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Socioeconomic disparities in heat vulnerability among adults in Finland

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Understanding how socioeconomic status (SES) relates to heat vulnerability in cooler climates remains limited. This study explored whether low SES is associated to increased heat vulnerability in Finland. Data from 1828 participants aged 25 and over were collected via surveys in 2020 and 2021. Heat vulnerability was assessed using a nine-item index and SES was categorized as low or other. Linear regression models (ß-coefficients, 95% CIs) adjusted for gender, age, and survey year, with additional stratification by gender and age. Low SES was significantly associated with increased heat vulnerability [ß = 1.16 (95% CI: 1.00–1.32)], and the association persisted after adjustment [ß = 1.06 (95% CI: 0.90–1.21)]. The effect estimates were slightly higher in men [ß = 1.13 (95% CI: 0.89–1.37)] compared to women [ß = 0.97 (95% CI: 0.76–1.18)] and in individuals over 65 years [ß = 1.09 (95% CI: 0.87–1.31)] compared to those under 65 [ß = 0.98 (95% CI: 0.76–1.20)]. However, the confidence intervals were overlapping in both comparisons. These findings highlight the need to address socioeconomic disparities in mitigating heat-related health risks, even in developed societies like Finland.

Keywords Socioeconomic status, Heat, Vulnerability, Adults, Finland, Questionnaire

Globally, it is widely recognized that heatwaves have adverse impacts on human health, including increased morbidity and mortality[1,2]. Global temperatures have risen significantly over the last two decades and will continue to increase in the future. In addition, heatwaves are becoming more frequent, severe, and longer lasting[3]. There is no universal definition of a heatwave, partly due to the global variation in climatic conditions[4]. Likewise, definition of vulnerability to the effects of extreme weather events, such as heatwaves, on public health has been conceptualized varyingly. We defined vulnerability to result from three groups of factors: exposure, sensitivity, and adaptive capacity[1].

During the 21st century, health effects of high summertime temperatures and heatwaves have been examined in numerous studies and in various countries, particularly in North America, Europe, Asia, and Australia[5]. In Europe, research on the impact of heatwaves on human health and well-being increased after the heatwave of 2003, which has been estimated to have caused tens of thousands of premature deaths in Europe[6]. In contrast to regions with warmer climates, where populations are better adapted to higher temperatures, adverse health effects of hot weather tend to occur at lower temperatures in cooler Northern European regions[7].

Despite the progress in the scientific knowledge on vulnerability, there remains a lack of systematic and consistent conceptual framework specifically tailored to heat hazards[8]. Sensitivity of individuals to heat exposure is considered to associate with age, body composition, gender, degree of acclimatization, medical conditions, and medication[4]. Vulnerability in turn is determined by factors affecting either sensitivity, exposure, or adaptive capacity. Socioeconomic position is potentially related to all these factors. The elderly are particularly at risk of heat-related adverse effects, influenced not only by physiological changes related to aging but also by diminished functional capacity and the prevalence of chronic illnesses[9]. Many diseases and medications used in their treatment may impair the body's thermoregulatory ability and reduce tolerance to additional stress from heat[10]. Social and environmental factors, including living alone and having a socially isolated lifestyle, further contribute to the increased risk[11]. While women are often found to be more vulnerable to heat exposure, heat poses a health

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risk for both genders[12]. Low socioeconomic status, living in an apartment with a high risk of overheating, and a lack of air conditioning have also been linked to an increased likelihood of adverse effects[12–14].

The association between socioeconomic status (SES) and health has been established in several studies[15,16]. Finland exhibits a relatively high level of income equality and a social welfare system that is characterized by universal healthcare, education, and generous social security benefits[17]. However, compared to some other Nordic countries like Denmark and Sweden, Finland faces challenges related to regional disparities and relatively high unemployment rates, particularly in rural areas[17]. Low SES has been associated with heat-related mortality in various European countries[18,19]. Additionally, a link has been identified between mortality rates and unemployment levels in Mediterranean cities[20,21]. However, there is limited research on how socioeconomic status is related to various vulnerability factors, especially in developed societies with cooler climates.

Epidemiological studies have demonstrated that heatwaves represent a substantial health risk in Finland[22,23]. During a prolonged heatwave in the summer of 2018, an estimated 400 Finns lost their lives due to heat-related causes[24]. While old age is widely recognized as a high-risk factor during heatwaves, there remains a gap in understanding whether socioeconomic status may influence vulnerability to heatwaves in the Nordic countries[25]. To address this gap, the objective of this study was to examine how socioeconomic and demographic factors are associated with vulnerability to heat in Finnish population aged 25 or older.

Methods

Design and participants

The data for this cross-sectional, population-based study was collected in 2020 and 2021 using a random sampling method. Mailed surveys that comprehensively covered questions related to heat-, social-, and health-related factors were distributed to adults aged 25 and over by mail. Respondents had the option to complete the survey by either returning a paper questionnaire or by responding to an online form on the internet. The questionnaire was available in Finnish, Swedish and English (online only). This study was part of the HEATCLIM project, which was conducted in a collaboration with the Finnish Institute of Health and Welfare, the University of Eastern Finland, Aalto university, and the Finnish Meteorological Institute. Datasets from the years 2020 and 2021 were combined. In 2020, there were 1094, and in 2021, 1013 respondents (response rate 39%). A random sample representing all adults aged 25 and over was derived from the Digital and Population Data Services Agency (DVV). The sample included all individuals with a permanent address in mainland Finland (excluding the Åland Islands) during weeks 33/2020 and 33/2021. The sample covered all language groups and included data on sex and year of birth. No regional or other weighting was applied, making this a true population-based random sample (with the exception of the age limit and geographical restriction). All procedures were performed in compliance with relevant laws and institutional guidelines and have been approved by the Research Ethics Committee of Finnish Institute for Health and Welfare. Ethical approval was granted in (ref. 2020 THL/2289/6.02.01/2020). Furthermore, the privacy rights of human subjects have been observed and that informed consent was obtained from participants. Based on the self-reports in the survey, we assessed the respondents' health status, functional capacity, social relationships, level of income and housing, and how they perceive health risks of heat. We restricted all analyses to the data from which individuals with missing information on key variables (sensitivity factors, income level, age, gender, survey year) had been excluded ($N = 279$). Eventually 1828 participants with complete data were included in the final analysis.

Vulnerability index score

Our first objective was to construct a vulnerability index based on various socioeconomic and health-related factors. To assess vulnerability to heatwaves, we constructed an index comprising of nine self-reported variables. The variables included in the heat vulnerability index were selected based on expert knowledge, guidelines from the World Health Organization[26], and existing literature identifying individual-level characteristics that have been associated with increased heat vulnerability. In addition to variables related to sensitivity and adaptive capacity, there were two variables that are known to be associated with heat exposure. The full matrix of pairwise chi-square associations is presented in supplementary files (Appendix 1.) The variables were as follows:

1. Living alone (Variable 1): Participants were asked if they live alone, and a score of 1 was assigned if they answered affirmatively. Otherwise, a score of 0 was assigned. Living alone or leading an isolated lifestyle is recognized to elevate the risk of heat-related impacts[11,27].
2. Presence of disorders (Variable 2): Participants were asked if they have one or more health-related disorders (e.g., various heart or lung disorders, diabetes, memory disorder, depression, arthritis, etc.), and a score of 1 was assigned if they answered affirmatively with 2 or more disorders. Otherwise, a score of 0 was assigned. Many diseases and medication use are known to increase vulnerability to heat[10].
3. Residence in an apartment building (Variable 3): Participants were asked if they live in a high-rise apartment building, and a score of 1 was assigned if they answered affirmatively. Otherwise, a score of 0 was assigned. High-rise living associated with higher age is known to associate with increased risk of morbidity and mortality during heatwaves[28].
4. Use of active cooling devices (Variable 4): Participants were asked if they have any active cooling devices at home (e.g., air source heat pump or any other air conditioning device) and a score of 0 was assigned if they answered affirmatively. Otherwise, a score of 1 was assigned. Use of active cooling devices has been reported to significantly decrease heat-related mortality[29].
5. BMI ≥ 30 (Variable 5): Participants were categorized based on their body mass index (BMI), and a score of 1 was assigned if their BMI was greater than or equal to 30. Otherwise, a score of 0 was assigned. Obesity affects thermoregulation and increases susceptibility to heat stress[30].

6. Ability to walk continuously for one kilometer (Variable 6): Participants were asked if they were able to walk continuously for 1 km, and a score of 0 was assigned if they answered affirmatively. Otherwise, a score of 1 was assigned. Low fitness and reduced physical ability increase vulnerability to heat[31].
7. Non-adherence to heat warnings (Variable 7): Participants were asked if they follow heat warnings, and a score of 0 was assigned if they answered affirmatively. Otherwise, a score of 1 was assigned. Heat warnings are an established tool to decrease health effects of heat, but on an individual level they need to be followed in order to have any effect. Following heat warnings was found to be beneficial during heatwaves, as it was associated with a higher risk of hospitalization for heat-related causes[32]. In Finland, the Finnish Meteorological Institute (FMI) issues a regional heat warning five days in advance when the daily maximum temperature is forecasted to exceed 27 degrees Celsius and the daily average temperature 20 degrees Celsius. The warnings are communicated on FMI's website and in the media, and they are intended to support citizens and vulnerable population groups in their self-preparedness. Guidelines for protection against adverse effects of heat are available on the website of the Finnish Institute for Health and Welfare (THL). However, as Finland lacks a national heat-health action plan, the heat warnings are currently not linked to pre-planned actions by national or regional authorities and, hence, do not automatically lead to official communication of heat advisories or other preparedness measures[33].
8. Awareness of risks (Variable 8): This variable was derived as a sum variable from a series of questions. Participants were asked if they believed that particular population groups were at risk during heatwaves (groups identified based on scientific studies), including Finnish citizens in general, elderly individuals, small children, people with heart disorders, respiratory disorders, or memory disorders, outdoor workers, and pregnant individuals. A score of 1 was assigned for each group that participants believed to be at risk, and the scores were summed to create the final variable. After the cut point of the sum variable was appointed, it scored to 0 if the respondent had identified various risk groups, otherwise, a score of 1 was assigned. Recognizing risks and learning how to adjust individual behaviors to prevent illness or fatalities during hot weather is particularly crucial for those who are most vulnerable to heat-related effects[34].
9. Education level (Variable 9): Participants were asked about their education level, and a score of 0 or 1 was assigned based on their highest level of education (low for comprehensive school or high-school, respectively). Studies have reported low education to be associated with increased risk of heat-related mortality[1,35].

The vulnerability index was calculated for each participant by summing the scores across these nine variables, resulting in a composite score ranging from 0 to 9, with higher scores indicating greater vulnerability to heatwaves. This provided a comprehensive measure of heat vulnerability. We conducted a sensitivity analysis by including a measure of indoor heat exposure—self-reported indoor temperature ≥ 28 °C during hot weather (reported by 33% of participants)—in the vulnerability index. Results are presented in Appendix 2 (Supplementary Files).

Socioeconomic status (SES)

In our study, SES was transformed into a dichotomous variable (low SES / other SES) using an equivalent income score that we had previously calculated using the OECD-modified scale[20]. First, the yearly household income was inquired through the survey. To compare income across households of varying sizes and compositions, an equivalent income score was calculated. In this study, a cut-off of €20,000/year in equivalized household income was used to define low income. While this is slightly above the official Finnish low-income threshold (approximately €17,000)[36], it reflects a pragmatic and theoretically grounded boundary that captures individuals experiencing economic disadvantage. The chosen threshold is close to the official line, yet broad enough to ensure sufficient group size for statistical analysis and comparability across socioeconomic categories. The household head was assigned a score of 1, each additional adult member 0.5, and each child 0.3. Single adult households served as the reference group, assigned a score of 1. The equivalence scores for each household member were summed to obtain a total equivalence number for the household. This total was then divided by the sum of the weighting factors to derive a representative income[20].

Statistical analyses

Data are presented as medians with interquartile ranges (IQR) or as counts with percentages. As covariates in the models, we included the year of survey, age, and gender. We examined the association of income level (low income) both with the vulnerability index and the individual vulnerability factors. To investigate the latter, we used cross-tabulated income level and sensitivity factor one at a time (with n, row, and column percentages) while simultaneously conducting the Chi-squared test. When examining the associations between income level and vulnerability index we cross-tabulated income level and sensitivity index and performed the Chi-squared tests to assess the statistical significance of the association. A Mann-Whitney U test was conducted to assess the statistical significance of continuous variables.

Furthermore, we performed linear regression analysis (ß-coefficients and their 95% CIs) to examine the associations between the heat-related vulnerability index (dependent variable) and various factors, including low income, gender, age, and survey year. As potential confounders we included factors that are associated with low SES and heat vulnerability; that is, gender (women/men) and age (years categorized to six age groups; 25–34, 35–44, 45–54, 55–64, 65–74 and 75 or over). In addition, we adjusted the models for survey year (2020 or 2021). Stata 17.0 (StataCorp LP; College Station, Texas, USA) statistical package was used for the analysis.

Results

The analysis data consisted of 1828 Finnish participants who were aged 25 years or older. Characteristics of the study participants are presented in the Table 1. The median age of the participants was 63, with less than

	N = 1828 (%/IQR)
Age, n (%)	
25–34	178 (9.7)
35–44	161 (8.8)
45–54	273 (14.9)
55–64	363 (19.9)
65–74	521 (28.5)
75+	332 (18.2)
Women, n (%)	991 (54.2)
Low income, n (%)	415 (22.7)
Survey year, n (%)	
2020	949 (51.9)
2021	879 (48.1)
Living alone, n (%)	493 (27.0)
Disease/disorder ≥ 2, n (%)	499 (27.3)
Apartment building, n (%)	612 (33.5)
No active cooling at home, n (%)	573 (31.4)
BMI ≥ 30, n (%)	306 (16.7)
Cannot walk one km without resting, n (%)	311 (17.0)
Does not follow heat warnings, n (%)	356 (19.5)
Does not acknowledge risks to vulnerable groups, n (%)	166 (9.1)
Low education, n (%)	825 (45.1)
Vulnerability index, median (IQR)	2 (2)

Table 1. Descriptive characteristics of the participants (*N* = 1828). BMI: Body mass index; IQR: Interquartile range.

one-fourth classified as having low income. One-third resided in apartment buildings, and one-sixth were categorized as obese. Additionally, slightly less than one-half had low education levels.

The distribution of the vulnerability index is illustrated in Fig. 1. Approximately 12% of the participants were assigned a score of 0, indicating that they did not meet the criteria for any questions related to heat-related vulnerability. In contrast, no responses fell into two of the highest values on the scale. Additionally, just under 10% of the participants were assigned values ranging from 5 to 7.

Table 2 presents the vulnerability index and its components by gender and age group, while Table 3 shows them by SES. Women were more likely than men to live alone ($p < 0.001$) and reside in apartment buildings ($p = 0.002$). Men, on the other hand, had lower educational attainment ($p < 0.001$), were less likely to heed heat warnings, and showed less awareness of heatwave risk groups ($p < 0.001$). Stratifying by age (< 65 and ≥ 65), older participants had a higher prevalence of chronic conditions, lived alone more often, lacked cooling devices, had difficulty walking 1 km, and had lower education ($p < 0.001$). Younger participants, however, had higher BMI ($p = 0.009$) and were less likely to follow heat warnings ($p < 0.001$).

Individuals with low SES ($N = 415$) differed significantly from those with other SES ($N = 1413$) in several heat vulnerability factors (Table 3). The low SES group was older (median age 67 vs. 62 years, $p = 0.001$), more likely to live alone (51% vs. 20%, $p < 0.001$), and had a higher prevalence of diseases (33% vs. 26%, $p = 0.004$). They also resided more often in apartment buildings (44% vs. 31%, $p < 0.001$), lacked active home cooling (43% vs. 28%, $p < 0.001$), and experienced walking difficulties (31% vs. 13%, $p < 0.001$). Additionally, low SES individuals had lower education levels (69% vs. 38%, $p < 0.001$) and a higher median vulnerability index (4 vs. 2, $p < 0.001$) The cross-tabulations with chi-squared tests of age, gender, income and survey year and their associations with vulnerability index are presented in Appendix 3. Participants with low SES exhibited a significantly higher prevalence of higher index score compared to the other group ($p < 0.001$). Similarly, higher index score was associated with older age ($p < 0.001$).

In the linear regression Model 1 assessing the relationship between SES and the vulnerability index (Fig. 2), we accounted for the potential influences of age, gender, and survey year [ß = 1.06 (95% CI:0.90–1.21]. The association between low SES and heat-related vulnerability seemed to be slightly stronger among men [Model 2: ß = 1.13 (95% CI:0.89–1.37)] compared to women [Model 3: ß = 0.97 (95% CI:0.76–1.18)]. However, the difference between genders was not statistically significant. Additionally, among participants of 65 years or older [Model 5: 1.09 (95% CI: 0.87–1.31)], the association of low SES on vulnerability remained significant and slightly stronger compared to participants under 65 years [Model 4: ß = 0.98 (95% CI:0.76—1.20)]. Again, the difference between the compared groups was not significant. More detailed results can be found in Appendix 4. The differences between genders and age groups remained similar in the sensitivity analysis (Appendix 2).

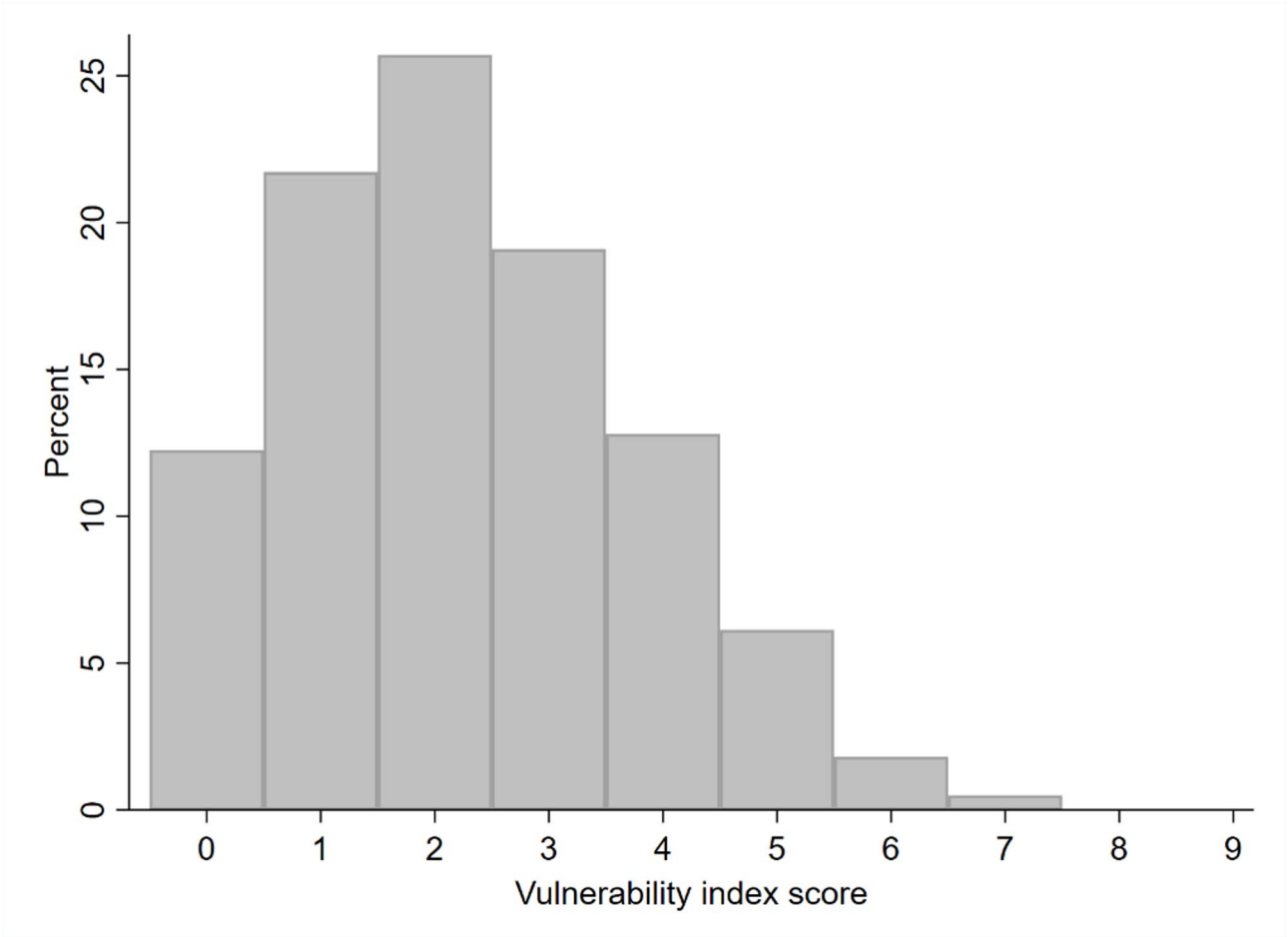

Fig. 1. Distribution of vulnerability index score.

	Men	Women		Age < 65	Age ≥ 65	
	(*N* = 837)	(*N* = 991)	p	(*N* = 975)	(*N* = 853)	p
Age, median (IQR)	63 (22)	62 (24)	0.62			
Living alone, n (%)	183 (21.9)	310 (31.3)	< 0.001	219 (22.5)	274 (32.1)	< 0.001
Disease/disorder ≥ 2, n (%)	224 (26.8)	275 (27.8)	0.64	174 (17.9)	325 (38.1)	< 0.001
Apartment building, n (%)	249 (29.8)	363 (36.6)	0.002	325 (33.3)	287 (33.7)	0.89
No active cooling at home, n (%)	270 (32.3)	303 (30.6)	0.44	270 (27.7)	303 (35.5)	< 0.001
BMI ≥ 30, n (%)	140 (16.7)	166 (16.8)	0.99	184 (18.9)	122 (14.3)	0.009
Cannot walk one km without resting, n (%)	132 (15.8)	179 (18.1)	0.19	75 (7.7)	236 (27.7)	< 0.001
Does not follow heat warnings, n (%)	197 (23.5)	159 (16.0)	< 0.001	256 (26.3)	100 (11.7)	< 0.001
Does not acknowledge risks to vulnerable groups, n (%)	118 (14.1)	48 (4.8)	< 0.001	100 (10.3)	66 (7.7)	0.06
Low education, n (%)	423 (50.5)	402 (40.6)	< 0.001	335 (34.4)	490 (57.4)	< 0.001
Vulnerability index, median (IQR)	2 (2)	2 (2)	0.13	2 (2)	2 (3)	< 0.001

Table 2. Descriptive characteristics of the participants (*N* = 1828) divided by gender and age. IQR: Interquartile range; BMI: Body mass index, SES: Socioeconomic status.

Discussion

In this study, we investigated whether socioeconomic status, represented by income level, is associated with accumulation of factors that make individuals more vulnerable to adverse effects of heat and heatwaves. Our results confirm a significant association between lower socioeconomic status and increased vulnerability to heat among Finnish population aged 25 and over. To our knowledge this is the first study to establish the relationship between low SES and heat vulnerability in the Nordic countries.

	Low SES ($N=415$)	Other SES ($N=1413$)	p
Age, median (IQR)	67 (27)	62 (21)	0.001
Living alone, n (%)	210 (50.6)	283 (20.0)	< 0.001
Disease/disorder ≥ 2, n (%)	136 (32.8)	363 (25.7)	0.004
Apartment building, n (%)	181 (43.6)	431 (30.5)	< 0.001
No active cooling at home, n (%)	178 (42.9)	395 (28.0)	< 0.001
BMI ≥ 30, n (%)	71 (17.1)	235 (16.6)	0.82
Cannot walk one km without resting, n (%)	128 (30.8)	183 (13.0)	< 0.001
Does not follow heat warnings, n (%)	88 (21.2)	268 (19.0)	0.31
Does not acknowledge risks to vulnerable groups, n (%)	34 (8.2)	132 (9.3)	0.47
Low education, n (%)	286 (68.9)	539 (38.2)	< 0.001
Vulnerability index, median (IQR)	4 (2)	2(3)	< 0.001

Table 3. Descriptive characteristics of the participants ($N=1828$) divided by income. IQR: Interquartile range; BMI: Body mass index, SES: Socioeconomic status.

In our study, the lower SES group exhibited significantly higher vulnerability index scores compared to the other SES group. The association between lower SES and heat vulnerability persisted even after adjusting for covariates and stratifying for gender and age, which indicates its robustness. It has been previously reported that in the Nordic countries, low-income communities could be more vulnerable to the effects of extreme heat, as limited financial resources hinder access to air conditioning and other essential services[37].Traditional Nordic houses, designed to withstand cold temperatures, often lack the necessary features to cope with extreme heat. Moreover, insulation designed for cold climates may trap heat during heatwaves, leading to indoor temperatures that are uncomfortably high[38,39]. Based on our results, in Finland individuals with low income are more likely to live in an apartment building and less likely to have active cooling devices at home. They are also more likely to live alone and, therefore, may not get help when needed to protect themselves from the harms of hot weather. Moreover, individuals in the lower SES group were more inclined to have lower levels of education. Prior research has established an association between lower education levels and increased mortality during heatwaves[1,40,41]. Additionally, people with low income are more likely to work in occupations in which working conditions expose them to high temperatures for extended periods. However, in our study, over half of the participants (51%) were already retired or no longer part of the workforce, yet the association persisted also among the older age group (above 64 years) in which most participants would be pensioners. It is important to note that working conditions were not measured in our study.

The association between low SES and heat-related vulnerability factors tended to be somewhat more pronounced in participants aged 65 and older. However, the result has to be interpreted cautiously because the confidence intervals of the compared age groups overlapped considerably. Nevertheless, the result suggests that among the elderly, low SES increases the health risk associated with heat even more than in the younger population. Older individuals are more vulnerable to heat stress due to physiological changes associated with aging[25]. Additionally, the high prevalence of chronic diseases among the elderly further increases their vulnerability[42]. Poor housing conditions and limited financial resources may also restrict chances for cooling and increase the health risk during heatwaves among the elderly[29,43]. Furthermore, reduced mobility could impede the ability of low SES elderly individuals to seek out cooler environments or access cooling centers during periods of extreme heat[11]. Additionally, lower SES is associated with social isolation[44], which has been found to be associated with higher heat-related mortality among the elderly[27]. Social isolation[41], limits access to social support networks and resources during heatwaves. In previous studies conducted in Finland, heatwaves have been found to be a health threat increasing morbidity and mortality particularly in the older population[22,23]. In our study, older participants had a higher proportion of chronic illnesses or medical conditions, had reduced mobility, lacked active cooling methods at home, and lived more often alone. As the proportion of elderly individuals in the Nordic population continue to rise[45], the region faces an increased risk of heat-related health impacts. For these groups and those caring for them, targeted information about the adverse effects of heat and the necessary measures for prevention should be provided, with specific attention to the low SES population.

The association between low SES and the heat-related vulnerability index seemed to be slightly stronger among men than women. However, the difference between the compared groups was again not statistically significant. Previous research from Australia found that in the most disadvantaged areas, men's likelihood of attending an emergency department rose by 10% on heatwave days while in women this increase was 4%[46]. Tooloo et al. (2014) concluded, that the higher risk among lower SES men during heatwaves might be partially attributed to increased heat exposure from outdoor occupations, as well as poorer health, lifestyle risks, lower social support, and challenges in accessing timely information[46]. Our results indicate that men may also be more prone to neglect heat warnings and demonstrate a lack of awareness regarding at-risk population groups. Additionally, we obderved that men had lower levels of education compared to women, which have been reported to associate with and heat-related mortality[1,40,41]. However, our study shows that in Finland low SES also increases vulnerability to heat in women. In general, hot weather is often reported to lead to higher mortality in women than men[12,47], and this has also been observed in a Finnish study[23]. Our results show that

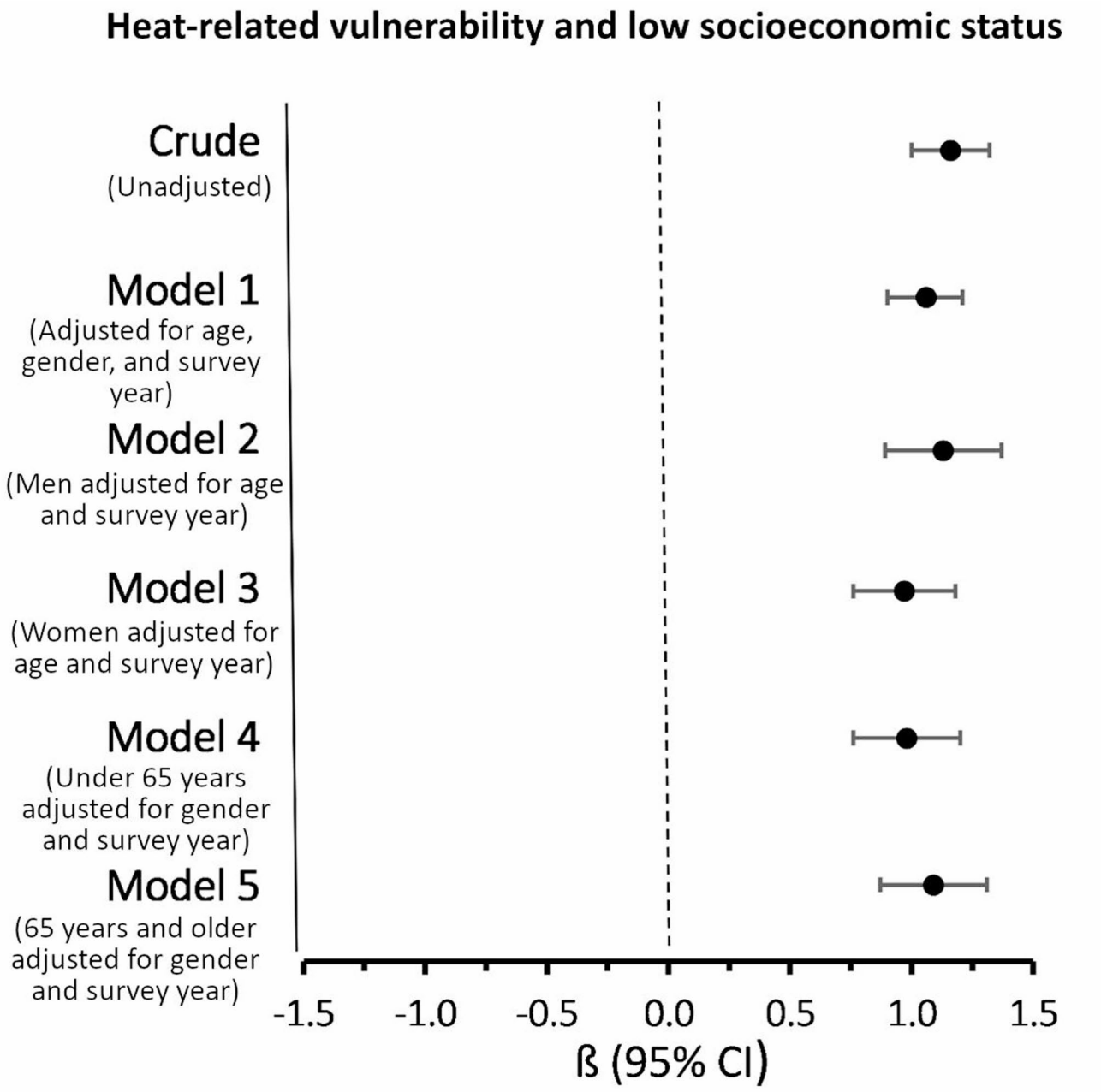

Fig. 2. Relationships between low socioeconomic status (SES) and heat-related vulnerability ($N = 1828$). Crude is unadjusted low SES. Model 1 is low SES adjusted for age, gender and survey year. Model 2 is low SES stratified for men and adjusted for age and survey year. Model 3 is low SES stratified for women and adjusted for age and survey year. Model 4 is low SES stratified for participants under 65 years of age and adjusted for gender and survey year. Model 5 is low SES stratified for participants 65 years old or older and adjusted for gender and survey year. ß values with 95% confidence intervals.

more women were living alone and living in apartment buildings, which are known to increase the vulnerabilty during heatwaves[11,27,28]. In addition to socioeconomic factors, the higher heat-related mortality in women could be related to physiological differences in thermoregulation between sexes, as well as behavioural factors[44].

While the Nordic countries have a strong reputation for their social and healthcare systems, preparedness to challenges related to heat is still inadequate in many ways[33]. It is noteworthy that low SES increases vulnerability to heat also within a Nordic welfare society. Developing heat-health action plans, coupled with early warning systems, and increasing heat resilience of buildings and urban areas are crucial actions to enhance preparedness to heatwaves and to adapt to warming summers[48]. Targeted measures focusing on protecting vulnerable populations, such as the elderly and low-income communities, are needed to address existing deficiencies and prevent severe health impacts. By addressing the interplay between demographic and socioeconomic factors in heat-related vulnerability, policymakers can develop more efficient strategies to enhance adaptive capacity

and resilience. This could involve implementing public awareness campaigns to educate the communities about the risks associated with heatwaves and about the ways to prevent adverse effects. Efforts should also be made to identify particularly vulnerable individuals who may require active measures such as outreach and assistance. Additionally, promoting community resilience by encouraging neighbors to check on each other during heatwaves and establishing financial assistance programs to help low-income individuals afford the costs associated with staying cool could be effective preventive measures[49].

Important aspects that need to be highlighted are that we gathered and analyzed data from a randomly selected group of adults after two summers, enabling us to draw generalizations. Additionally, we enlisted a relatively sizable sample of the Finnish adult population, and we examined various established vulnerability factors in our study. However, it is important also to acknowledge certain limitations. One significant limitation of our study is the relatively low response rate of 38% in the survey used for data collection. This response rate raises concerns regarding potential non-response bias, as individuals who chose not to participate may differ systematically from those who did, possibly skewing the findings. This could lead to an underrepresentation of certain demographic groups or perspectives, impacting the generalizability and validity of the results. Moreover, the subjective nature of self-assessing may introduce reporting bias, potentially influencing the outcome. Finally, while our index includes a range of known vulnerability indicators, we acknowledge that it does not capture all potentially relevant factors. Greenspace availability and household overcrowding, for example, may influence heat vulnerability in certain settings, but were not included due to limited data availability and lower contextual relevance in Finland.

Conclusion

In conclusion, low socioeconomic status is associated with heat-related vulnerability in adult population of Finland, a highly developed country with cool climate. Our study emphasizes the need for taking into account socioeconomic disparities when creating strategies for preventing adverse health impacts of heat while improving the adaptive capacity in rising temperatures. Future studies could explore additional factors contributing to heat vulnerability and assess the effectiveness of interventions aimed at mitigating these vulnerabilities.

Data availability

The datasets generated during and/or analysed during the current study are available from the corresponding author on reasonable request (ville.paivarinne@thl.fi).

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Declarations

Competing interests

The authors declare no competing interests.

Additional information

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