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Exploring regional inequities in food safety practices and food security in Italy: A cross-sectional study

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ABSTRACT

Objective: This study examined regional disparities in food security and food safety knowledge and behavior among Italian adults.
Methods: Between January and June 2024, we conducted a cross-sectional anonymous online survey targeting Italian residents aged ≥18. The sample size was calculated a priori assuming a 50% prevalence, 95% confidence, and 3% margin of error, yielding a target of 1067 participants. Validated Italian versions of the Food Security Survey Module (It-FSSM) and the Food Safety Knowledge and Behavior Questionnaire (It-FSKB) were employed to assess participants' knowledge and behaviors. Sociodemographic data, including age, sex, body mass index (BMI), educational level, physical activity, smoking habits, and food apps usage, were collected. Multinomial logistic regression—adjusted for age, sex, BMI, and educational level—was used to evaluate regional differences.
Results: Among 1752 participants (70.4% women; mean age: 36.01 ± 13.84 y), those in the South area and Islands were significantly less likely to report high food safety knowledge (relative risk ratio [RRR] = 0.66; 95% confidence interval [CI]: 0.54–0.82; P = 0.000) and high food safety behaviors (RRR = 0.64; 95% CI: 0.52–0.79; $P < 0.001$), and more likely to experience moderate food insecurity (RRR = 1.64; 95% CI: 1.00–2.69; $P = 0.048$) compared to participants to the North. Participants in the Center were over twice likely than those in the North to report high food security versus very low (RRR = 2.72; 95% CI: 1.15–6.43; $P = 0.023$) and were also 30% less likely to use food delivery apps rarely rather than not at all (RRR = 0.70; 95% CI: 0.50–0.97; $P = 0.034$).
Conclusions: This study highlights significant regional disparities, with the South area and Islands facing the greatest challenges. These findings provide evidence to guide targeted public health interventions and policies promoting food safety and security across Italy.
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Introduction

Food safety and food security are essential to public health, as both directly influence population well-being and nutrition [1].

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Food safety refers to the practices and systems that ensure food is free from harmful contaminants, whereas food security encompasses the availability, accessibility, and affordability of sufficient, safe, and nutritious food for all individuals [2]. According to the Food and Agriculture Organization (FAO), food insecurity and malnutrition persist worldwide, particularly in rural areas, affecting vulnerable populations such as women and young people [3], with 2.33 billion people—nearly 30% of the global population—experiencing inadequate food access in 2023 [4]. Foodborne diseases also remain a major challenge worldwide, with millions of cases annually that are largely preventable through appropriate hygiene and handling practices [5].

Food safety and food security are closely interconnected and play a pivotal role in reducing the burden of foodborne illnesses and malnutrition and promoting sustainable development. Addressing food insecurity is a key goal of the 2030 Agenda for Sustainable Development envisioning a Sustainable Future Society, with SDG Indicator 2.1.2 monitoring global progress [6]. Ensuring food safety requires a multisectoral approach and is a shared responsibility among national authorities, food producers, handlers, and consumers [7]. Governments play a critical role by prioritizing food safety as a public health concern, developing evidence-based policies, and implementing risk-based and flexible regulatory frameworks. Meanwhile, food handlers and consumers must adopt safe food handling practices, including the World Health Organization (WHO) Five Keys to Safer Food, whether at home, in restaurants, or local markets [8].

Although Italy is renowned for its culinary tradition and the Mediterranean diet, it is not immune to challenges [9]. National reports estimate that around 8 to 10% of households experience some level of food insecurity, with a higher prevalence in the South and Islands compared to the North [10]. The latest *ActionAid* and *Istat* reports highlight that socioeconomic disparities across regions contribute significantly to differences in access to safe and nutritious food, with southern populations facing more pronounced challenges. Food safety knowledge and practices also vary geographically, influenced by education levels, socioeconomic status, and public health infrastructure. The North regions, generally characterized by higher economic development and robust infrastructures [13,14], have been associated with better food-related behaviors and outcomes, while the South area and Islands face greater challenges due to economic constraints and infrastructural gaps [12]. These disparities highlight the importance of assessing region-specific factors to design targeted interventions. Existing literature consistently shows that socioeconomic status, education, and access to resources are key determinants of food safety knowledge and food security [15]. In the Italian context, national surveys confirm that lower-income households and those with limited educational attainment—particularly in the South and Islands—are more vulnerable to food insecurity and less likely to adopt safe food-handling practices [11,12] because they may influence access to safe and affordable food, particularly for vulnerable households

Digital tools such as food waste prevention platforms and food delivery applications are increasingly used and may influence access to safe and affordable food. However, their role in shaping food security and food safety behaviors has not been comprehensively explored [16–18]; actually, there remains limited research that comprehensively evaluates these factors within the Italian context. In particular, the extent to which emerging tools such as food delivery and waste prevention applications can systematically contribute to mitigating food insecurity and enhancing food safety behaviors requires further investigation. This study aims to evaluate food safety knowledge, behaviors, and food security levels in the Italian population, with a focus on identifying regional differences. We hypothesize that adults living in the South and Islands display lower food safety knowledge and practices, and higher food insecurity, compared with those in the North and Center, even after accounting for sociodemographic factors.

Methods

Study design

This study employs an observational, cross-sectional design in order to assess food safety and food security knowledge and behaviors among the general Italian population. In particular, the US Adult Food Security Survey Module was used for food security [19] and the Food Safety Knowledge Questionnaire for food safety [20]. Both the Food Security Survey Module (It-FSSM) and the Food Safety Knowledge and Behavior questionnaire (It-FSKB) were previously translated, culturally adapted, and validated for the Italian population, following international guidelines for self-report measures. The translation process involved forward translation by two independent bilingual translators, reconciliation into a single version, back-translation by two independent translators unaware of the original, and final review by an expert committee to resolve discrepancies and ensure conceptual equivalence [21].

Data collection

The study included eligible participants who were at least 18 y old and residing in Italy (inclusion criteria; $\geq$18 y, resident in Italy, provided informed consent; and the exclusion criteria: $<$18 y or nonconsenting participants). Recruitment was conducted via convenience sampling, using online dissemination through professional networks, and social media platforms. Data collection occurred anonymously from January to June 2024 through an online survey, designed in Microsoft Forms (Microsoft 365 A5). Participants reviewed the study's purpose and received completion instructions before starting the survey. Informed consent was a prerequisite; those who did not consent were automatically directed to the end of the questionnaire. To minimize incomplete or missing responses, all questions were mandatory, ensuring participants could not proceed to other sections without answering each question.

Sociodemographic and lifestyle data

The initial section of the survey delved into sociodemographic aspects such as sex (options: female, male, prefer not to say), age, height and weight, marital status (single, married/co-habiting, separated/divorced and widowed); family size (from 1 to 5 and more), region of residence. Regarding Italian regions, we classified them into three groups: North (Valle d'Aosta, Piemonte, Liguria, Lombardia, Emilia-Romagna, Trentino-Alto Adige, Veneto and Friuli-Venezia Giulia), Center (Toscana, Marche, Umbria and Lazio) and South and Islands (Abruzzo, Molise, Campania, Puglia, Basilicata and Calabria, Sicilia, Sardegna). Educational level was categorized as high (including bachelor degree or higher), medium (including high school), and low (including elementary or middle school). Physical activity (PA) was evaluated with the question: "How often do you practice physical activity?" and the answers were categorized into sedentary ("I do not practice it"), light PA ("I practice it 1–2 times a week") and moderate-vigorous PA ("I practice it three or more times a week"). Smoking habit was investigated with a question: "Do you smoke or have you ever smoked tobacco?" with the following options: "I have never smoked tobacco"; "I used to smoke

but I quit"; "I smoke occasionally"; "I smoke regularly." For the analyses, participants were categorized as Never, Former, or Current smokers, with the latter category including both regular and occasional smokers. In addition to sociodemographic and lifestyle factors such as physical activity and smoking, we collected information on the use of food delivery and food waste prevention applications. These variables were included because digital food-related tools may influence dietary behaviors, food safety practices, and food security by modifying how individuals access, purchase, and manage food. Use of food-related mobile applications was assessed with two separate questions: 1) frequency of food delivery app usage and 2) frequency of food waste prevention app usage. For both questions, participants were asked "How often do you use this type of app?" with the following response options: never, rarely ($\leq$1 time/mo), sometimes (1–2 times/week), and often ($\geq$3 times/week). Responses were subsequently grouped into three groups: "No" (never), "Rarely" ($\leq$1 time/mo), and "At least once a week" (including sometimes and often).

Food security

Food security was assessed using the Italian version of the 10-item Food Security Survey Module (It-FSSM) [21], originally developed by the United States Department of Agriculture to assess food security in the United States (USDA) [19]. This tool assesses food security by exploring experiences related to food access and affordability over the past 12 mo. Each question targets aspects such as economic constraints on food choices and frequency of food scarcity, providing insights into food security levels among Italian respondents. A high level of reliability was found with standardized Cronbach's α of 0.91 for It-FSSM. The τ ranged between 0.595 and 1.000, with significant correlations ($P < 0.001$) [21]. For the food security dimension, scores were computed based on the criteria outlined in the original questionnaire. Responses marked as "yes," "often," "sometimes," "almost every month," and "in some but not all months" were classified as affirmative, and assigned 1 point, otherwise 0. The total food security score for each participant was calculated by summing the affirmative responses, providing an absolute score representing the individual's food security status. Food security levels were categorized as follows: high food security among adults for a score equal to 0; moderate for a score between 1 and 2; low for a score between 3 and 5; and very low for a score between 6 and 10. These categories allowed for a graded assessment of food security, with higher scores indicating greater levels of food insecurity.

Food safety

Food safety was measured using the Italian version of the Food Safety Knowledge and Behavior (It-FSKB) questionnaire [21] adapted from Paden et al [20].

The It-FSKB is divided into knowledge and behavior sections. The knowledge section contains 45 statements across 5 domains: general food safety, cross-contamination, food preparation, food storage, and clean-up practices. Participants respond with agreement or disagreement, with responses scored to assess comprehension of safe food-handling practices. The behavior section uses a 23-item 5-point Likert scale to examine practical aspects like adherence to expiration dates and management of damaged packaging, gauging safe food consumption behaviors. A high level of reliability was found with standardized Cronbach's α of 0.75 for It-FSKB, moreover, the mean κ was 0.669, standard error (SE = 0.019) for FSKB [21].

This structure is intentional, as the questionnaire was designed to capture a broader range of practical behaviors in addition to knowledge. In order to ensure transparency, in the present study we reported both the knowledge and behavior subscores separately, as well as the overall combined score, and therefore, scores were calculated for each subsection, as well as an overall score.

For the knowledge sections, based on agreement/disagreement items, each correct response was assigned a score of 1, while incorrect responses were scored as 0. The scores for each subsection were summed to create a total score per subsection (general food safety, cross-contamination, food preparation, food storage, and clean-up practices). The median score was then calculated for each subsection. The scores were dichotomized: participants with scores above the median were classified as having "high" specific subsection knowledge, while those with scores below the median were classified as "low." The food safety total knowledge score was assessed combining the results of all the knowledge subscales.

For the behavior section (23-item 5-point Likert scale), scores from individual items were summed to generate a total score for the section. The median of these summed scores was calculated, and, similar to the agreement/disagreement sections, scores were dichotomized into "high" (above the median) or "low" (below the median) categories.

The overall food safety score was calculated by summing the scores from all sections. The median of this combined score was used to dichotomize participants into "high food safety" (score above the median) or "low food safety" (score below the median).

Sample size

The minimum required sample size was calculated a priori using Cochran's Modified Formula for Finite Populations for cross-sectional surveys, assuming a 80% expected prevalence of adequate food safety or food security [22,23] (in particular, we estimated a 80% prevalence of sufficient food safety knowledge while a 90% prevalence of food security), a 95% confidence level, and a 5% margin of error, referring to the population in the selected areas (North = 27 477 166; Center = 11 711 089; South/Islands = 19 782 975) which yielded a target of approximately 738 participants.

To increase representativeness and account for potential non-response, we aimed to recruit at least 281 participants across each Italian macro-region.

Statistical analysis

Categorical variables were presented as frequencies and percentages, while continuous variables were summarized using means and standard deviations. Shapiro–Wilk test was used to check the normal distribution of continuous variables, and it was found that no variable followed the normal distribution. Group differences were analyzed using the Kruskal–Wallis test for continuous variables and Pearson's chi-squared test for categorical variables. To evaluate regional disparities, multinomial logistic regression models were applied with the macro-geographical area of residence (North, Center, South/Islands) as the dependent variable, while food safety knowledge, food safety behavior, and food security levels were included as independent variables. Models were adjusted for age, sex, and BMI, (the latter used as continuous scale), and educational level, to assess whether observed regional differences persisted after controlling for potential confounders. Adjustment variables were selected a priori based on evidence from the literature showing their consistent association with food safety and food security outcomes. Due to the relatively small

sample size of the Central region, stratified analyses by region were not feasible; however, we report both crude and adjusted results to ensure transparency. Results are expressed as relative risk ratio (RRR) with 95% confidence intervals (95% CI). The level of significance chosen for statistical analysis was 0.05. Data were analyzed using statistical software STATA version C16.

Data quality

Several measures were implemented to ensure data quality. First, the online questionnaire was designed so that all questions were mandatory, preventing missing responses. Second, the platform (Microsoft Forms) restricted duplicate entries by recording IP addresses and preventing multiple submissions from the same device. Third, prior to analysis, data were checked for inconsistencies and implausible values (e.g., extreme BMI values), which were excluded following prespecified rules.

Ethical approval

All data were collected anonymously, and participation was entirely voluntary. The information gathered was stored in a secure, password-protected database and analyzed in aggregate form. The study adhered to the principles of the Declaration of Helsinki and received approval from the Ethics Committee of the University of Milan, Milan, Italy (ID: 111.23).

Results

Descriptive characteristics of the sample

In this study, we included a total of 1752 participants, of whom 851 (48.6%) were residents of North Italy, 284 (16.2%) were residents of Center Italy, and 617 (35.2%) were residents of South and Island of Italy. Sociodemographic characteristics, lifestyle factors, food safety and food security data are reported in Table 1.

Overall, the sample consisted of 70.4% women, with a mean age of 36.0 ± 13.8 y and a mean BMI of 23.6 ± 4.4 kg/m^2. Although the distribution of sexes was comparable across the different geographical areas, participants residing in Central Italy were significantly older, while those living in South and Islands had a higher BMI (24.2 ± 4.9 kg/m^2). Overall, 40% of participants were married or cohabiting, and 60.2% had a high level of education. However, differences emerged across geographical areas. We observed higher percentages of married individuals and those with a high level of education among participants residing in Central Italy compared to other areas. Regarding lifestyle, 78.3% of participants engaged in physical activity of any intensity, with higher prevalence in those residing in Central Italy, and 27.3% were smokers. Finally, 6.5% of participants experienced low or very low food security, and approximately half reported low food safety, with differences across geographical areas. We observed lower food safety scores and a lower percentage of participants with high food security in the southern regions and islands compared with central and northern Italy (Fig. 1).

Multinomial regression analysis

The multinomial logistic regression analysis, adjusted by age, sex, BMI, and educational level, revealed several significant regional differences in food safety and security. Using the North as the reference, the South and Islands consistently exhibited lower relative likelihoods of engaging in safe food knowledge, alongside greater relative risks of food insecurity, compared to other regions.

In detail, regarding lifestyle-related variables, the multinomial regression analysis showed that participants from the Center were 30% less likely to use these apps rarely than not at all compared to their North counterparts (RRR = 0.70; 95% CI: 0.50–0.97; $P = 0.034$) (Fig. 2). No significant differences in food delivery app use were observed in the South/Islands compared with the North. Similarly, no regional differences emerged for food waste prevention app usage (Fig. 2).

Significant disparities were observed for food security levels. Participants from the Center were more than twice as likely as those in the North to report high food security rather than very low food security (RRR = 2.72; 95% CI: 1.15–6.43; $P = 0.023$). Conversely, participants in the South and Islands exhibited a notably higher relative risk of reporting moderate food security compared with very low food security (RRR = 1.64; 95% CI: 1.00–2.69; $P = 0.048$), indicating an increased likelihood of food insecurity in this area (Fig. 2).

When examining food safety knowledge specifically, substantial regional differences emerged. Participants in the South/Islands had significantly lower odds of reporting high knowledge in food preparation (RRR = 0.66; 95% CI: 0.53–0.83; $P = 0.000$), storage (RRR = 0.69; 95% CI: 0.56–0.86; $P = 0.001$), and food safety practices (RRR = 0.66; 95% CI: 0.54–0.82; $P < 0.001$), compared with the North. These findings are confirmed when all the component of food safety knowledge are considered all together: overall, participants from the South and Islands are 34% less likely to report high food safety knowledge (total) (RRR = 0.66; 95% CI: 0.54–0.82; $P < 0.001$) compared with their Northern counterparts (Fig. 3).

Food safety behaviors also followed a similar pattern. Participants in the South and Islands are significantly less likely to report high food safety behaviors (RRR = 0.64; 95% CI: 0.52–0.79; $P < 0.001$). As a result, their overall food safety scores, combining both knowledge and practice aspects, are significantly lower: participants from the South and Islands are 37% less likely than those in the North to attain a high overall food safety score (RRR = 0.63; 95% CI: 0.51–0.77; $P < 0.001$) (Fig. 3). This result highlights the need for targeted interventions to improve food safety knowledge and practices in this area.

Discussion

This study highlights significant regional disparities in food safety knowledge, behaviors, and food security across Italy. In particular, participants from South and Islands exhibited significantly lower food safety knowledge and behaviors, and a higher prevalence of low or very low food security compared to their North counterparts. These findings confirm the existence of a pronounced geographic divide, which appears influenced by socioeconomic and educational factors.

The observed higher levels of food safety knowledge and behavior in North Italy are consistent with existing research linking economic stability, higher educational attainment, and stronger infrastructural systems with improved food-related behaviors [11]. Similarly, European studies have demonstrated that socioeconomic advantages correlate with better food safety practices and lower risks of food insecurity [24]. This trend aligns with our findings, where North and central Italy, characterized by higher socioeconomic indicators, demonstrated superior food safety and security outcomes compared to southern regions. These results reinforce the well-documented association between socioeconomic status and food-related knowledge and practices. Conversely, residents of southern Italy and the islands demonstrated lower knowledge of food preparation, storage, and safety practices, likely due to gaps in education and awareness initiatives. Their

Table 1
Descriptive characteristics of the sample, stratified by macro-geographical area of residence

Sociodemographic variables	Total sample (n = 1752)	North (n = 851)	Center (n = 284)	South and Islands (n = 617)	P-value
Sex					0.910*
Women	1.233 (70.4)	603 (70.9)	197 (69.4)	433 (70.2)	
Men	511 (29.2)	245 (28.8)	86 (30.3)	180 (29.2)	
I prefer not to answer	8 (0.5)	3 (0.4)	1 (0.3)	4 (0.6)	
Age in years (mean ± SD)	36.01 ± 13.84	34.69 ± 13.20	42.77 ± 16.08	34.71 ± 12.65	**<0.0011**†
BMI	23.62 ± 4.39	23.18 ± 4.05	23.81 ± 4.09	24.15 ± 4.90	**0.0002**†
Marital status					**<0.001***
Single	942 (53.8)	450 (52.9)	118 (41.5)	374 (60.6)	
Married/co-habiting	715 (40.8)	351 (41.2)	141 (49.7)	223 (36.2)	
Separated/divorced	70 (4.0)	37 (4.3)	15 (5.3)	18 (2.9)	
Widowed	25 (1.4)	13 (1.5)	10 (3.5)	2 (0.3)	
Family size					**<0.001***
1–2 members	554 (31.6)	284 (33.4)	126 (44.4)	144 (23.3)	
3–4 members	990 (56.5)	467 (54.9)	130 (45.8)	393 (63.7)	
5 or more members	208 (11.9)	100 (11.7)	28 (9.8)	80 (13.0)	
Educational Level					**<0.001***
High (degree or more)	1,054 (6.02)	502 (59.0)	216 (76.0)	336 (54.5)	
Medium (high school)	627 (35.8)	307 (36.1)	59 (20.8)	261 (42.3)	
Low (elementary or middle school)	71 (4.0)	42 (4.9)	9 (3.2)	20 (3.2)	
Physical activity					**0.004***
Sedentary	381 (21.7)	185 (21.7)	59 (20.8)	137 (22.2)	
Light	620 (35.4)	277 (32.6)	92 (32.4)	251 (40.7)	
Moderate-vigorous	751 (42.9)	389 (45.7)	133 (46.8)	229 (37.1)	
Smoking habit					0.056*
Former smoker	317 (18.1)	150 (17.6)	66 (23.3)	101 (16.4)	
Never smoker	957 (54.6)	477 (56.1)	150 (52.8)	330 (53.5)	
Current smoker	478 (27.3)	224 (26.3)	68 (23.9)	186 (30.1)	
Food delivery App					**<0.001***
No	1.049 (59.9)	501 (58.9)	206 (72.6)	342 (55.4)	
Rarely	616 (35.1)	313 (36.8)	68 (23.9)	235 (38.1)	
At least once a week	87 (5.0)	37 (4.3)	10 (3.5)	40 (6.5)	
Food waste App					0.353*
No	1.311 (74.8)	635 (74.6)	219 (77.1)	457 (74.1)	
Rarely	411 (23.5)	206 (24.2)	60 (21.1)	145 (23.5)	
At least once a week	30 (1.7)	10 (1.2)	5 (1.8)	15 (2.4)	
Food safety (general)					0.473*
High	1,113 (63.5)	532 (62.5)	189 (66.6)	392 (63.5)	
Low	639 (36.5)	319 (37.5)	95 (33.4)	225 (36.5)	
Food safety (cross-contamination)					0.506*
High	1,353 (77.2)	660 (77.6)	225 (79.2)	468 (75.9)	
Low	399 (22.7)	191 (22.4)	59 (20.8)	149 (24.1)	
Food safety (preparation)					**0.001***
High	1,190 (67.9)	607 (71.3)	199 (70.1)	384 (62.2)	
Low	562 (32.1)	244 (28.7)	85 (29.9)	233 (37.8)	
Food safety (food storage)					**0.004***
High	1,121 (64.0)	570 (67.0)	188 (66.2)	363 (58.8)	
Low	631 (36.0)	281 (33.0)	96 (33.8)	254 (41.2)	
Food safety (food hygiene)					**0.050***
High	1,151 (65.7)	536 (63.0)	199 (7.01)	416 (67.4)	
Low	604 (34.3)	315 (37.0)	85 (29.9)	201 (32.6)	
Food safety (practice)					**0.001***
High	877 (50.1)	463 (54.4)	141 (49.6)	273 (44.2)	
Low	875 (49.9)	388 (45.6)	143 (50.4)	344 (55.8)	
Food safety (total knowledge)	77.19 ± 19.38	79.00 ± 18.41	77.39 ± 20.52	74.59 ± 19.88	**<0.001**†
Food safety (behavior)	68.88 ± 10.39	70.01 ± 9.78	69.46 ± 10.65	67.05 ± 10.84	**<0.001**†
Food Safety Total category					**<0.001***
High	883 (50.4)	463 (54.4)	153 (53.9)	267 (43.3)	
Low	869 (49.6)	388 (45.6)	131 (46.1)	350 (56.7)	

Statistically significant results are in bold.
*Chi-square test.
†Kruskal–Wallis test.

lower food safety behavior scores indicate that knowledge alone is insufficient for proper practices. Limited economic resources and educational opportunities contribute to reduced access to high-quality food and awareness of safe practices.

In addition to food security and food safety, we explored a set of lifestyle-related variables (BMI, physical activity, smoking habits, and the use of food-related applications). Our findings showed that BMI values were higher in participants from the South and Islands, which may reflect the combined effects of food insecurity, reduced adherence to healthy dietary patterns, and greater reliance on calorie-dense, processed foods, further straying from the traditional Mediterranean diet and deepening regional health disparities. The Mediterranean diet, characterized by its reliance on fresh, minimally processed foods, abundant use of fruits, vegetables, legumes, whole grains, olive oil, and moderate consumption of fish and dairy, has been associated with health benefits [25,26]. However,

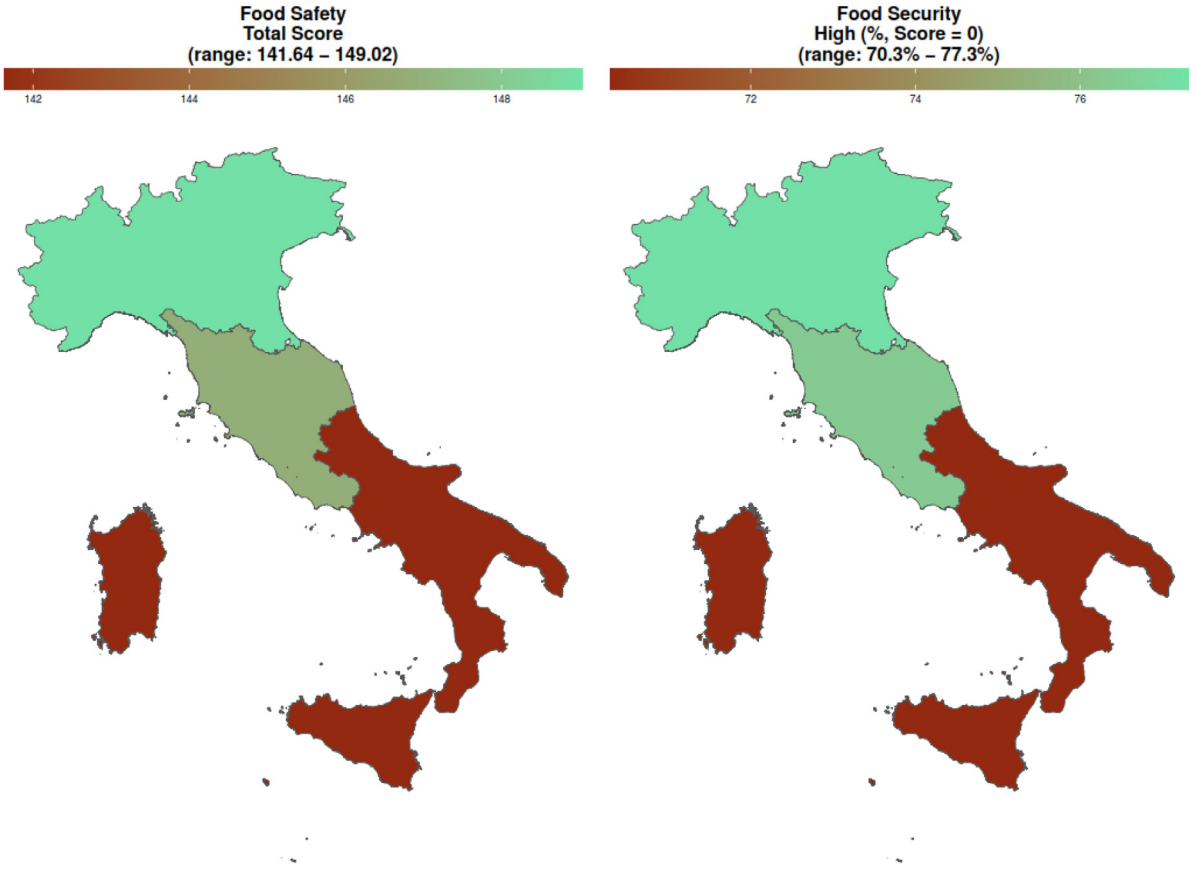

Fig. 1. Geographical distribution of food safety (total score) and food security in Italy.

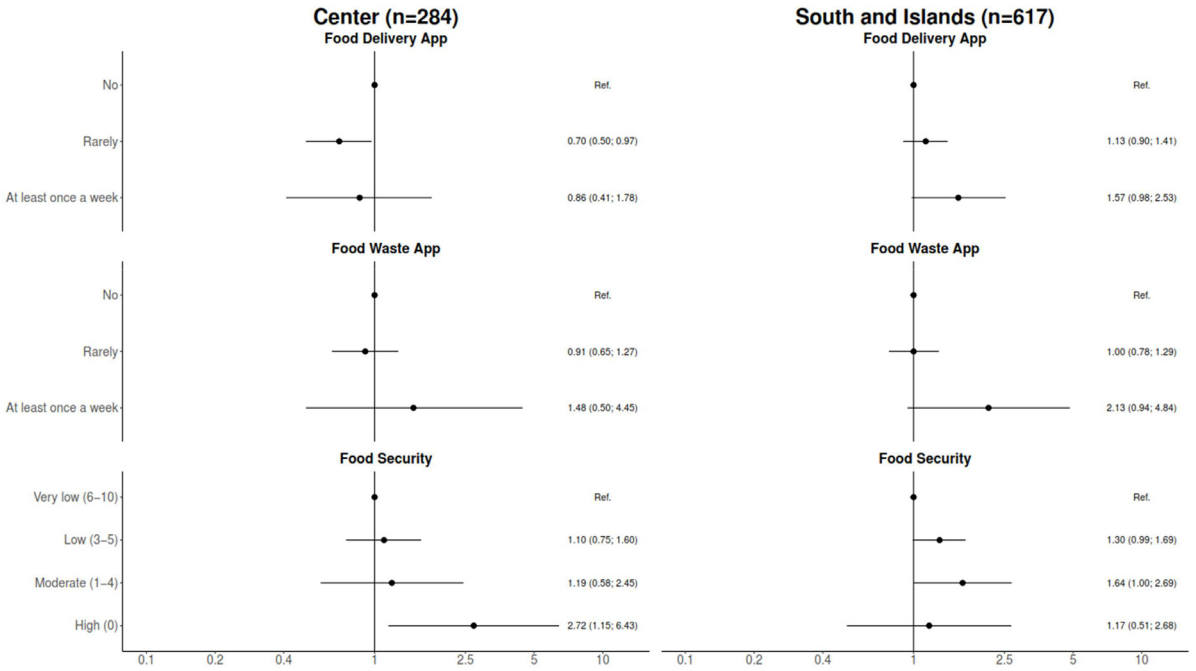

Fig. 2. Multinomial logistic regression results for food-related behaviors and food security across Italian regions. The plot presents adjusted relative risk ratios (RRR) with 95% confidence intervals for the use of food delivery apps, food waste apps, and food security levels in Center (n = 284) and South and Islands (n = 617) regions.

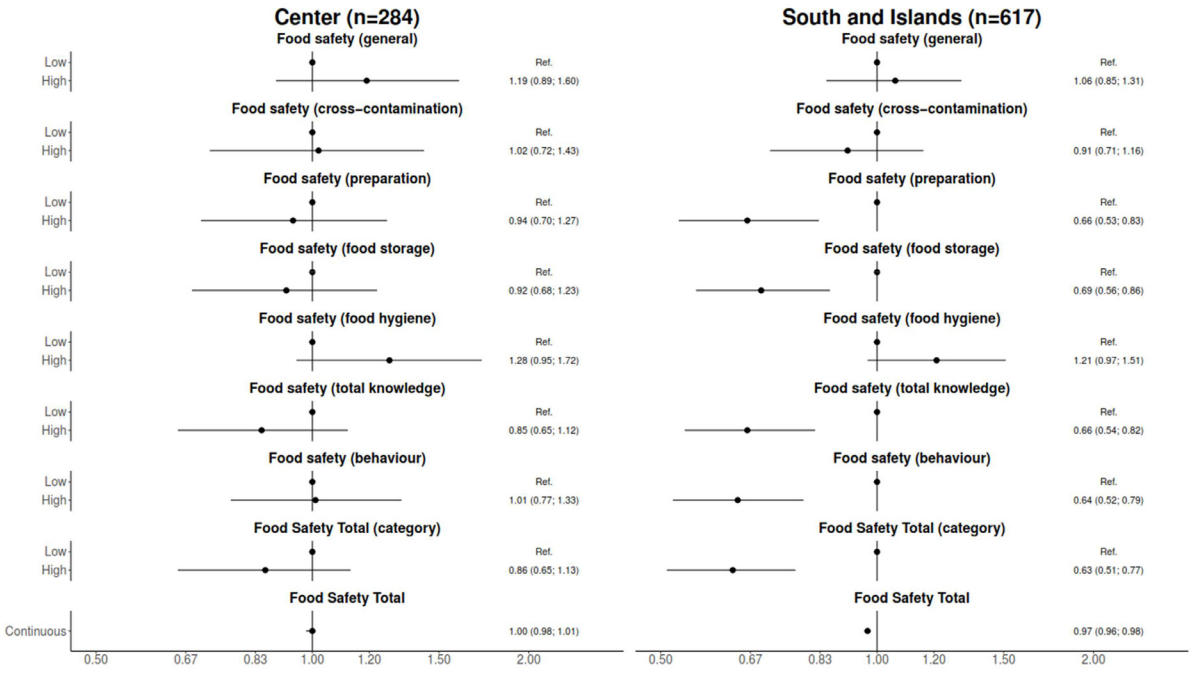

Fig. 3. Multinomial logistic regression results for food safety knowledge and behavior across Italian regions. The plot presents adjusted relative risk ratios (RRR) with 95% confidence intervals for different food safety domains in Center (n = 284) and South and Islands (n = 617) regions.

although the Mediterranean diet is historically known as the "diet of the poor," reflecting the lifestyle and dietary patterns of the lower-income populations in southern Italy during the early 1950s, a notable shift away from this dietary pattern is now particularly observed among the southern Italy and poorest segments of the population [27,28]. This trend is likely driven by the widespread availability and affordability of highly processed, low-cost foods [29], coupled with the fact that adhering to the Mediterranean diet requires substantial of knowledge and awareness also regarding its health benefits [30].

The increased prevalence of food insecurity and lower food safety knowledge in southern Italy and the islands found in the current study corroborates evidence from national and international reports [11]. The FAO and other public health research have frequently identified southern Europe as a region more vulnerable to food insecurity due to lower income levels, limited educational outreach, and reduced accessibility to resources [7]. Moreover, inadequate public awareness and fewer food safety education programs in these areas could explain the significant gaps in knowledge and practices identified in this study.

Finally, regarding digital behaviors, a noteworthy element is the limited use of food delivery and waste prevention apps in the south, which aligns with evidence suggesting lower levels of technological adoption and infrastructure development in this area [31]. This disparity could represent a significant opportunity to address gaps in food safety and resource management. Previous studies have highlighted the role of digital tools in improving food security by facilitating access to surplus food, reducing food waste, and enhancing consumer awareness of food safety standards [17,18]. Promoting the adoption of these technologies in the South, through targeted public health interventions and policies, could help mitigate regional disparities. Specifically, tailored campaigns that focus on increasing digital literacy, combined with incentives for technology use, may encourage broader participation and generate positive outcomes [32]. Moreover, integrating these tools into regional food safety strategies may contribute to more efficient resource utilization and foster a culture of sustainability and safety awareness. Such initiatives could ultimately improve food security while addressing environmental and social inequities in the region. The finding of higher food security in central Italy compared to North regions, while intriguing, may reflect unique regional policies or community support systems that mitigate food access challenges. Such phenomena have been noted in local studies but require further exploration.

Implications for policies and preventive practices

Our findings highlight the need for targeted public health interventions, particularly in Southern Italy and the Islands, to improve food safety knowledge and practices. Educational programs focusing on safe food handling and storage, integrated into broader public health campaigns, may help reduce these disparities [33]. Promoting the use of food management and waste-prevention technologies, such as mobile apps, could also represent a complementary strategy to enhance both food safety and food security, although further evaluation is needed. Integrating food safety training into school curricula and community-based programs may increase public awareness and foster safer practices [34]. Moreover, targeting public health interventions that promote both food security/safety and adherence to the Mediterranean diet could be of paramount importance. For example, initiatives to enhance access to affordable, culturally appropriate foods central to the Mediterranean diet, alongside educational campaigns focusing on food safety and nutritional literacy, could mitigate regional disparities [35–37]. Community engagement should also be leveraged as a powerful mean to drive behavior change, as grassroots movements and locally led initiatives have the potential to offer scalable and culturally sensitive solutions [9]. These implications

should be considered with caution, as the cross-sectional nature of our study precludes causal inferences.

Future directions

Longitudinal studies would provide valuable insights into temporal trends and causal relationships, offering a clearer picture of how food safety and security behaviors evolve over time. Moreover, longitudinal studies could examine the impact of targeted interventions on improving food-related outcomes. Expanding the scope to include other demographic groups, such as children and elderly populations, would provide a more comprehensive understanding of vulnerabilities and intervention needs. Through these combined efforts, a more equitable and sustainable approach to food security and safety can be achieved.

Strengths and limitations

This study has several notable strengths. The inclusion of a large sample size, encompassing 1752 participants from diverse Italian regions, enhances the robustness and representativeness of the findings. Moreover, the use of translated and validated tools ensures cultural and linguistic appropriateness, bolstering the reliability and relevance of the data collected. The comprehensive analytical approach, which includes multinomial logistic regression, provides a nuanced understanding of the complex relationships between sociodemographic factors and food safety and security behaviors.

However, some limitations must be acknowledged. The cross-sectional design restricts the ability to draw causal inferences. Additionally, reliance on self-reported measures introduces the potential for social desirability bias and recall bias, another potential bias might be a selection bias due to online recruitment. Another limitation is the uneven geographical representation, as the smaller sample size from the central region may limit the generalizability of certain findings, as well as the predominance of women in our sample (70%), which may introduce sex-related bias and reduce the representativeness of the findings for the general Italian population. Furthermore, although regression models adjusted for age, sex, BMI, and education allowed us to test whether regional disparities persisted independently of these factors, stratified analyses by region were not possible due to the limited sample size in the Central area. This may have reduced our ability to fully capture region-specific associations. Future studies with larger and more balanced regional samples are warranted to explore whether factors such as sex or education exert differential effects within each macro-area. Moreover, the exclusive use of online data collection may inadvertently exclude individuals with limited internet access, potentially underrepresenting vulnerable populations and influencing the overall results. A further limitation is the absence of information on participants' income or perceived economic status, which are well-established determinants of both food security and food safety behaviors. The lack of this variable may have limited our ability to fully capture socioeconomic influences on the observed regional disparities. Lastly, convenience sampling was use for recruitment, that although this non-probability sampling strategy allowed broad participation, it limits generalizability of the findings and is acknowledged as a study limitation.

Conclusions

This study reveals significant regional disparities in food safety and security within Italy, with southern regions and islands exhibiting poorer outcomes. These findings underscore the need for targeted public health interventions to address the observed gaps in knowledge, practices, and access to safe and nutritious food. By improving food safety practices and reducing food insecurity, we can advance health equity and contribute to achieve Sustainable Development Goals.

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Declaration of competing interest

All authors have nothing to declare.

CRediT authorship contribution statement

Andrea Devecchi: Writing – original draft, Conceptualization. **Lorenzo Stacchini:** Writing – review & editing, Data curation. **Daniele Nucci:** Writing – original draft. **Maria Regina Ferrando:** Writing – review & editing. **Elisa Proietti:** Writing – review & editing. **Martina Moretton:** Writing – review & editing. **Elena Formisano:** Writing – review & editing. **Alessandro Leone:** Writing – review & editing. **Vincenza Gianfredi:** Writing – review & editing, Supervision, Formal analysis, Conceptualization.

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