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Sociodemographic and regional differences in dietary climate impact: findings from Finnish population surveys

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Introduction: Diet contributes substantially to one's carbon footprint. Climate impact of diet varies between certain sociodemographic groups, but no studies have comprehensively compared the climate impact of diet between sociodemographic groups and regions in Finland. Aims of this study were to compare absolute and energy-adjusted dietary climate impacts between sociodemographic groups and to illustrate their regional distributions on maps.

Methods: The FinHealth 2017 Study data (n = 5,123) comprising individuals aged 18–99 years, and additionally for the spatial analyses, FINRISK 2012 and Health 2011 survey data were utilized (combined n = 14,692). Dietary intake information was collected using validated food frequency questionnaires. Products' climate impacts, produced with the life cycle assessment, were linked to the ingredient groups used in food consumption data, and individual-level climate impacts/day [kg CO_2 equivalents (eq)/day and kg CO_2 eq/megajoule/day] were estimated. Statistical analyses for maps were based on 10×10 km square data and on spatial Besag-York-Mollie model. Linear regression model was used to study differences between sociodemographic groups.

Results and discussion: Men had higher absolute and energy-adjusted dietary climate impacts than women did. In women and in men, the climate impacts were the highest in the 35–54-year-olds, and those living with underage children, and the lowest in the 75–99-year-olds and those living alone. Women living in remote rural areas, and men in the highest income quintile had high dietary climate impacts. On maps, the climate impacts were low in southern Finland near the capital region. Higher levels appeared in men especially in parts of central Finland. Results of absolute and energy-adjusted climate impacts showed mainly similar patterns. Information on the differences between sociodemographic groups can be used when targeting policies concerning transition towards more climate-friendly diets to sociodemographic groups with high dietary climate impacts.

KEYWORDS

climate impact of diet, greenhouse gas emissions, sociodemographic differences, regional distributions, distribution map

1 Introduction

The climate and other environmental crises call for urgent actions (IPCC, 2022). Food system, comprising of primary production, industrial processing, transportation, packaging, preparation and consumption of food, and generation and treatment of waste, causes one third of all greenhouse gas emissions (GHGE) globally (Crippa et al., 2021). Similarly, at an individual level, diet contributes substantially to one's carbon footprint, which refers to consumption-related climate impact caused by GHGEs. The size of the carbon footprint of diet is dependent on the amount of food consumed and the composition of the diet. A large variation exists in carbon footprints among different foods. To date, a wealth of data is available on different foods' climate impacts produced by the Life cycle assessment (Clune et al., 2017; Poore and Nemecek, 2018; Moberg et al., 2019; Crippa et al., 2021; Clark et al., 2022), although not comprehensively. Based on these data, the climate impacts of diets have been widely studied particularly in wealthy countries (e.g., González-García et al., 2018; Hallström et al., 2022), including Finland (Saarinen et al., 2023). In these studies, diets rich in plant-based foods have generally had smaller carbon footprints than diets rich in animal-based foods, particularly beef. In addition, the EAT-Lancet Commission (Willett et al., 2019) provided a global reference for a sustainable diet, addressing both health and environmental aspects, containing far less animal-based foods than diets in affluent countries today. Thus, a shift towards more plant-based diets has been suggested to mitigate the food system's GHGEs (Hallström et al., 2015; Willett et al., 2019; Blomhoff et al., 2023). In addition to environmental benefits, such shift would also benefit population health (Laine et al., 2021). Decreasing consumption of animal-based products would reduce dietary climate impacts and disparities in them between different groups especially in affluent countries (Li et al., 2024).

Besides meat consumption, reductions should be made in total energy intake, to reduce diet-related GHGEs and to avoid obesity (Perignon et al., 2017). In previous studies, daily dietary climate impacts have been calculated as such (absolute dietary climate impact) or considering the energy intake (energy-adjusted dietary climate impact) (Rose et al., 2019; Strid et al., 2019; Hjorth et al., 2020; Auclair and Burgos, 2021; Hallström et al., 2022). Indeed, by equalizing for the total daily energy intake, the climate impact of different diets can be compared. As energy and nutritional requirements vary between individuals, due to for example differences in body size and physical activity level (Blomhoff et al., 2023; Cloetens and Ellegård, 2023), general decrease in daily food consumption is not a rational generic goal to reduce dietary climate impact. Instead, changes in the compositions of diets are needed (Willett et al., 2019). In addition, energy intake needs to be balanced to the individual energy requirement (Cloetens and Ellegård, 2023).

Average dietary shift needs to be adjusted by sociodemographic groups, such as age, education level or employment status due to the variation in the composition of the diets and in the absolute amounts of intakes between different groups (Valsta et al., 2022). For example, as individuals with different socioeconomic status (SES) have on average different dietary habits and nutrient intakes (Valsta et al., 2022; Toujgani et al., 2024), the shift should take different starting levels and preferences into account and be tailored to be conceivable and acceptable for different groups. In order to tailor effective policies to promote the dietary shift in different sociodemographic groups—and especially in groups with the greatest need for change—evaluation of the present situation of dietary climate impacts in different groups is imperative. When striving to promote the dietary shifts in different sociodemographic groups, information on differences both in the composition of the diet and in the absolute amounts of intakes between groups is valuable (Stubbendorff et al., 2025). Making the differences in absolute and energy-adjusted dietary climate impacts across the sociodemographic groups visible aids to identify groups with, e.g., high absolute climate impact (due to, e.g., higher energy intake requirement) but lower energy-adjusted climate impact (due to more climate-friendly composition of the diet), or vice versa. Understanding of the differences in the absolute and energy-adjusted dietary climate impacts between sociodemographic groups can be utilized to target measures to groups with the largest carbon footprints. Even though the need to make shifts towards more climate-friendly diet may apply to all sociodemographic groups, identifying groups with both high absolute and high energy-adjusted climate impact is of primary importance to allow targeted measures and policy planning.

Previous studies have largely focused on the evaluation of climate impacts of hypothesized diets and diet scenarios (e.g., country-specific national dietary guidelines, Mediterranean diet, or healthy dietary patterns) (González-García et al., 2018; Springmann et al., 2020; Musicus et al., 2022; Frank et al., 2024; Conrad et al., 2025). In such diet scenarios cultural acceptability and regional accessibility are key issues in realization of the shift towards the scenario diet (Rancilio et al., 2022), yet the studied diets may not always be generally feasible. Indeed, some recent studies have started to focus on climate impacts of actual diets in different sociodemographic groups. Call for decreasing dietary climate impact basically falls upon everyone, yet variation exists in the climate impacts of diets, and thereby in the magnitude of dietary changes needed. It is known that dietary habits differ between, e.g., different SES groups (González-García et al., 2018; Valsta et al., 2022). Consequently, also climate impacts of diets have been shown to vary between certain sociodemographic groups, albeit not always analogously between studies (Kliejunas et al., 2024). A German study found that women who were single or employed, and men who were married had higher dietary GHGEs than other individuals (Koelman et al., 2022). A Swedish study based on the large Västerbotten Intervention Programme demonstrated a higher dietary climate impact among men than among women (Strid et al., 2019). As for energy-adjusted diets, higher sums were calculated for younger individuals, those with higher educational level, and those living in urban areas, among women and men (Strid et al., 2019). These data also revealed that individuals with the greatest decrease in the dietary climate impact during a 10-year follow-up had initially lower educational level and were less often married (Hjorth et al., 2020). Rose et al. (2019) indicated higher climate impact for men than for women, and for people in their 30s and 40s than for people older than 66 years. In addition, Hyland et al. (2017) reported that men, younger individuals, those with secondary education and those with student employment status had significantly higher climate impact compared to other sociodemographic groups in Ireland. However, neither Rose et al. (2019), Auclair and Burgos (2021), nor Lengle et al. (2024) found differences between educational or income groups. As results of the previous studies are partially divergent, and information on differences between categories of certain sociodemographic indicators (e.g., household structure) is limited, more studies focusing on numerous sociodemographic group indicators are needed to form a more comprehensive picture of differences in climate impacts between different groups. As same kind of campaigns, nudging or other measures do not work for everyone, it is important to identify groups with the highest climate impacts to be able to plan and promote appropriate actions to different groups.

To the authors' knowledge no studies, however, have considered both absolute and energy-adjusted dietary climate impacts according to numerous sociodemographic group indicators as well performed a regional scale illustration in Finland. Yet, information on differences between groups and regions is needed when tailoring actions to decrease climate impact of diet in different sociodemographic groups. Results from Finland—a Nordic European country—can probably be extrapolated to similar western populations. Accordingly, aims of this study were to compare dietary climate impact between sociodemographic groups and to illustrate regional distributions of dietary climate impact across our case study area, Finland. Dietary climate impacts were examined as absolute sums per day and as adjusted for daily energy intake. Due to a notable level-difference between women and men in climate impact (Hyland et al., 2017; Strid et al., 2019; Lengle et al., 2024) and energy intake (Valsta et al., 2018), because of different energy requirements and composition of diet, the analyses were conducted separately for women and men.

2 Materials and methods

2.1 Study participants

The nationally representative FinHealth 2017 Study (Valsta et al., 2018; Borodulin and Sääksjärvi, 2019; Kaartinen et al., 2020) was utilized to examine *differences in the diet's GHGE sum between sociodemographic groups*. In addition, *for the map analyses on regional differences in the diet's GHGE sum*, FINRISK 2012 (Borodulin et al., 2018) and Health 2011 Surveys (Lundqvist and Mäki-Opas, 2016) were utilized. General aims of these cross-sectional surveys were to obtain information on health, wellbeing, and functional capacity, and on the prevalence and distribution of chronic disease risk factors in the Finnish adult population. Stratified random sampling design was used in each survey. Information was collected with health examinations, questionnaires and interviews except in the FINRISK 2012 survey, which did not utilize interviews. The data collected in the surveys were supplemented with information from national registers (e.g., age, sex, education). All surveys were performed in accordance with the Declaration of Helsinki and approved by the ethics committee of Helsinki and Uusimaa hospital district. All participants gave their written informed consent.

The FinHealth 2017 Study was conducted in 50 study areas representing the continental Finland. The original invited sample consisted of 10,247 adults aged 18 and older and living in mainland Finland. Of this sample 5,123 filled in the food frequency questionnaire (FFQ) and were used in this study to examine differences between sociodemographic groups (Supplementary Figure 1). For the map analyses, additional data were used to increase the sample size and to improve the spatial representativeness. In the FINRISK 2012 survey (Borodulin et al., 2018), information was collected in five selected study areas. The invited sample composed of 10,000 individuals aged 25–74 years, of which 4,812 filled in the FFQ. The Health 2011 Survey was conducted in 80 study areas. The invited sample comprised 10,129 individuals aged 18 or older and living in mainland Finland, of which 4,759 filled in the FFQ. Of the FinHealth 2017 Study sample of 5,123 that was used to study the diet's GHGE sum between sociodemographic groups, two participants had missing information in the map coordinates and were thus excluded from the map analyses. In the map analyses including all three surveys, the combined data consisted of 14,692 individuals (8,218 women, 6,474 men) (Supplementary Figure 1).

2.2 Dietary assessment

In each survey, information on habitual dietary intake during the last 12 months was collected with a validated semi-quantitative FFQ including approximately 130 foods, food groups and beverages and 9–10 frequency options ranging from "none" to "6 + times a day" (Männistö et al., 1996; Paalanen et al., 2006; Kaartinen et al., 2012). The FFQs used in the three surveys were mostly similar with minor updating between the surveys. Daily intakes of food ingredients and energy (megajoules, MJ) were calculated using in-house dietary software (Finessi) (Reinivuo et al., 2010) based on the national food composition database (Fineli®). The food ingredients were grouped into 87 ingredient groups in the FinHealth 2017 data and into 66 ingredient groups in the FINRISK 2012 and the Health 2011 data. The larger number of ingredient groups in FinHealth 2017 was due to small changes made to the FFQ in 2017 that reflected the contemporary diet.

2.3 Estimation of dietary climate impacts

Diet's climate impact sum was produced by linking *climate impact coefficients* (kg CO_2 eq/kg food), produced with the life cycle assessment (LCA), to each food ingredient group in the survey datasets (Supplementary Table 1). Coefficients for 87 product groups were retrieved from Luke's (the Natural Resources Institute Finland) FoodMin dietary model (Saarinen et al., 2023), and were thus based on Luke's previous LCA studies and scientific literature. The FoodMin model contains coefficients for Finnish and imported products separately, but in this study, they were combined into one value for each product group following self-sufficiency rates so that coefficients represent food products consumed in Finland. In this study, only food products from FoodMin model were included in the dietary climate impact excluding consumption activities such as cooking, shopping, food storage and consumer's food waste, as well as part of manufacturing phases and packaging. However, these phases are roughly similar for all diets, and only have a small share of total dietary climate impact (Saarinen et al., 2023), so they have a negligible effect in comparisons of the climate impacts of different diets. Individual-level dietary climate impact/day (kg CO_2 eq/day) was estimated by multiplying the intake of each ingredient group by the respective group's coefficient, and by summing the climate impacts of all ingredient groups. In addition, energy-adjusted dietary climate impact/day was calculated by dividing the daily climate impact by energy intake (megajoules)/day.

2.4 Sociodemographic and geographical region variables

In this study, FinHealth 2017 Study was utilized to examine differences in the diet's GHGE sum between sociodemographic groups. Age, urbanization level of residential area, household structure, education, main activity (employment status), and household income were selected as sociodemographic and socioeconomic indicators. Sex (women/men) served as a stratifying variable in all analyses. As information on sex was obtained from the Population Register Centre, it did not necessarily represent actual gender identity of the participant. In this study the terms "sex," "women" and "men" are used while acknowledging that in each case they do not necessarily correspond to actual gender of the respondent.

2.4.1 Register-based variables

Information on participants' age, urbanization level of residential area, and map coordinates of residence were obtained from the Population Register Centre. Age was categorized into 18–34/35–54/55–74/75–99 -year groups. All residential areas were classified across an urban–rural axis based on classification of the Population Register Centre: urban areas; areas near urban areas or rural centres; remote rural areas. For each participant, an urban–rural classification was assigned based on their place of residence. In addition, map coordinates of residence as such were used to illustrate maps of Finland.

Information on education, based on the highest completed degree, was drawn from national registers of Statistics Finland and was used as categorized as follows: (1) basic [comprehensive school (years 1–9 in the current school system in Finland) or lower], (2) intermediate [upper secondary school (high school) or vocational school (usually 3–4 years after comprehensive school)], and (3) high (lower or higher university degree, university of applied sciences degree, polytechnic degree, or higher).

2.4.2 Survey-based variables

Information on household structure, main activity, and household income were collected with questionnaires. Household structure was categorized into three classes: household with only one adult living alone/household with at least one adult and at least one underage child/household with at least two adults and no underage children. Main activity was categorized as follows: employed (including entrepreneurs and those working for a family business without salary)/other (including students, those retired, unemployed, on family-leave, and others). For the household income variable, questions on total household income during the last year before tax deductions, and on number of adult and underage household members were used. The household income question comprised 10 predefined categories from "less than €15,000," and "€15,001–€25,000" to "more than €90,000." For this study, upper limits of the categories (and in the highest category, lower limit multiplied by two) were divided by the weighted sum of household members, given a value of 1.0 to the first adult, a value of 0.7 to additional adults, and a value of 0.5 to the underage household members (OECD Project on Income Distribution and Poverty, 2021). Further, the quotient was categorized into sex-specific quintiles.

2.5 Statistical methods

All analyses were conducted separately for women and men due to significant differences in the volume and composition of their diets. Differences in sociodemographic characteristics between women and men were tested with F-test (Table 1). To estimate the most important food sources for climate impacts in our study, we calculated the proportions (%) of the total dietary climate impact from each food ingredient group separately for women and for men, and further aggregated the 87 ingredient groups into 15 main groups (Table 2). These 15 main aggregate groups were used only for the analyses of the food sources for climate impacts to demonstrate more concisely the shares of different food ingredient groups. Linear regression model with adjusted means and standard errors was used to study differences in climate impacts (as kg CO_2 eq/day and as kg CO_2 eq/MJ/day) between categories of selected sociodemographic and -economic factors in men and in women (Table 3). In the linear models (Table 3), age in 10-year categories was adjusted for. The effect modification of sex in the differences in climate impacts between sociodemographic groups was studied by including an interaction term between sex and a sociodemographic factor at issue in the model.

Inverse probability weights were used to mitigate non-participation bias (Härkänen et al., 2016). The analyses concerning sociodemographic group differences were conducted with SAS Enterprise Guide, version 7.15 HF7 (SAS Institute Inc., Cary, NC, USA).

Geographical variation of absolute and energy-adjusted dietary climate impacts and energy intake was analyzed using the spatial Besag-York-Mollie model using 10×10 km square data. In this model, each square had a mean parameter separately for women and men, and additional covariates in the regression model were categorical survey, age group and square root of population size of the square. The analyses were conducted using the GeoBugs package (Thomas et al., 2004) (version 1.2) of the WinBugs software (Lunn et al., 2000) (version 1.4). In the Markov chain Monte Carlo simulation four parallel chains were run with 30,000 iterations of burn-in before 30,000 iterations with thinning equal to 20. Convergence was assessed using the Gelman-Rubin test and autocorrelations, which indicated good convergence, implemented in the coda package (Plummer et al., 2006) of the R software (R Core Team, 2020). The statistical maps were based on the expected means of the squares, which were age adjusted using the population age distribution. The results were reported as posterior expectations and 95% credible intervals.

3 Results

We first assessed the differences in dietary climate impacts and sociodemographic characteristics across women and men (Table 1). Overall, women had lower absolute and energy-adjusted climate impacts than men. The largest shares of the dietary climate impact were attributed to red and processed meat (38 and 30%), and the dairy products (22 and 24%) in both men and women (Table 2). For the rest of the food groups, the shares ranged between 0.2 and 10%.

TABLE 1 Characteristics (means and standard errors or prevalence) of study population (FinHealth survey, *n* = 5,123).

Characteristics	Women		Men		*P*-value[1]
	n	Mean (SE) or %	*n*	Mean (SE) or %	
Absolute dietary climate impact (GHGE) sum (kg CO_2 eq/day), mean	2,873	4.43 (0.03)	2,250	5.65 (0.05)	<0.0001
Energy-adjusted dietary climate impact (GHGE) sum (kg CO_2 eq/MJ/day), mean	2,873	0.56 (0.002)	2,250	0.58 (0.003)	<0.0001
Energy intake (KJ/day), mean	2,873	7,991 (49.6)	2,250	9,775 (69.3)	<0.0001
Energy intake (kcal/day), mean	2,873	1910 (11.9)	2,250	2,336 (16.6)	<0.0001
Age (years), mean	2,873	55.2 (0.31)	2,250	55.3 (0.33)	0.22
Urbanization level of residential area, %	2,871		2,249		
Urban areas	1703	59.3	1,297	57.7	0.16
Areas near urban areas, rural centres	675	23.5	551	24.5	0.16
Remote rural areas	493	17.2	401	17.8	0.870
Household structure, %	2,860		2,244		
Living alone	779	27.2	453	20.2	0.0007
At least one adult and one child	697	24.4	527	23.5	0.95
Adults only	1,384	48.4	1,264	56.3	0.002
Education, %	2,873		2,250		
Low	556	19.4	427	19.0	0.74
Intermediate	1,037	36.1	950	42.2	0.0002
High	1,280	44.6	873	38.8	0.0003
Main activity, %	2,865		2,246		
Employed	1,367	47.7	1,165	51.9	<0.0001
Other	1,498	52.3	1,081	48.1	<0.0001
Household income quintiles, %	2,746		2,189		
1st (lowest)	533	19.4	381	17.4	0.10
2nd	426	15.5	445	20.3	<0.0001
3rd	697	25.4	420	19.2	<0.0001
4th	548	20.0	441	20.2	0.69
5th (highest)	542	19.7	502	22.9	0.15

eq, equivalent; GHGE, greenhouse gas emissions; kcal, kilocalorie; KJ, kilojoule; MJ, megajoule. [1]*P*-value for differences between groups.

3.1 Differences in dietary climate impact between sociodemographic groups

We assessed differences in absolute and energy-adjusted dietary climate impacts across sociodemographic groups using the FinHealth 2017 Survey data (Table 3). As for age groups, absolute and energy-adjusted dietary climate impacts were the lowest in women and men aged 75–99 years. Among women, age group 18–34 years had almost as low absolute dietary climate impact as the oldest age group, but their energy-adjusted climate impact was the highest, together with age group 34–49 years. Men aged 18–34 and 35–49 years had the highest absolute and energy-adjusted dietary climate impacts of all men.

To assess the impact of the place and type of residence on the dietary climate impact for women and men, an urbanization level of residential area variable was introduced (Table 3). Women living in urban areas had lower absolute dietary climate impact than women living in remote rural areas. However, urbanization level of residential area did not emerge as statistically significant variable in energy-adjusted dietary climate impact in women or men. For men, this was the case also for the absolute dietary climate impacts.

As for indicator of household structure, those living alone had the lowest absolute and energy-adjusted dietary climate impacts (Table 3). Correspondingly, persons living in a household with underage children, had the highest sums both among women and men.

No statistically significant differences between educational groups emerged (Table 3). Employed women and men had higher energy-adjusted dietary climate impacts, and men also higher absolute dietary climate impact, than those with other main activities. Neither of the dietary climate impact indicators showed differences between the household income quintiles in women. Instead, both absolute and energy-adjusted dietary climate impacts were the lowest in men in the lowest income quintile and the highest in men in the highest quintile.

3.2 Regional distributions of dietary climate impacts across Finland

Figures 1A–D illustrate the regional differences in absolute and energy-adjusted dietary climate impacts in women and men utilizing also FINRISK 2012 and Health 2011 Surveys in addition to FinHealth 2017 Survey. Three data sets were combined to create a data large enough to represent whole Finland. Supplementary Figure 2 demonstrates the region names of Finland, to which we refer in the following. The illustrations of both dietary climate impact indicators showed some notable differences between regions across Finland. For example, the lowest absolute dietary climate impacts for both women and men appeared in Uusimaa and in some surrounding areas in southern Finland (Figures 1A,B). Higher end levels of the climate impact occurred for men and for women generally in more northern Finland and for men especially in parts of western and eastern central Finland (parts of Ostrobothnia and North Karelia). Higher levels of energy-adjusted dietary climate impact appeared in women and in men along southern and western coast of Finland, in Lapland, and in some larger towns (Figures 1C,D). Men also had higher energy-adjusted levels in southern parts of Finland (Figure 1D). In addition to the dietary climate impact maps (Figures 1A–D), Figures 1E,F illustrate regional differences in energy intake (MJ) in men and in women and were produced to aid in interpreting the dietary climate impact maps. Energy intake appeared to show partly parallel distributions across regions as the absolute climate impacts.

TABLE 2 The shares (%) of the aggregate ingredient groups contributing to the dietary climate impact (GHGE sum, kg CO_2 eq/day) in women and in men (FinHealth survey, *n* = 5,123).

Aggregate ingredient groups	Women (*n* = 2,873)	Men (*n* = 2,250)
	%	%
Alcoholic drinks	1.73	2.89
Beverages	5.08	4.50
Cereals	3.67	3.35
Dairy	23.85	22.15
Of which cheese	*10.75*	*10.67*
Eggs	2.11	2.02
Fats	5.35	4.76
Fish	3.83	3.86
Flavorings	0.13	0.17
Fruit	5.74	4.71
Legumes and nuts	0.88	0.62
Potatoes	0.22	0.28
Poultry	4.88	4.54
Red and processed meat	30.47	38.31
Of which beef	*18.09*	*22.21*
Sugars and sweets	2.02	1.59
Vegetables	10.03	6.24

eq, equivalent; GHGE, greenhouse gas emissions.

4 Discussion

We found differences in absolute and energy-adjusted dietary climate impacts between sociodemographic groups and regions in Finland. In line with a previous study (Strid et al., 2019), the results of absolute and energy-adjusted climate impacts were mostly parallel with some exceptions indicating that in most groups both the absolute amounts of intakes and the composition of the diet contribute to the higher climate impact. In the following, different sociodemographic group indicators and regional differences are discussed in detail.

4.1 Differences in dietary climate impacts between sociodemographic groups and geographical regions

Of the studied indicators the most prominent differences in absolute and energy-adjusted dietary climate impacts were attributed to sex: men had clearly higher levels than women. This finding agrees with a growing body of literature (Temme et al., 2014; Bälter et al., 2017; Hyland et al., 2017; van Dooren et al., 2018; Rose et al., 2019; Strid et al., 2019; Hjorth et al., 2020; Kliejunas et al., 2024). Gimpfl et al. (2025), however, found that women had higher energy-adjusted GHGEs compared to men when the analyses were weighted and adjusted for potential confounders. In addition, in the study by van Dooren et al. (2018), the differences did not remain significant when adjusted for energy intake. In general, men have higher energy requirements than women do, which results in a greater absolute climate impact. Studies have also shown that men's diets are less healthy than women's (Prättälä et al., 2007; Valsta et al., 2022). In this study, the greatest share of the dietary climate impact was caused by consumption of red and processed meat both in men and women. In men, however, the share was even larger. Higher meat consumption among men than women has also been documented in literature (Temme et al., 2014; Sares-Jäske et al., 2022; Valsta et al., 2022), which indicates that red and processed meat consumption plays an important role in the sex differences of dietary climate impact. Traditionally masculinity has been associated with meat consumption (Rothgerber, 2013; Kildal and Syse, 2017; Rosenfeld and Tomiyama, 2021), and the role of meat in diet has also been shown to be subjectively more important to men than to women (Sares-Jäske et al., 2022). In this study, it appeared that while in men the absolute and the energy-adjusted dietary climate impacts showed similar results between sociodemographic groups, in women some variation existed between the two indicators on how they distributed between the groups. These differences have been scrutinized in the following paragraphs.

The absolute and energy-adjusted dietary climate impacts were generally higher in younger than in older participants. However, while women in the youngest age group (18–34 years), had low absolute climate impact, their energy-adjusted dietary climate impact was high, suggesting that young women have in general lower energy intake than women in older age groups, but their diets contain more foods with higher climate impact. This implicates that in this group, attention should be focused especially on quality of diets. Previous studies have demonstrated somewhat analogous age-related results with dietary climate impacts being higher among younger individuals (Hyland et al., 2017; Rose et al., 2019; Strid et al., 2019). Even though age-scales in these studies have been dissenting, some of the studies have shown an approximately similar "working-age" group, as was used in this

TABLE 3 Dietary climate impact (GHGEs) in categories of selected sociodemographic and -economic factors in women and in men (FinHealth survey, *n* = 5,123).

Sociodemographic and -economic factors	Women			Men		
	GHGE sum, mean (SE)[a]			GHGE sum, mean (SE)[a]		
	n	Absolute kg CO_2 eq/day	Energy-adjusted kg CO_2 eq/MJ/day	*n*	Absolute kg CO_2 eq/day	Energy-adjusted kg CO_2 eq/MJ/day
Age	2,873			2,250		
18–34	424	4.18 (0.15)	0.58 (0.009)	297	5.88 (0.17)	0.62 (0.01)
35–54	927	4.60 (0.05)	0.58 (0.005)	714	5.99 (0.10)	0.61 (0.006)
55–74	1,181	4.37 (0.05)	0.55 (0.003)	1,024	5.45 (0.08)	0.56 (0.004)
75–99	341	4.17 (0.09)	0.51 (0.006)	215	4.99 (0.17)	0.51 (0.008)
P for differences between groups		<0.0001	<0.0001		<0.0001	<0.0001
P for sex-interaction					0.0008	0.002
Urbanization level of residential area	2,871			2,249		
Urban areas	1703	4.24 (0.07)	0.55 (0.004)	1,297	5.47 (0.08)	0.57 (0.005)
Areas near urban areas, rural centres	675	4.29 (0.11)	0.55 (0.005)	551	5.69 (0.15)	0.58 (0.006)
Remote rural areas	493	4.68 (0.07)	0.57 (0.008)	401	5.56 (0.14)	0.56 (0.007)
P for differences between groups		<0.0001	0.10		0.37	0.07
P for sex-interaction					0.003	0.0008
Household structure	2,860			2,244		
Living alone	779	4.03 (0.09)	0.54 (0.006)	453	5.16 (0.13)	0.56 (0.007)
At least one adult and one child	697	4.72 (0.14)	0.56 (0.008)	527	6.04 (0.16)	0.59 (0.008)
Adults only	1,384	4.36 (0.08)	0.56 (0.006)	1,264	5.52 (0.09)	0.57 (0.005)
P for differences between groups		0.0008	0.03		<0.0001	0.009
P for sex-interaction					0.11	0.008
Education	2,873			2,250		
Low	556	4.36 (0.18)	0.56 (0.008)	427	5.36 (0.15)	0.57 (0.008)
Intermediate	1,037	4.28 (0.08)	0.55 (0.005)	950	5.56 (0.11)	0.57 (0.005)
High	1,280	4.33 (0.09)	0.55 (0.006)	873	5.65 (0.10)	0.58 (0.006)
P for differences between groups		0.82	0.65		0.22	0.52
P for sex-interaction					0.10	0.08
Main activity	2,865			2,246		
Employed	1,367	4.30 (0.10)	0.57 (0.006)	1,165	5.75 (0.11)	0.59 (0.006)
Other	1,498	4.33 (0.09)	0.55 (0.005)	1,081	5.39 (0.11)	0.56 (0.005)
P for differences between groups		0.84	0.009		0.02	0.002
P for sex-interaction					0.002	0.02
Household income	2,746			2,189		
1st (lowest)	533	4.30 (0.10)	0.55 (0.007)	381	5.25 (0.14)	0.56 (0.008)
2nd	426	4.43 (0.10)	0.56 (0.007)	445	5.65 (0.15)	0.57 (0.008)

(Continued)

TABLE 3 (Continued)

Sociodemographic and -economic factors	Women			Men		
	GHGE sum, mean (SE)[a]			GHGE sum, mean (SE)[a]		
	n	Absolute kg CO_2 eq/day	Energy-adjusted kg CO_2 eq/MJ/day	*n*	Absolute kg CO_2 eq/day	Energy-adjusted kg CO_2 eq/MJ/day
3rd	697	4.21 (0.08)	0.55 (0.005)	420	5.55 (0.12)	0.57 (0.007)
4th	548	4.38 (0.09)	0.56 (0.007)	441	5.59 (0.12)	0.58 (0.006)
5th (highest)	542	4.27 (0.09)	0.56 (0.008)	502	5.82 (0.11)	0.60 (0.006)
P for differences between groups		0.20	0.28		0.01	0.001
P for sex-interaction					0.15	

[a]Adjusted for age. eq, equivalent; GHGE, greenhouse gas emissions; MJ, megajoule; SE, standard error.

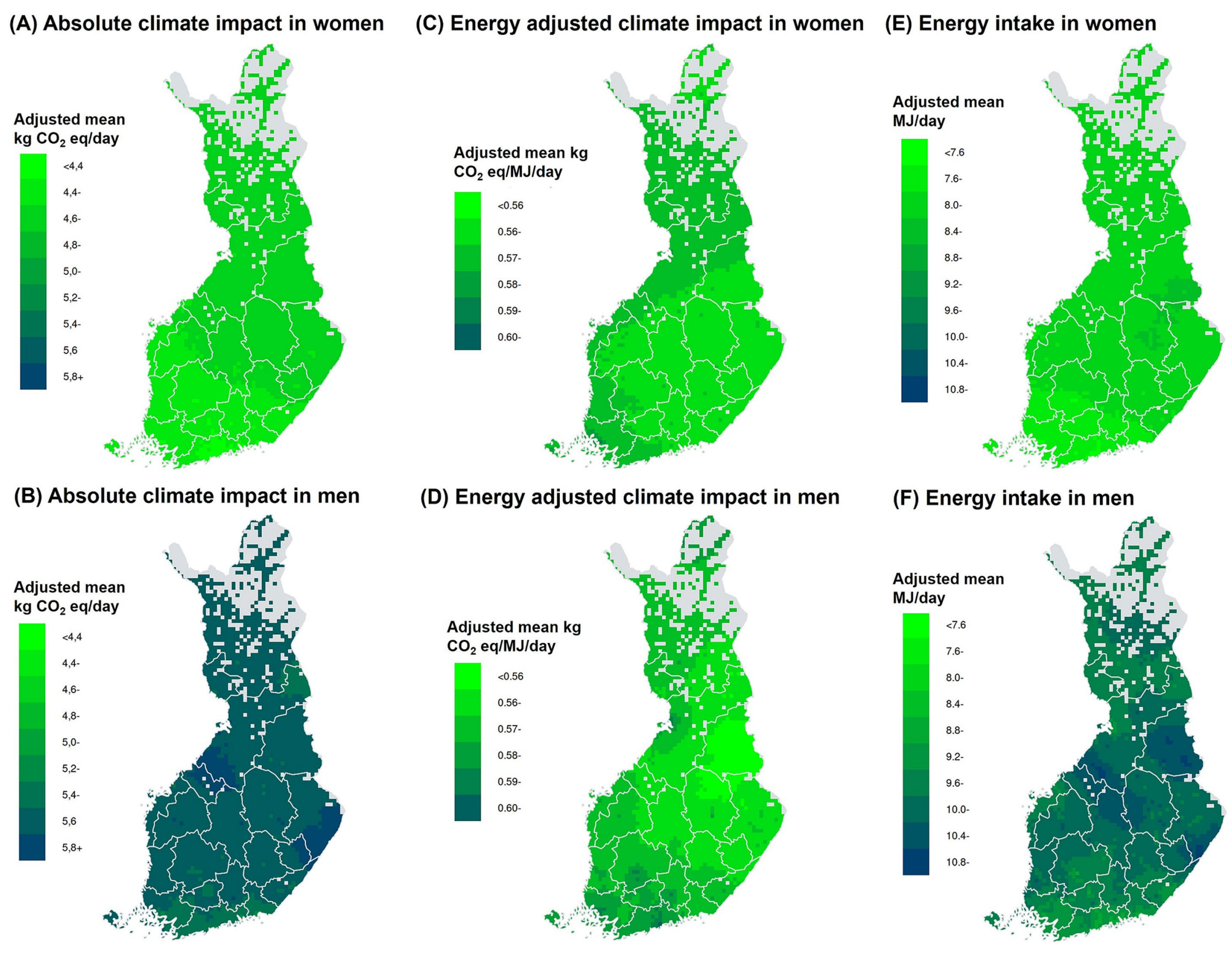

FIGURE 1
(A–F) Regional differences in absolute (kg CO_2 eq/day) and energy intake adjusted (kg CO_2 eq/MJ/day) climate impact (greenhouse gas emissions, GHGE) and energy intake (MJ) from diet illustrated on maps of Finland in women and in men. Grey areas denote uninhabited regions with no information.

study, to have the highest sums (Rose et al., 2019; Strid et al., 2019). However, a review study concluded that while a slight majority of studies showed positive association between age and GHGEs, some of the associations were negative and some lacked significance (Kliejunas et al., 2024). Various contributors may inflict the differences between age groups. For example, food culture, traditions and values may differ between the age groups in different countries. Among aged individuals, physical challenges in chewing and swallowing may, for example, decrease meat consumption (Hildebrandt et al., 1997). Conversely, individuals in the working-age group may more often prepare meals—often including meat—for their family or eat warm lunch at work—also often including meat—than younger or older individuals and thus, end up consuming more foods with high climate impact.

As for the different household structure groups, the highest absolute and energy-adjusted dietary climate impacts were seen among individuals living with underage children. By contrast, individuals living alone had the lowest dietary climate impacts. Individuals living in households with underage children have also been shown to consume more meat than those living in other kind of households (Guenther et al., 2005; Sares-Jäske et al., 2022), which probably is a major contributor to high dietary climate impact in this group. Results of our previous study suggested that even though women living in households with children consumed more meat than other women, they still did not find meat to be any more important part of their diet than other women did (Sares-Jäske et al., 2022). According to a strong Finnish tradition, families with children have two warm meals a day—each of these meals usually containing meat or fish—which may increase the amount of consumption of meat among the parents as well. High meat consumption and dietary climate impact in this group may thus partly derive from traditional assumptions of children needing red meat to grow or women tending to prepare foods that are appealing to their spouses and children. In accordance, Marinova and Bogueva (2019) concluded that family traditions are an important reason for meat consumption. In order to decrease meat consumption and consequently dietary climate impact among families with children, more alternative products and recipes containing more plant-based ingredients that are appealing also to children and easy for parents to prepare are needed.

In line with some previous findings (Rose et al., 2019; Auclair and Burgos, 2021; Kliejunas et al., 2024), this study found no differences in dietary climate impact between educational groups. Previous studies have, however, also shown either secondary education (Hyland et al., 2017) or higher education (Strid et al., 2019) to be associated with higher dietary climate impact. Findings of a German study indicated an inverse trend between dietary GHGEs and education, with higher education associated with lower GHGE (Gimpfl et al., 2025). This finding, however, attenuated to non-significant in the weighted and adjusted regression analysis. Literature has indicated educational differences also in composition of diets. For instance, in the Finnish setting, individuals with lower education tend to consume less fruit and vegetables but more red and processed meat (Valsta et al., 2022). Consumption of cheese – a food having a relatively high climate impact coefficient – has in turn been shown to be lower among women with lower education (Valsta et al., 2022). Thus, different foods with high climate impact may be preferred in different educational groups (e.g., red and processed meat vs. cheese) however leading in quite equal climate impacts.

The absolute dietary climate impacts in this study were higher in employed men than in respective individuals with other main activities. This was the case also for the energy-adjusted dietary climate impact but for women and for men. In accordance, van Dooren et al. (2018) demonstrated the highest level of dietary climate impact among employed individuals compared to unemployed or retired individuals. Conversely, an Irish study showed the highest dietary climate impact among students compared to other employment status categories (Hyland et al., 2017). The main activity categories used in this study are relatively heterogeneous. Thus, lower dietary climate impact among the group including other individuals besides those employed may be accounted for various reasons related to, for instance, lower income or different customs or values. By contrast, employed individuals may better afford to buy foods with high climate impact, for instance meat, or have better access to them in food catering services.

In this study, men in the highest household income quintile had the highest absolute and energy-adjusted dietary climate impacts. This agrees with some of the previous findings (Vázquez-Rowe et al., 2017). A review study concluded that the relationship between income and dietary GHGEs is inconsistent (Kliejunas et al., 2024). Van Dooren et al. (2018), however, reported that even though income, or education alone were not significantly related to the level of dietary climate impact, a SES variable combining both indicators showed a direct association with climate impact. Even though it is known that red meat has a major contribution to dietary climate impacts in Finland as well (Saarinen et al., 2023), in our previous study utilizing the same data (Sares-Jäske et al., 2022) income did not show significant association with red and processed meat consumption. Our results of household income not being associated with dietary climate impact in women are also consistent with many of the previous findings considering women and men (van Dooren et al., 2018; Reynolds et al., 2019; Rose et al., 2019; Auclair and Burgos, 2021; Perignon et al., 2023). Income impacts consumer choices. Affordability of foods is one of the key drivers in forming diets, and some previous studies have claimed that economic factors are a barrier to consume healthy foods with lower climate impacts especially in lower-income groups (Darmon and Drewnowski, 2015). Thus, it seems promising that in this and many other studies, individuals with the lowest income did not have greater dietary climate impacts. Part of this, however, could possibly be explained by a generally lower food consumption that is attributable to deprivation. Regardless, a previous study showed that it is possible to compose nutritionally adequate and lower GHGE diets with low price, but cultural acceptability of such diets can be a more notable barrier in adopting them (Irz et al., 2024a).

This study examined regional differences in dietary climate impact by using two different regional indicators. Firstly, while inspection of urbanization level of residential area (three categories on urban–rural axis) revealed no differences in men, women living in remote rural areas had the highest absolute dietary climate impact. This result differs from a Swedish study demonstrating a higher energy-adjusted dietary climate impact among women and men living in urban areas (Strid et al., 2019). Similarly, Hyland et al. (2017) found no differences between categories according to urbanization.

Secondly, as a novelty, this study illustrated geographic differences in dietary climate impact of the population on maps of Finland. Energy-adjusted dietary climate impact maps revealed some similarities and some differences with absolute dietary climate impact maps. In some of the regions, such as parts of Lapland, women and men appeared to have both higher absolute and energy-adjusted dietary climate impact levels suggesting that in these regions the diets both contain more energy, and their composition is less climate-friendly. However, residents of some larger towns, and women and men living in parts of southern and southwestern Finland, had relatively low absolute dietary climate impacts but the energy-adjusted dietary climate impacts were relatively high indicating that they consumed generally less energy but relatively more foods with higher climate impact. For some regions, the opposite was observed: in parts of eastern Finland the diets appeared to cause more climate impacts and contain more energy, but their energy-adjusted dietary climate impacts were lower suggesting that they contained relatively more climate-friendly foods.

Sociodemographic, socioeconomic and food culture-related differences across regions probably explain great part of the divergence. Differences related to preferences and traditions vary across Finland. For example, consumption of certain traditional dishes — part containing more meat, part more vegetables, berries or fish — are common in specific regions. At the same time, for example differences in age and educational distributions across regions may affect the average diet and consumer habits in certain regions. Differences in such factors exist both across urban–rural axis and between geographical regions. In Finland, areas near Helsinki and in southern Finland in general are more often densely populated while northern and eastern parts of the country are dominated by rural and sparsely populated areas. Thus, differences in geographical axis may also be largely affected by urban–rural axis related differences in diet. Residents of rural areas have both been shown to consume more meat (Guenther et al., 2005; Vainio et al., 2016; Sares-Jäske et al., 2022), but also to find meat more important in their diet (Sares-Jäske et al., 2022) than residents of urban areas. Geographical differences in consumption of red and processed meat — being great contributors to dietary climate impact generally and in this study — are presumably responsible for part of the variation in dietary climate impact (Härkänen et al., 2022; Sares-Jäske et al., 2022). Indeed, our previous illustrations of red and processed meat consumption across regions of Finland indicate largely parallel patterns with the dietary climate impacts, the levels being higher in parts of northern Finland and the lowest in Uusimaa near Helsinki (Kaljonen et al., 2022). Illustrations of indices of recommended food choices (Härkänen et al., 2022) and of Finnish dietary recommendations (Kaljonen et al., 2022) also show, that in many of the regions where this study found higher energy-adjusted dietary climate impacts, they found lower diet index scores representing poorer diet quality. Combination of these findings thus suggests that by adhering more closely to the dietary recommendations could provide synergy benefits also in reducing the climate impacts of the diet. Finding of differences between regions can be utilized within regions to develop and promote, for instance institutional food catering services, to more climate-friendly.

4.2 Methodological considerations

One of the strengths of this study is the use of large and versatile population surveys (Lundqvist and Mäki-Opas, 2016; Borodulin et al., 2018; Borodulin and Sääksjärvi, 2019) and possibility to link climate impact coefficients to dietary information on individual level. This allows the study of actual diets in different sociodemographic groups and regions (Hyland et al., 2017; Strid et al., 2019; Auclair and Burgos, 2021), thus, taking into account for instance differences in cultural traditions and preferences affecting food choices. Another strength was the simultaneous scrutiny of both absolute and energy-adjusted dietary climate impacts in various sociodemographic groups and regions. Both absolute and energy-adjusted dietary climate impacts are important indicators of climate-friendliness of the diet, but their different perspectives must be kept in mind when interpreting the results (Hallström et al., 2015; Stubbendorff et al., 2025). Absolute dietary climate impact measures the total climate impact of an individual and is dependent both on amount and on climate impact-related quality of foods consumed, while energy-adjusted dietary climate impact measures only climate impact-related quality of the diet. Also, another strength of this study was the use of several sociodemographic group indicators, that enabled the examination of differences according to, for example, different aspects of SES. Individuals with higher education have been shown to have greater knowledge on recommended dietary choices (De Vriendt et al., 2009). On the other hand, higher income better enables purchase of climate-friendly foods that in some cases may be more expensive. Use of several indicators is essential in order to identify groups the support and policy actions need to be targeted to.

However, there are some weaknesses and methodological issues in the present approach as well. This study, along with many of the previous studies, could not evaluate individual energy requirement of the participants. Indeed, greater level of absolute dietary climate impact in some groups may result from greater excess food intake or greater energy requirement. However, the results of energy-adjusted dietary climate impact complement the knowledge by providing information of groups that have a less climate-friendly composition of the diet.

This study did not examine the composition of diet in sociodemographic groups and regions. Different food sources have diverging contributions to the dietary climate impact in different sociodemographic groups. Even though it is known, and also this study showed, that red and processed meat induce major contributions, also other foods contribute to the dietary climate impact. In addition to meat, for instance, dairy products, drinks, and discretionary foods have been shown to have considerable contributions to the dietary climate impact (Temme et al., 2014; Hendrie et al., 2016; Hyland et al., 2017) although in a recent Finnish study on nutritionally adequate diets, a fish- and dairy-rich diet scenario had relatively low climate impact compared to diet scenarios containing meat and quite close to vegan diet (Saarinen et al., 2023). Sociodemographic differences exist in consumption of such foods and for instance, it appears that while there are no notable educational differences in milk consumption, cheese consumption seems to grow in parallel with the educational level (Sanchez-Villegas et al., 2003; Valsta et al., 2022). Such differences in sources of climate impact and in consumption patterns in different sociodemographic groups deserve greater scrutiny in future studies.

Under-reporting of energy intake and foods considered unhealthy and over-reporting of foods considered healthy and “desirable” may affect results of all dietary surveys. Magnitude of such misreporting may vary between sociodemographic group and according to background characteristics, for instance BMI (Livingstone and Black, 2003; Castro-Quezada et al., 2015). Thus, misreporting may have affected results of this study in terms of absolute energy intake and composition of diets.

Non-participation in population surveys has increased over the years, and especially individuals with low socioeconomic status tend to have lower participation rate (Reinikainen et al., 2018). Thus the estimated means based on the participants might not represent the true population averages. This non-participation bias, however, was mitigated by using inverse probability weights in the analyses (Härkänen et al., 2016). Also, these surveys did not cover the whole country, thus geographical differences in some areas might not have been detected.

The data of this study was collected in 2017 (sociodemographic variables and geographical regions) and in 2011 and 2012 (geographical regions). Since then, the COVID-19 pandemic and the geopolitical situation in Europe have affected the food systems and food security. In addition, dietary habits and availability of certain foods may have changed during these years. Thus, findings of this study may not quite represent the situation of today, and future studies with newer data should be conducted to complement these results.

Questions also may arise concerning the climate impacts coefficients. Methodological details in the life cycle assessment typically vary between studies generally reducing comparability between the product-level coefficients (Roy et al., 2009; Ridoutt et al., 2017; González-García et al., 2018). This may lead to misestimations of dietary climate impact or hinder the comparison between different diet scale studies but has probably less effect on group comparison results within a study—provided that the coefficients are compatible with the object of the study. Indeed, as this study focussed on comparing values between sociodemographic groups and regions rather than generating exact GHGE sum values, this issue is not of major concern. More important than absolute values is that the coefficients correctly rank the products and produce reliable results for dietary assessment. In our previous studies, the coefficients used in this study, have produced consistent dietary comparison results with studies using data from other approaches indicating that the data requirements are not as strict for dietary assessments than for product comparisons (Irz et al., 2024b; Saarinen et al., 2025). In this study, the climate impact coefficients for foods were generated according to the Finnish context as far as possible (Saarinen et al., 2023).

This study presented the results on dietary climate impacts considering the impact of sex, age and energy intake, and opting to omit controlling for other potential confounding factors, despite the fact that such factors may have impacted the comparisons of sociodemographic categories. However, as in reality these factors would also be associated with the studied sociodemographic characteristics, and as the aim of this study was to identify the groups that have the highest climate impact, comprehensive adjustment for potential confounding factors may have inhibited such identification.

In this study, the climate impact of diet was considered. Future studies should focus also on other aspects of environmental impacts when examining sociodemographic group and regional differences.

5 Conclusion

We identified sociodemographic groups and regions in Finland with high absolute or energy-adjusted dietary climate impact. Such groups were men; in women and in men, the 35–54-year-olds and those living with underage children; in women, those living in remote rural areas; and in men, those in the highest income quintile. As for regions, higher levels appeared in men especially in parts of western and eastern central Finland. Results of absolute and energy-adjusted climate impacts showed mainly similar patterns with only some exceptions. This implicates that in most groups both the absolute amounts of intakes and the composition of the diet contribute to the higher climate impact. Some exceptions with differing results of the two climate impact indicators suggest that future studies should consider examining both absolute and energy-adjusted dietary climate impacts, and study whether differences appear in other settings and in other sociodemographic groups. Tradition-, preference- and food culture-related differences in food consumption across sociodemographic groups and regions probably explain part of the differences between sociodemographic groups and between geographic areas. The results imply that especially in the groups and regions with high absolute and high energy-adjusted dietary climate impact, a shift towards more plant-based diet can reduce the impact. Thus, even though dietary transition is needed in each sociodemographic group, targeting public health interventions to these potential target groups with high climate impacts could be most effective. For instance, information provided by this study can be used within regions with higher dietary climate impact in planning public health or catering service campaigns to enhance the diet to more climate-friendly. Further, marketing strategies to promote more plant-based diets can be tailored to take the socioeconomic characteristics of the group and their potential specific barriers into account. For instance, for families with children, easy, tasty and time-efficient plant-based alternatives may be an efficient way to promote more plant-based diets. Different policies and means may be effective in different groups. Targeted means that take into consideration, as closely as possible, the background of the group, the level of the knowledge on healthy and climate-friendly diet, and the barriers, willingness and resources to make the changes, are needed to promote and implement the change in different settings, for instance, food catering services, food industry and retail, marketing strategies, and health care services.

Data availability statement

The data that support the findings of this study are available from the Finnish Social and Health Data Permit Authority Findata. Restrictions apply to the availability of these data, which were used under license for this study. Data are available at: https://findata.fi/en/ with the permission of Findata.

Ethics statement

The studies involving humans were approved by Ethics Committee of Helsinki and Uusimaa Hospital district. The studies were conducted in accordance with the local legislation and institutional requirements. The participants provided their written informed consent to participate in this study.

Author contributions

LS-J: Conceptualization, Data curation, Formal analysis, Investigation, Methodology, Project administration, Visualization, Writing – original draft, Writing – review & editing. TH: Conceptualization, Data curation, Formal analysis, Investigation, Methodology, Software, Visualization, Writing – original draft, Writing – review & editing. HT: Conceptualization, Data curation, Formal analysis, Investigation, Methodology, Resources, Software, Supervision, Visualization, Writing – review & editing. MS: Data curation, Investigation, Methodology, Writing – original draft, Writing – review & editing. JS: Investigation, Methodology, Writing – review & editing. LV: Conceptualization, Funding acquisition, Investigation, Methodology, Resources, Supervision, Writing – review & editing. LP: Conceptualization, Funding acquisition, Investigation, Methodology, Supervision, Writing – review & editing.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Generative AI statement

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Supplementary material

The Supplementary material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/fsufs.2025.1543646/full#supplementary-material

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