Finland in 2025 [Internet]. Helsinki: Ministry of Education and Culture; 2026 [accessed May 27, 2026]. Available from: https://julkaisut.valtioneuvosto.fi/handle/11111/13433

88. Prince SA, Roberts KC, Melvin A, Butler GP, Thompson W. Gender and education differences in sedentary behaviour in Canada: an analysis of national cross-sectional surveys. BMC Public Health. 2020 Dec;20(1):1170. doi:10.1186/s12889-020-09234-y

89. Loyen A, Van Der Ploeg HP, Bauman A, Brug J, Lakerveld J. European Sitting Championship: Prevalence and Correlates of Self-Reported Sitting Time in the 28 European Union Member States. PLOS ONE. 2016 Mar 2;11(3):e0149320. doi:10.1371/journal.pone.0149320

90. Yang L, Cao C, Kantor ED, Nguyen LH, Zheng X, Park Y, et al. Trends in Sedentary Behavior Among the US Population, 2001-2016. JAMA. 2019 Apr 23;321(16):1587. doi:10.1001/jama.2019.3636

91. Cohen AK, Rai M, Rehkopf DH, Abrams B. Educational attainment and obesity: a systematic review. Obes Rev. 2013 Dec;14(12):989–1005. doi:10.1111/obr.12062

92. Bridger Staatz C, Kelly Y, Lacey RE, Blodgett JM, George A, Arnot M, et al. Life course socioeconomic position and body composition in adulthood: a systematic review and narrative synthesis. Int J Obes. 2021 Nov;45(11):2300–15. doi:10.1038/s41366-021-00898-z

93. McLaren L. Socioeconomic Status and Obesity. Epidemiol Rev. 2007 May 2;29(1):29–48. doi:10.1093/epirev/mxm001

94. Valkonen J, Valkonen L, Lallukka T. Educational differences in adult body mass index: age-period-cohort analysis (2000-2022). Eur J Public Health. 2025 Oct 1;35(Supplement_4):ckaf161.1027. doi:10.1093/eurpub/ckaf161.1027

95. Kanter R, Caballero B. Global Gender Disparities in Obesity: A Review. Adv Nutr. 2012 Jul;3(4):491–8. doi:10.3945/an.112.002063

96. Wells JCK, Marphatia AA, Cole TJ, McCoy D. Associations of economic and gender inequality with global obesity prevalence: Understanding the female excess. Soc Sci Med. 2012 Aug;75(3):482–90. doi:10.1016/j.socscimed.2012.03.029

97. Matthews S, Manor O, Power C. Social inequalities in health: are there gender differences? Soc Sci Med. 1999 Jan;48(1):49–60. doi:10.1016/S0277-9536(98)00288-3

98. Sobal J, Stunkard AJ. Socioeconomic status and obesity: A review of the literature. Psychol Bull. 1989;105(2):260–75. doi:10.1037/0033-2909.105.2.260

99. Wardle J, Waller J, Jarvis MJ. Sex Differences in the Association of Socioeconomic Status With Obesity. Am J Public Health. 2002 Aug;92(8):1299–304. doi:10.2105/AJPH.92.8.1299

100. Ogden CL, Fakhouri TH, Carroll MD, Hales CM, Fryar CD, Li X, et al. Prevalence of Obesity Among Adults, by Household Income and Education — United States, 2011–2014. MMWR Morb Mortal Wkly Rep. 2017 Dec 22;66(50):1369–73. doi:10.15585/mmwr.mm6650a1

101. Laaksonen M, Sarlio-Lähteenkorva S, Lahelma E. Multiple Dimensions of Socioeconomic Position and Obesity among Employees: The Helsinki Health Study. Obes Res. 2004 Nov;12(11):1851–8. doi:10.1038/oby.2004.230

102. Loman T, Lallukka T, Laaksonen M, Rahkonen O, Lahelma E. Multiple socioeconomic determinants of weight gain: the Helsinki Health Study. BMC Public Health. 2013 Dec;13(1):259. doi:10.1186/1471-2458-13-259

103. Lahelma E. Sosioekonomiset terveyserot 100-vuotiaassa Suomessa. Sos Aikakauslehti. 2017 Feb 3;54(1). doi:10.23990/sa.60619

104. Adler NE, Ostrove JM. Socioeconomic Status and Health: What We Know and What We Don't. Ann N Y Acad Sci. 1999 Dec;896(1):3–15. doi:10.1111/j.1749-6632.1999.tb08101.x

105. Martikainen P, Bartley M, Lahelma E. Psychosocial determinants of health in social epidemiology. Int J Epidemiol. 2002 Dec;31(6):1091–3. doi:10.1093/ije/31.6.1091

106. Claassen MA, Klein O, Bratanova B, Claes N, Corneille O. A systematic review of psychosocial explanations for the relationship between socioeconomic status and body mass index. Appetite. 2019 Jan;132:208–21. doi:10.1016/j.appet.2018.07.017

107. Pineda E, Stockton J, Scholes S, Lassale C, Mindell JS. Food environment and obesity: a systematic review and meta-analysis. BMJ Nutr Prev Health. 2024 Jun;7(1):204–11. doi:10.1136/bmjnph-2023-000663

108. Kim TJ, Von Dem Knesebeck O. Income and obesity: what is the direction of the relationship? A systematic review and meta-analysis. BMJ Open. 2018 Jan;8(1):e019862. doi:10.1136/bmjopen-2017-019862

109. Wilcox S, Sharpe PA, Liese AD, Dunn CG, Hutto B. Socioeconomic factors associated with diet quality and meeting dietary guidelines in disadvantaged neighborhoods in the Southeast United States. Ethn Health. 2020 Nov 16;25(8):1115–31. doi:10.1080/13557858.2018.1493434

110. Richardson AS, Boone-Heinonen J, Popkin BM, Gordon-Larsen P. Are neighbourhood food resources distributed inequitably by income and race in the USA? Epidemiological findings across the urban spectrum. BMJ Open. 2012;2(2):e000698. doi:10.1136/bmjopen-2011-000698

111. Fikkan JL, Rothblum ED. Is Fat a Feminist Issue? Exploring the Gendered Nature of Weight Bias. Sex Roles. 2012 May;66(9–10):575–92. doi:10.1007/s11199-011-0022-5

112. O'Donoghue G, Kennedy A, Puggina A, Aleksovska K, Buck C, Burns C, et al. Socio-economic determinants of physical activity across the life course: A "DEterminants of DIet and Physical ACtivity" (DEDIPAC) umbrella literature review. PLOS ONE. 2018 Jan 19;13(1):e0190737. doi:10.1371/journal.pone.0190737

113. Papadopoulos D, Sosso FAE. Socioeconomic status and sleep health: a narrative synthesis of 3 decades of empirical research. J Clin Sleep Med. 2023 Mar;19(3):605–20. doi:10.5664/jcsm.10336

114. Papatriantafyllou E, Efthymiou D, Zoumbaneas E, Popescu CA, Vassilopoulou E. Sleep Deprivation: Effects on Weight Loss and Weight Loss Maintenance. Nutrients. 2022 Apr 8;14(8):1549. doi:10.3390/nu14081549

115. Cook P, Bellis M. Knowing the risk. Public Health. 2001 Jan;115(1):54–61. doi:10.1038/sj.ph.1900728

116. Adamou H, Paquette MC, François D, Robitaille É, Ouindpanga SS, Lebel A. Life-course socioeconomic status and obesity: scoping review. Popul Health Metr. 2025 Nov 18;23(1):63. doi:10.1186/s12963-025-00424-7

117. Simmonds M, Llewellyn A, Owen CG, Woolacott N. Predicting adult obesity from childhood obesity: a systematic review and meta-analysis. Obes Rev. 2016 Feb;17(2):95–107. doi:10.1111/obr.12334

118. Gebremariam MK, Lien N, Nianogo RA, Arah OA. Mediators of socioeconomic differences in adiposity among youth: a systematic review. Obes Rev. 2017 Aug;18(8):880–98. doi:10.1111/obr.12547

119. Pudrovska T, Reither EN, Logan ES, Sherman-Wilkins KJ. Gender and Reinforcing Associations between Socioeconomic Disadvantage and Body Mass over the Life Course. J Health Soc Behav. 2014 Sep;55(3):283–301. doi:10.1177/0022146514544525

120. Endres LK, Straub H, McKinney C, Plunkett B, Minkovitz CS, Schetter CD, et al. Postpartum Weight Retention Risk Factors and Relationship to Obesity at 1 Year. Obstet Gynecol. 2015 Jan;125(1):144–52. doi:10.1097/AOG.0000000000000565

121. Borodulin K, Zimmer C, Sippola R, Mäkinen TE, Laatikainen T, Prättälä R. Health Behaviours as Mediating Pathways between Socioeconomic Position and Body Mass Index. Int J Behav Med. 2012 Mar;19(1):14–22. doi:10.1007/s12529-010-9138-1

122. Ward H, Tarasuk V, Mendelson R, McKeown-Eyssen G. An exploration of socioeconomic variation in lifestyle factors and adiposity in the Ontario Food Survey through structural equation modeling. Int J Behav Nutr Phys Act. 2007 Dec;4(1):8. doi:10.1186/1479-5868-4-8

123. Gearon E, Backholer K, Hodge A, Peeters A. The mediating role of dietary factors and leisure time physical activity on socioeconomic inequalities in body mass index among Australian adults. BMC Public Health. 2013 Dec;13(1):1214. doi:10.1186/1471-2458-13-1214

124. Gearon E, Peeters A, Ng W, Hodge A, Backholer K. Diet and physical activity as possible mediators of the association between educational attainment and body mass index gain among Australian adults. Int J Public Health. 2018 Sep;63(7):883–93. doi:10.1007/s00038-018-1100-z

125. De Mestral C, Chatelan A, Marques-Vidal P, Stringhini S, Bochud M. The Contribution of Diet Quality to Socioeconomic Inequalities in Obesity: A Population-based Study of Swiss Adults. Nutrients. 2019 Jul 12;11(7):1573. doi:10.3390/nu11071573

126. Bartoskova Polcrova A, Ksinan AJ, González-Rivas JP, Bobak M, Pikhart H. The explanation of educational disparities in adiposity by lifestyle, socioeconomic and mental health mediators: a multiple mediation model. Eur J Clin Nutr. 2024 May;78(5):376–83. doi:10.1038/s41430-024-01403-1

127. Moreno-Llamas A, San Sebastián M, Gustafsson PE. The transmission of social inequalities through economic difficulties and lifestyle factors on body mass index: An intersectional mediation analysis in the Swedish population. Soc Sci Med. 2024 Nov;360:117314. doi:10.1016/j.socscimed.2024.117314

128. Lallukka T, Pietiläinen O, Jäppinen S, Laaksonen M, Lahti J, Rahkonen O. Factors associated with health survey response among young employees: a register-based study using online, mailed and telephone interview data collection methods. BMC Public Health. 2020 Dec;20(1):184. doi:10.1186/s12889-020-8241-8

129. City of Helsinki. Staff Report 2022 [Internet]. Helsinki: City of Helsinki; 2022 [accessed October 5, 2026]. Available from: https://www.hel.fi/static/kanslia/julkaisut/2023/city-of-helsinki-staff-report-2022.pdf

130. Kujala UM, Kaprio J, Sarna S, Koskenvuo M. Relationship of Leisure-Time Physical Activity and Mortality: The Finnish Twin Cohort. JAMA. 1998 Feb 11;279(6):440. doi:10.1001/jama.279.6.440

131. MacKinnon DP, Fairchild AJ, Fritz MS. Mediation Analysis. Annu Rev Psychol. 2007 Jan 1;58(1):593–614. doi:10.1146/annurev.psych.58.110405.085542

132. European Parliament, Council of the European Union. Regulation (EU) 2016/679 of the European Parliament and of the Council of 27 April 2016 on the protection of natural persons with regard to the processing of personal data and on the free movement of such data, and repealing Directive 95/46/EC: General Data Protection Regulation [Internet].

Official Journal of the European Union. 2016 [accessed October 5, 2026];L119:1–88. Available from: http://data.europa.eu/eli/reg/2016/679/oj

133. World Medical Association. World Medical Association Declaration of Helsinki: Ethical Principles for Medical Research Involving Human Participants. JAMA. 2025 Jan 7;333(1):71–4. doi:10.1001/jama.2024.21972

134. Finnish National Board on Research Integrity TENK. The Finnish code of conduct for research integrity and procedures for handling alleged violations of research integrity in Finland 2023 [Internet]. Helsinki: Finnish National Board on Research Integrity TENK; 2023 [accessed October 5, 2026]. Available from: https://tenk.fi/sites/default/files/2023-05/RI_Guidelines_2023.pdf

135. Strain T, Flaxman S, Guthold R, Semenova E, Cowan M, Riley LM, et al. National, regional, and global trends in insufficient physical activity among adults from 2000 to 2022: a pooled analysis of 507 population-based surveys with 5·7 million participants. Lancet Glob Health. 2024 Aug;12(8):e1232–43. doi:10.1016/S2214-109X(24)00150-5

136. Cleland V, Tian J, Buscot MJ, Magnussen CG, Bazzano L, Burns TL, et al. Body-mass index trajectories from childhood to mid-adulthood and their sociodemographic predictors: Evidence from the International Childhood Cardiovascular Cohort (i3C) Consortium. eClinicalMedicine. 2022 Jun;48:101440. doi:10.1016/j.eclinm.2022.101440

137. Azur MJ, Stuart EA, Frangakis C, Leaf PJ. Multiple imputation by chained equations: what is it and how does it work? Int J Methods Psychiatr Res. 2011 Mar;20(1):40–9. doi:10.1002/mpr.329

138. Jones L, Barnett A, Vagenas D. Common misconceptions held by health researchers when interpreting linear regression assumptions, a cross-sectional study. PLOS One. 2025 Jun 5;20(6):e0299617. doi:10.1371/journal.pone.0299617

139. Li CY, Sung FC. A review of the healthy worker effect in occupational epidemiology. Occup Med. 1999;49(4):225–9. doi:10.1093/occmed/49.4.225

140. Podsakoff PM, MacKenzie SB, Lee JY, Podsakoff NP. Common method biases in behavioral research: A critical review of the literature and recommended remedies. J Appl Psychol. 2003;88(5):879–903. doi:10.1037/0021-9010.88.5.879

141. Osler M, Heitmann BL. The Validity of a Short Food Frequency Questionnaire and its Ability to Measure Changes in Food Intake: A Longitudinal Study. Int J Epidemiol. 1996;25(5):1023–9. doi:10.1093/ije/25.5.1023

142. Therese L. Lillegaard I, Øverby N, Andersen L. Evaluation of a short food frequency questionnaire used among Norwegian children. Food Nutr Res. 2012 Jan;56(1):6399. doi:10.3402/fnr.v56i0.6399

143. Noethlings U, Hoffmann K, Bergmann MM, Boeing H. Portion Size Adds Limited Information on Variance in Food Intake of Participants in the EPIC-Potsdam Study. J Nutr. 2003 Feb;133(2):510–5. doi:10.1093/jn/133.2.510

144. Waller K, Kaprio J, Kujala UM. Associations between long-term physical activity, waist circumference and weight gain: a 30-year longitudinal twin study. Int J Obes. 2008 Feb;32(2):353–61. doi:10.1038/sj.ijo.0803692

145. Marshall AL, Miller YD, Burton NW, Brown WJ. Measuring Total and Domain-Specific Sitting: A Study of Reliability and Validity. Med Sci Sports Exerc. 2010 Jun;42(6):1094–102. doi:10.1249/MSS.0b013e3181c5ec18

Appendix 1. Gender differences in indirect effects of socioeconomic position on body mass index in the Helsinki Health Study Cohort (n = 4,400, 80% women) in Phase 1 (2017).

Education (Ref. High education)	**Mediator**	**W Indirect effect (95% CI)**	**M Indirect effect (95% CI)**	**W –M Difference (95% CI)**	**p-value for difference**
Middle education	Fruit and vegetables	0.05 (0.01, 0.09)	0.02 (-0.03, 0.08)	0.03 (-0.04, 0.09)	0.36
	Red and processed meat	0.04 (0.01, 0.07)	0.09 (0.02, 0.20)	-0.05 (-0.17, 0.03)	0.32
	Sweets and confectionery	0.00 (-0.01, 0.02)	0.03 (-0.12, 0.18)	-0.03 (-0.17, 0.12)	0.68
	Alcohol	-0.01 (-0.03, 0.00)	0.01 (-0.03, 0.08)	-0.02 (-0.09, 0.02)	0.41
	Vigorous physical activity	0.18 (0.12, 0.26)	0.02 (-0.06, 0.11)	0.16 (0.05, 0.27)	0.003
	Sedentary time	0.02 (-0.01, 0.06)	0.09 (0.01, 0.22)	-0.07 (-0.20, 0.02)	0.24
	Total indirect effect	0.28 (0.18, 0.39)	0.26 (0.02, 0.51)	0.02 (-0.24, 0.30)	0.86
Low education	Fruit and vegetables	0.15 (0.08, 0.23)	0.07 (-0.09, 0.23)	0.09 (-0.09, 0.26)	0.34
	Red and processed meat	0.06 (0.02, 0.10)	0.12 (0.03, 0.23)	-0.06 (-0.18, 0.04)	0.28
	Sweets and confectionery	0.01 (-0.01, 0.03)	0.03 (-0.09, 0.15)	-0.02 (-0.14, 0.10)	0.74
	Alcohol	-0.01 (-0.04, 0.00)	0.01 (-0.03, 0.07)	-0.02 (-0.09, 0.02)	0.35
	Vigorous physical activity	0.35 (0.26, 0.43)	0.10 (0.02, 0.21)	0.25 (0.11, 0.36)	<0.001
	Sedentary time	0.02 (-0.02, 0.07)	0.10 (0.01, 0.25)	-0.08 (-0.23, 0.02)	0.19
	Total indirect effect	0.57 (0.43, 0.72)	0.42 (0.18, 0.69)	0.15 (-0.14, 0.43)	0.30

High education = master's degree or higher, middle education = bachelor's degree, low education = upper secondary or vocational school or lower, BMI = body mass index (body weight in kilograms divided by height in meters squared, kg/m^2), CI = confidence interval, M=men, W=women

Appendix 2. The mediating role of dietary factors and physical activity in the age-adjusted education–BMI association among women and men after Multiple imputation by chained equations (MICE)*

			Association between education and mediator	Association between mediator and BMI**	Mediated effect (indirect effect)	
Mediator	**Education** (Ref. High education)	**Gender**	**a-path (95% CI)**	**b-path (95% CI)**	**a x b (95% CI)**	**Proportion mediated (%)**
Fruit and vegetables	Middle	W	-1.1 (-1.33, -0.84)	-0.03 (-0.03, -0.03)	0.033 (0.025, 0.041)	3.2%
		M	-2.25 (-2.71, -1.82)	-0.02 (-0.03, -0.02)	0.051 (0.033, 0.071)	4.8%
	Low	W	-4.95 (-5.22, -4.66)	-0.03 (-0.03, -0.03)	0.148 (0.129, 0.169)	5.1%
		M	-5.96 (-6.37, -5.54)	-0.02 (-0.03, -0.02)	0.135 (0.09, 0.184)	7.8%
Red and processed meat	Middle	W	0.26 (0.21, 0.31)	0.07 (0.06, 0.09)	0.02 (0.014, 0.026)	1.9%
		M	0.64 (0.53, 0.76)	0.13 (0.11, 0.16)	0.086 (0.065, 0.11)	8.1%
	Low	W	0.55 (0.49, 0.61)	0.07 (0.06, 0.09)	0.041 (0.031, 0.05)	1.4%
		M	0.85 (0.76, 0.95)	0.13 (0.11, 0.16)	0.114 (0.092, 0.139)	6.5%
Sweets and confectionery	Middle	W	-0.11 (-0.18, -0.03)	-0.03 (-0.04, -0.02)	0.003 (0.001, 0.006)	0.3%
		M	-1.14 (-1.28, -1.01)	0 (-0.03, 0.03)	0.001 (-0.033, 0.033)	0.1%
	Low	W	-0.28 (-0.35, -0.2)	-0.03 (-0.04, -0.02)	0.009 (0.005, 0.013)	0.3%
		M	-0.68 (-0.83, -0.53)	0 (-0.03, 0.03)	0 (-0.02, 0.02)	0%
Alcohol	Middle	W	-0.19 (-0.25, -0.13)	0.04 (0.02, 0.06)	-0.007 (-0.011, -0.004)	-0.7%
		M	0.88 (0.66, 1.13)	0.04 (0.02, 0.05)	0.033 (0.017, 0.052)	3.1%
	Low	W	-0.37 (-0.44, -0.31)	0.04 (0.02, 0.06)	-0.014 (-0.02, -0.008)	-0.5%
		M	0.34 (0.11, 0.57)	0.04 (0.02, 0.05)	0.013 (0.004, 0.025)	0.7%

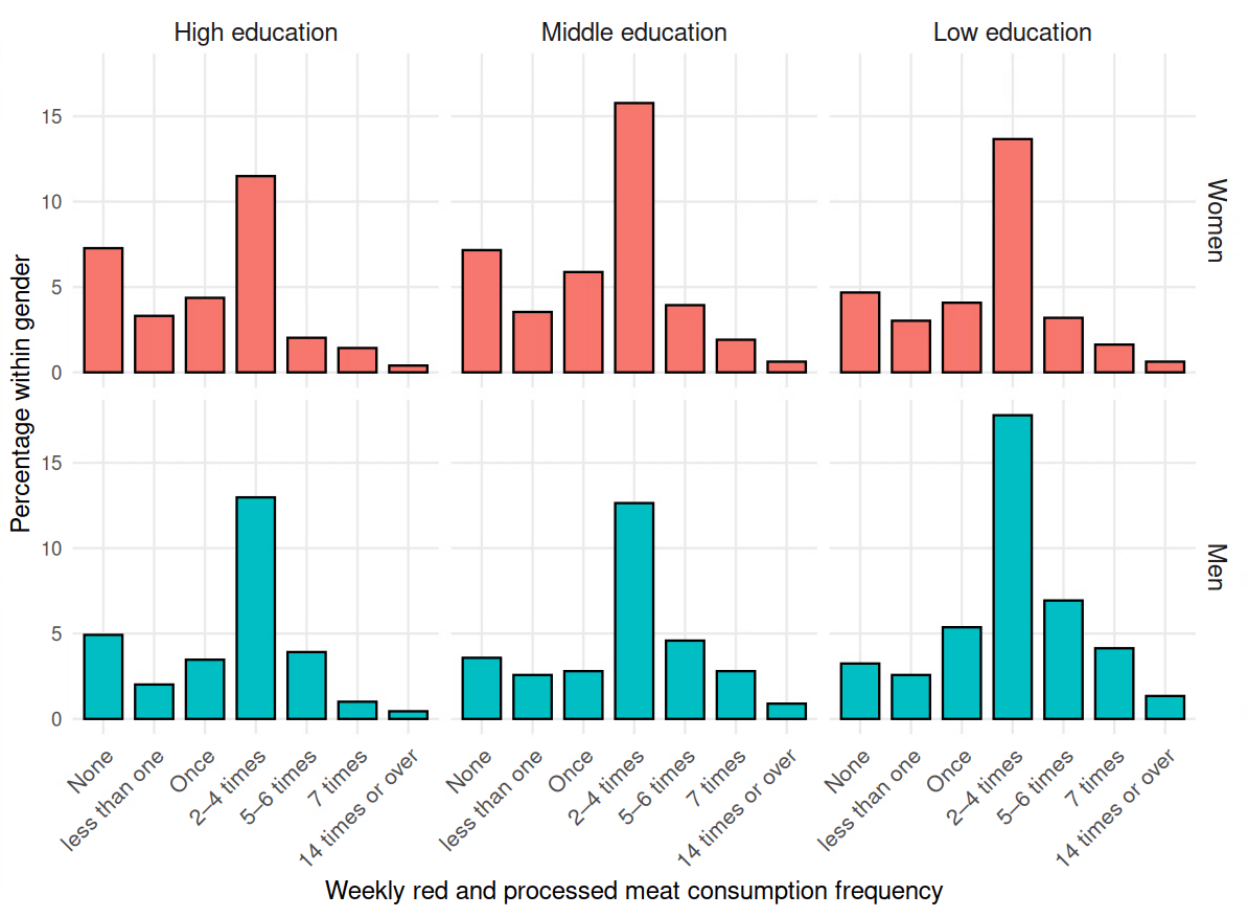
Appendix 2. *Continued*

Mediator	Education (Ref. High education)	Gender	Association between education and mediator **a-path (95% CI)**	Association between mediator and BMI** **b-path (95% CI)**	Mediated effect (indirect effect) **a x b (95% CI)**	**Proportion mediated (%)**
Vigorous physical activity	Middle	W	-4.97 (-5.62, -4.34)	-0.03 (-0.03, -0.03)	0.137 (0.119, 0.156)	13.3%
		M	-10.24 (-12.33, -8.26)	-0.01 (-0.01, -0.01)	0.067 (0.051, 0.085)	6.2%
	Low	W	-8.75 (-9.45, -8.1)	-0.03 (-0.03, -0.03)	0.242 (0.22, 0.264)	8.3%
		M	-10.14 (-12.24, -8.09)	-0.01 (-0.01, -0.01)	0.066 (0.049, 0.085)	8.8%
Sedentary time	Middle	W	0.15 (0.1, 0.21)	0.22 (0.2, 0.23)	0.033 (0.021, 0.047)	3.2%
		M	0.52 (0.4, 0.64)	0.07 (0.05, 0.1)	0.039 (0.023, 0.057)	3.7%
	Low	W	0.08 (0.02, 0.14)	0.22 (0.2, 0.23)	0.018 (0.004, 0.031)	0.6%
		M	0.71 (0.59, 0.82)	0.07 (0.05, 0.1)	0.053 (0.033, 0.076)	3.0%
All mediators together	Middle	W	-	-	0.219 (0.194, 0.246)	
		M	-	-	0.277 (0.223, 0.331)	
	Low	W	-	-	0.443 (0.407, 0.478)	
		M	-	-	0.381 (0.32, 0.44)	

* N=5897, number of imputations: 20.

**adjusted for socioeconomic position and other mediators

High education = master's degree or higher, middle education = bachelor's degree, low education = upper secondary or vocational school or lower, BMI = body mass index (body weight in kilograms divided by height in meters squared, kg/m²), CI = confidence interval, M=men, W=women



Appendix 3. Distribution of weekly red and processed meat consumption frequency by gender and education level in the Helsinki Health Study Cohort (n = 4,400, 80% women) in Phase 1 (2017). High education = master's degree or higher, middle education = bachelor's degree, low education = upper secondary or vocational school or lower