Critical Public Health

ISSN: 0958-1596 (Print) 1469-3682 (Online) Journal homepage: www.tandfonline.com/journals/ccph20

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To cite this article: Daniel Teshome Gebeyehu, Leah East, Stuart Wark & Md Shahidul Islam (2025) Impact of COVID-19 on the food safety practices of food insecured individuals: interruption of the interdependence food safety and food security association, Critical Public Health, 35:1, 2492797, DOI: 10.1080/09581596.2025.2492797

To link to this article: https://doi.org/10.1080/09581596.2025.2492797

CRITICAL PUBLIC HEALTH
2025, VOL. 35, NO. 1, 2492797
https://doi.org/10.1080/09581596.2025.2492797

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RESEARCH ARTICLE

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Impact of COVID-19 on the food safety practices of food insecured individuals: interruption of the interdependence food safety and food security association

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ABSTRACT

The objective of this study was to identify the indirect impact of COVID-19 on the food safety of individuals potentially experiencing a food security crisis. Structured food safety questions were formed for the food safety practice assessment and standardized 'Food Insecurity Experience Scale' questions were used to assess individuals' food insecurity experience. The food safety items were taken as dependent variables (effect to be tested), and the food insecurity items were taken as independent variables (the cause that determines the impact). Ordinal logistic regression using the Polytomous Universal Model (PLUM) was used for inferential analysis. Demographic variables (location, level of education, living arrangements/family size, and type of work for income generation) were significantly associated ($p < .05$) with both the food safety practice and food insecurity experience of individuals before the pandemic's occurrence. However, no statistically significant association was observed between demographic characteristics and the food safety practices and food insecurity experience of individuals post the emergence of COVID-19. COVID-19 and its infection prevention measures improved the food safety practices of individuals and negatively impacted their food security experience, with no indirect impact on food safety due to their food security crisis was identified by this study. COVID-19 has improved the food safety practices of individuals, yet detrimentally impacted their food security. As a result, encouraging the sustainability of optimal food safety practices, planning and implementing food security resilience strategies, establishing emergency preparedness taskforces, taking lessons from COVID-19, and being prepared for future pandemics are recommended.

ARTICLE HISTORY
Received 15 January 2025
Accepted 7 April 2025

KEYWORDS
Association interruption; impact; COVID-19; food safety; food security; Ethiopia

Introduction

COVID-19 is a highly contagious infectious disease that was deemed a 'global health threat' and pandemic in 2020 (Pollard et al., 2020). COVID-19 has and continues to substantially affect the daily lives of people around the world (Auriemma & Iannaccone, 2020; Bonotti & Zech, 2021; Gopalan & Misra, 2020; WHO, 2024a). Similar to many other sectors, COVID-19 has severely impacting food security and safety through direct and indirect food system obstructions, including agricultural and economic productivity reductions, import-export alterations, and ignorance of the food safety sector during the pandemic (Devereux et al., 2020; Louie et al., 2022). Even though COVID-19's impact is multidimensional and widely distributed, its food security and safety burden in low- and middle-income countries was and is expected to be exacerbated (Kansiime et al., 2021; Picchioni et al., 2022).

According to Hanning et al. (2012) and Esfarjani et al. (2019), food security and safety are closely interlinked concepts impacting human life with common driving factors. Sadati et al. (2021) corroborated that food safety reduces food spoilage and wastage, increasing food availability and ensuring food security. Foods contaminated with disease-causing agents (unsafe food) create a cycle of mortality, morbidity, economic crisis, and food insecurity (WHO, 2024b). For instance, an individual infected with foodborne diseases will experience higher levels of morbidity and even mortality. Furthermore, the individual's ability to work and their livelihood can be diminished, resulting in potential food insecurity. A range of studies (Esfarjani et al., 2019; Hanning et al., 2012; Khor et al., 2019; King et al., 2017) confirmed that any disruption in the food security of individuals or households results in a negative impact in their food safety practice, but it is currently unclear what impact the emergence of COVID-19 had on the food security and food safety relationship.

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Supplemental data for this article can be accessed online at https://doi.org/10.1080/09581596.2025.2492797.

Previous studies (Alsultan et al., 2023; AlTarrah et al., 2021; Djekic et al., 2021; Prasetya et al., 2022) reported that COVID-19 had a positive impact on the food safety practices of individuals, while other studies (Charlebois & Music, 2021; Ma et al., 2021) have identified a negative impact of COVID-19 on food safety. It has been repeatedly argued that COVID-19 affects the food security of people, (Kansiime et al., 2021; Kent et al., 2022; Niles et al., 2021; Picchioni et al., 2022) but its indirect impact on food safety through food security remains unclear. While some research has examined COVID-19's impact on food security and food safety, no study has yet been undertaken using pre- and post-COVID-19 emergence food security and safety data in Ethiopia. The overarching objective of this study was to identify the indirect impact of COVID-19 on the food safety practices of individuals potentially experienced a food security crisis in Ethiopia. It is predicted that the findings of this study will be significant in identifying integrated food safety and food security intervention areas, which are important aspects of public health that remain unexplored. Further, it is believed that the findings of this study can be used as a guide for emergency preparedness and planning responses to future pandemic/s.

Hypothetical model

Based on the findings of previous research works that showed negative, (Charlebois & Music, 2021; Kansiime et al., 2021; Kent et al., 2022; Ma et al., 2021; Niles et al., 2021; Picchioni et al., 2022) and positive (Alsultan et al., 2023; AlTarrah et al., 2021; Djekic et al., 2021; Prasetya et al., 2022) impacts of the pandemic, the hypothetical model indicated in Figure 1 was prepared, and the hypothesis was tested using pre- and post-comparative analysis (before and after COVID-19 emergence) using the presumptive COVID-19 emergence date as a reference. The model is designed to show the possible impacts of COVID-19 on the food safety practice of individuals due to the application of COVID-19 IPC measures (Alsultan et al., 2023; AlTarrah et al., 2021; Djekic et al., 2021; Prasetya et al., 2022), changed food safety control measures during the pandemic (Charlebois & Music, 2021; Ma et al., 2021) and pandemic-related food security crises (Kansiime et al., 2021; Kent et al., 2022; Niles et al., 2021; Picchioni et al., 2022). This graphical model was developed to graphically describe the impacts of COVID-19 on food safety and security and its implication on the health and economy of individuals. As described by different scholars, (Esfarjani et al., 2019; Hanning et al., 2012; Sadati et al., 2021) food safety and food security have inter-dependent relationship, but their relationship in the presence of the factor 'COVID-19' has not been studied yet. The overall null hypothesis of this study is that the existing association of food safety and security would remain consistent, regardless of the emergence of COVID-19.

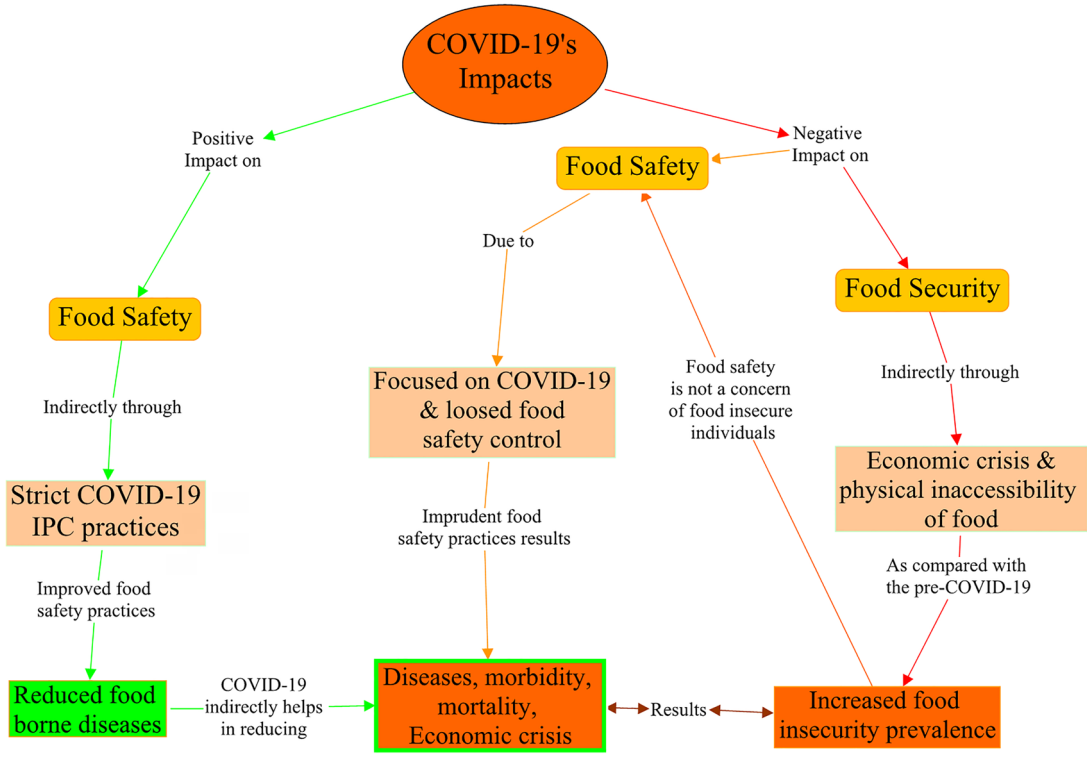

Figure 1. The possible changes of food safety and food security associations due to the emergence of COVID-19 - as described by previous studies.

Methods

Study location

This study aimed to examine the impact of COVID-19 on food safety practices among individuals potentially facing food security challenges in both metropolitan and regional areas of Ethiopia. Participants were selected from both settings to assess how COVID-19 affected them differently based on their place of residence. The primary goal was to determine whether the interdependent and positive relationship between food security and food safety was disrupted due to the pandemic.

The study was conducted in Ethiopia's capital city, Addis Ababa, along with three regional cities: Kombolcha, Dessie, and Debre Birhan. Addis Ababa, the country's largest metropolitan area, has an estimated population of 3,774,000 (Ethiopian Statistical Service, 2021). The estimated populations of Kombolcha, Dessie, and Debre Birhan are 125,654, 257,126, and 139,724, respectively (Ethiopian Statistical Service, 2021).

Regional cities where participants primarily spoke Amharic were chosen to minimize language and translation biases. Additionally, these cities were purposively selected based on their proximity to Addis Ababa to accommodate research budget and manpower constraints. Apart from considerations of language, budget, and resources, the selection of these specific regional cities was not directly related to food safety or food security conditions.

Study design, sampling procedure, and sample size calculation

The study sample consisted of individual food buyers who were randomly selected from open air food markets in the four selected study locations. These participants' food safety practices and their food insecurity trends, both before and after the emergence of COVID-19 were assessed and compared. Since the data depended on participants recalling past events, a retrospective study design was used.

The survey started on April 16, 2023, and concluded on June 31, 2023. Participants were asked to recall their food safety practices and food security experiences from one year before and after the first case of COVID-19 reported in Ethiopia (March 13, 2020). Responses indicating 'I don't remember' were excluded from the data analysis to enhance the validity of the study and reduce recall bias. Additionally, based on the Food Insecurity Experience Scale (FIES), any items with more than 10% of responses marked as 'N/A' were omitted from the analysis. After coding with numerical values, three open markets from ten different suburbs of Addis Ababa and one open market from each regional city were randomly selected by lottery method. Shops of six different food items (cereals; spices; live animals; animal products; vegetables and fruits; and packed and processed foods) in each selected open market were identified, with one shop from each food item again randomly selected by lottery method. In practice, this approach resulted in a potential sample arising from 36 shops from the six selected open markets, all of which were randomly selected.

Two data collectors worked together to recruit potential participants from the nominated shops. The sequence of the respondents was based on the final queue to the billing personnel (cashier/shop clerk), with every tenth person in the queue invited to participate in the survey. The volunteer participants/food buyers were separated from the queue and taken to a designated private area created specifically for the survey. These private areas varied across different shops. In some stores, participants were interviewed in enclosed rooms, while in markets with limited space, temporary rooms were set up using curtain partitions. This private interview was conducted to give participants the freedom to express themselves and ensure those around them did not influence their responses. Participants had to be over 18 years old, but there were no exclusions based on gender, educational and marital status, family size, and source of income. The number of individuals surveyed from each food item departments and the number of individuals selected from metropolitan and regional cities were proportional. One data collector initially identified the potential participant from their sequence in the billing area, while the second data collector then approached the individual after they finished their shop and conducted the survey after gaining consent.

We used Fisher's formula, as shown below, to estimate the minimum sample size.

$$n = \frac{Z^2 PQ}{d^2} = \frac{(1.96)^2 (0.5)(0.5)}{(0.05)^2} = 384$$

Where:

n = minimum sample size

Z = normal deviant at 95% confidence interval (1.96)

P = the change (prevalence) of individuals' food safety practices due to COVID-19's impact on food security. Since there was no previous study identified on this topic, 50% prevalence rate was used.

$Q = 1\text{-}P$

d = measure of precision = 0.05

The minimum sample size that was identified using the Fisher's formula was then corroborated against the Australian Bureau of Statistics (ABS) Sample Size Calculator (Australian Bureau of Statistics, 2024), which recommended a minimum

sample size of 385. Since the difference was negligible, it was proposed prior to the commencement of sampling that data from a minimum of 385 participants would be collected. As per Reyes, (2016), the researchers expected a 3% non-response rate, and the total sample collected was 396.

Data collection tools and data management

COVID-19's impact on the food security of individuals was assessed in this study using the 8-item Food Insecurity Experience Scale (FIES) (FAO, 2024). FIES was designed to assess the food insecurity status of individuals and households using the food access dimension of food security. The FIES questions (see Supplementary additional file 1) asked participants to recall their food intake experience both twelve months pre- and post-COVID-19 emergence. The Amharic translation of FIES questions was taken from the Gallup® World Poll (GWP) (FAO, 2024). The FIES questions has dichotomous 'yes/no' answers, but if a participant either stated that they could not recall their food insecurity situation or did not wish to answer any question, their response was recorded as 'Not Applicable' (N/A).

All participants who were surveyed for the impact of COVID-19 on individuals' food insecurity were then also surveyed for the impact of COVID-19 on their food safety. The four food safety steps (cleaning; separating; cooking; and chilling) recommended by the Centre for Diseases Prevention and Control (2024) were used to assess the impact of COVID-19 on individuals' food safety practices. There were structured questions under each food safety step with three ordinal responses (*always; sometimes*; or *never*) (see Supplementary additional file 2). Levelling the response of participants in three categorical ordinal responses was based on the recommendations of different scholars (Al-Wutayd et al., 2021; Bin Abdulrahman et al., 2019; Diwan et al., 2016; Głąbska et al., 2020). The food safety survey questions were pilot-tested on 70 individuals from an open-air market different from the actual data collection sites before the main data collection began. Researchers such as Julious (2005), Sim and Lewis (2012), and Teare et al. (2014) have suggested various pilot study sample sizes, including 24, >55, and 70, respectively. Based on the recommendations of Sim and Lewis (2012) and Teare et al. (2014), a sample size of 70 participants was chosen for this pilot study.

The internal consistency of the survey questions in the pilot study was assessed using Cronbach's alpha coefficient, with a value of 0.6 or higher considered reliable. The Cronbach alpha values for the pre- and post-COVID-19 food safety assessments were 0.9 and 0.7, respectively. Based on the pilot data analysis, two questions with Cronbach's alpha values below 0.6 were removed.

In addition to their food insecurity status and food safety practice, information on the participants' demographic characteristics (age, location, gender, educational status, marital status, type of work for income generation, and family size) were collected, and their association with the pooled food safety practice of individuals were analysed. The food insecurity and food safety survey data were recorded in IBM SPSS version 28, together with the participants' demographic data.

Data analysis

The datasets for participants' food safety practices and food security statuses were prepared and analysed using IBM SPSS Version 28. The responses of individuals on food safety practice questions were pooled into a single cumulative variable that indicated the summarized food safety practice of each participant and the same was done for food insecurity experiences.

A multicollinearity diagnosis was conducted using the Variance Inflation Factor (VIF) in SPSS to ensure statistical reliability. According to Kim (2019), any independent variable with a VIF value exceeding 5 was considered to exhibit a high level of multicollinearity and was therefore excluded from the analysis. To assess the possibility of overfitting, the dataset observations were randomly splitted into training and test variables. In line with scholars' (Vrigazova, 2021) recommendations, 70% of the dataset was allocated for training, while the remaining observations were assigned to the test dataset. The Receiver Operating Characteristic (ROC) tool in SPSS was then used to compute the Area Under the Curve (AUC). The model's performance for the test and training variables was compared and the AUC value exceeding 0.7 was deemed acceptable (Mandrekar, 2010).

Previous studies categorized participants' food safety practices using terms such as 'poor,' 'moderate,' and 'good' (Fekadu et al., 2024) or 'low,' 'medium,' and 'high'(Hessel et al., 2019). However, to avoid judgmental terminology, we opted for a three-level Likert scale categorization using 'insufficient,' 'moderate,' and 'optimum.' Any participant who responded 'never' to the cleaning related food safety practice questions were pooled to 'insufficient' food safety practices. In the same way, the individuals who responded, 'sometimes' and 'always' for cleaning related food safety questions were pooled to 'moderate' and 'optimum' food safety practices, respectively. A cumulative ordinal dependent variable with categories of *food secure, mild food insecure, moderate food insecure,* and *severe food insecure* was produced from the FIES item responses. Using these variables, both descriptive analysis (percentages, numerical values, ranges, tables, and figures) and inferential statistical analysis using ordinal logistic regression were applied. The intervariable associations and the effect of individuals' food insecurity on their food safety practices were inferentially analysed using the Polytomous Universal Model (PLUM) for ordinal logistic regression.

To examine whether individuals' demographic variables influenced their food safety practices and experiences of food insecurity, inferential analysis was conducted on both pre- and post-pandemic data. Both food safety practices and food insecurity experiences were treated as dependent variables, while demographic variables served as independent predictors for both. Each food safety practice item's effect on the pooled food safety practice was separately analyzed using ordinal logistic regression (see Supplementary additional file 2).

For analysing the impact of the COVID-19-related food security crisis on individuals' food safety practices, individual food insecurity experience items were treated as independent variables (cause), while a single dependent variable (effect) was pooled from food safety practice items. The effect of food insecurity items on the aggregated food safety practices was assessed using PLUM-based ordinal logistic regression. As confirmed by different studies, food security and safety are closely associated (Esfarjani et al., 2019; Hanning et al., 2012; Sadati et al., 2021). If food insecurity experiences and food safety practices exhibit an association prior to the emergence of the pandemic but not afterward, this would suggest that the relationship between food security and food safety has been disrupted. Such an interruption may indicate that external factors introduced by the pandemic have altered the previously established interdependence between these two variables, potentially due to shifts in access, policy interventions, or behavioural adaptations in response to the crisis. The effect of food insecurity on individuals' food safety practices due to COVID-19 emergence was measured using an odds ratio with a 95% confidence interval. A p-value of less than 0.05 was considered statistically significant in determining associations between variables.

The food security changes due to COVID-19 were calculated by subtracting the frequency of pre-COVID-19 emergence food insecurity experiences for each item from post-COVID-19 emergence food insecurity experiences. The result was expressed in '+' (increased) and '−' (decreased) signs preceded by the numerical values. The changes in pooled food safety practices and food insecurity experience are expressed in the form of graphs.

Results

To determine the indirect impact of COVID-19 on the food safety practices of individuals that were potentially experienced the food security crisis, the pre- and post-COVID-19 emergence food safety practices and food insecurity experiences of individuals were assessed. Of 396 samples collected, half (50%) were from metropolitan city (Addis Ababa) and the remaining half were from regional cities (Dessie, Debre Birhan, and Kombolcha) (Table 1). A greater proportion (51.5%) of the sample participants were females, while the remaining 48.5% were males (Table 1).

Effect of demographic variables on individuals' food safety practices and food security experiences

Before the emergence of COVID-19, the demographic variables (location, level of education, living arrangements/family size, and type of work for income generation) were significantly associated with both the food safety practices and food insecurity experiences of individuals (Table 1). Age had a statistically significant effect ($p = .002$, odds = 2.57) on pre-COVID-19 food insecurity experiences only (Table 1). This suggests that individuals over the age of 50 were 2.57 times more likely to experience food insecurity compared to those aged 41–50 years (Table 1). The demographic characteristics that had a significant effect on the food safety practices of individuals also had an effect on their food insecurity experiences before COVID-19 emergence. Due to the impact of COVID-19, this positive relationship between food safety and food security was interrupted during the pandemic (Table 1).

Individuals' pre-and post-COVID-19 food insecurity experiences and food safety practices associations

When compared to the pre-pandemic situation, post-pandemic food insecurity prevalence significantly increased. In addition, each food insecurity indicator (FIES items) increased following the COVID-19 pandemic as compared to the situation prior to its emergence (Table 2). As an example of this change, a substantial number (30%) of participants who were eating enough amount of food before the COVID-19 pandemic were eating lesser amounts of food following its occurrence (Table 2).

Before the emergence of COVID-19, participants' worries about food insecurity due to a lack of food or other resources had a statistically significant effect ($p = .034$, odds = 0.1; 95% CI = 0.13–0.84) on their food safety practices (Table 2). This suggests that individuals concerned about food insecurity had food safety practices that were 0.1 times lower than the recommended standards compared to those who did not experience such concerns. Additionally, individuals without food for the whole day were significantly associated (Wald = 5.98, $p = .015$, odds = 22.88) with lower food safety practices before the pandemic. Specifically, those who stayed without food for a whole day had 22.88 times more insufficient food safety practices than those who had access to food within 24 hours.

Unlike the pre-pandemic situation, no statistically significant relationship was observed between the FIES items and pooled food safety practices after the emergence of COVID-19. This suggests that the pandemic disrupted the previously established relationship between food security and safety.

Individuals' food safety practice and food insecurity experience changes due to COVID-19's impact

COVID-19 has impacted the food safety practices (positive impact) and food security experience (negative impact) of individuals (Figure 2). Following COVID-19 emergence, a considerable number (22.2%) of participants who had either insufficient or moderate food safety practices were improved to optimum food safety practices (Figure 2). However, the number of individuals who were food secure before COVID-19 was reduced by 21.5%, and more severely food insecure individuals increased by 15.9% following COVID-19 (Figure 2).

Table 1. The effect of individuals' demographic variables on their food insecurity experiences and food safety practices both before and after the emergence of COVID-19.

			Pre-COVID-19 emergence				Post-COVID-19 emergence			
			Food safety		Food insecurity		Food safety		Food insecurity	
Variables	Categories	Numbers (%)	*p* value (odds)	95% CI	*p* value (odds)	95% CI	*p* value (odds)	95% CI	*p* value (odds)	95% CI
Location	Addis Ababa	198 (50)	.006 (4.906)	1.575–15.285	.002 (0.37)	0.200–0.700	.408 (1.357)	0.659–2.796	.277 (0.72)	0.396–1.304
	Dessie	66 (16.7)	.175 (2.607)	0.652–10.419	.756 (1.13)	0.521–2.452	.462 (0.714)	0.291–1.751	.919 (0.96)	0.465–1.995
	Kombolcha	66 (16.7)	.017 (5.044)	1.331–19.109	.697 (1.16)	0.544–2.485	.785 (0.884)	0.363–2.148	.866 (0.94)	0.464–1.907
	Debre Birhan	66 (16.7)	–	–	–		–	–	–	–
Age	18–30	61 (15.4)	.857 (0.894)	0.265–3.020	.091 (1.93)	0.700–4.142	.081 (0.456)	0.188–1.102	.420 (1.36)	0.645–2.8
	31–40	103 (26)	.584 (1.349)	0.462–3.937	.055 (1.92)	2.452–3.727	.308 (0.673)	0.314–1.441	.222 (1.5)	0.782–2.888
	41–50	147 (37.1)	.838 (1.11)	0.409–3.010	.002 (2.57)	2.485–4.673	.113 (0.583)	0.299–1.136	.072 (1.72)	0.9523–0.116
	>50	85 (21.5)	–	–	–		–	–	–	–
Gender	Male	192 (48.5)	.370 (0.681)	0.294–1.578	.193 (1.37)	0.852–2.206	.256 (0.733)	0.429–1.252	.583 (1.14)	0.711–1.834
	Female	204 (51.5)	–	–	–	–	–	–	–	–
Level of education	Non-educated	56 (14.1)	.0001 (0.017)	0.003–0.097	.001 (0.24)	0.103–0.582	.0001 (0.002)	0.001–0.007	.753 (0.86)	0.352–2.130
	Primary school	89 (22.5)	.178 (0.45)	0.141–1.437	.810 (0.92)	0.465–1.820	.0001 (0.066)	0.028–0.157	.791 (0.91)	0.446–1.852
	Secondary school	128 (32.3)	.139 (0.482)	0.183–1.267	.510 (1.23)	0.668–2.252	.0001 (0.046)	0.020–0.107	.267 (1.36)	0.788–2.363
	Higher Education	123 (31.1)	–		–	–	–	–	–	–
Marital status	Unmarried	117 (29.5)	.097 (3.768)	0.786–18.055	.465 (0.74)	0.328–1.664	.317 (1.638)	0.623–4.310	.175 (0.61)	0.300–1.245
	Married	203 (51.3)	.152 (0.405)	0.118–1.396	.126 (0.64)	0.361–1.134	.862 (0.943)	0.490–1.817	.345 (0.76)	0.427–1.347
	Divorced	76 (19.2)	–	–	–	–	–	–	–	–
Living arrangement	No dependent	133 (33.6)	.0001 (168.937)	19.217–148.121	.0001 (11.53)	4.892–27.166	.059 (2.496)	0.968–6.438	.0001 (4.06)	1.873–8.807
	Couple	59 (14.9)	.001 (27.578)	3.790–200.646	.0001 (8.96)	3.967–20.228	.989 (1.007)	0.409–2.480	.0001 (4.77)	2.213–10.268
	Have one child	31 (7.8)	.002 (68.224)	4.529–102.633	.0001 (6.42)	2.684–15.369	.716 (0.834)	0.313–2.219	.02 (0.28)	0.097–0.817
	Have 2–4 children	40 (10.1)	.0001 (56.927)	9.119–35.362	.041 (0.42)	0.186–0.966	.724 (0.851)	0.346–2.089	.417 (0.7)	0.298–1.651
	Have 5+ children	133 (33.6)	–	–	–	–	–	–	–	–
Work for income generation	GO employee	62 (15.7)	.015 (0.21)	0.060–0.742	.0001 (0.13)	0.059–0.301	.021 (0.324)	0.124–0.842	.093 (0.53)	0.250–1.112
	NGO employee	64 (16.2)	.0001 (105.639)	10.616–105.179	.0001 (21.73)	4.479–105.460	–	–	.0001 (7.21)	2.988–17.414
	Casual labourer	61 (15.4)	.004 (0.069)	0.011–0.424	.0001 (0.25)	0.116–0.528	.0001 (0.154)	0.063–0.375	.0001 (0.19)	0.091–0.413
	Daily labourer	151 (38.1)	.0001 (0.01)	0.001–0.075	.0001 (0.2)	0.096–0.432	.05 (0.431)	0.186–1.000	.0001 (0.16)	0.072–0.331
	Business owner	58 (14.6)	–	–	–	–	–	–	–	–

The hyphen sign (-) is the reference dummy variable with zero statistical values; CI stands for 'confidence interval'.

Table 2. Impact of FIES items on the food safety practice of individuals before and after the emergence of COVID-19.

items (short forms of FIES items as per (Cafiero et al., 2018)	Food insecurity changes due to COVID-19	Pre-COVID-19			Post-COVID-19		
		Wald (X^2)	*p* value	Odds (95% CI)	Wald (X^2)	*p* value	Odds (95% CI)
WORRIED	+22%	4.51	.034	0.1 (0.13–0.84)	–	–	–
HEALTHY	+12.7%	–	–	–	0.52	.819	1.21 (0.23–6.29)
FEWFOODS	+13.9%	2.59	.107	7.76 (0.64–94.12)	0.49	.48	0.49 (0.07–3.59)
SKIPPED	+29.6%	5.19	.23	0.03 (0.002–0.62)	0.73	.394	3.81 (0.18–82.7)
ATELESS	+30%	2.79	.095	138.4 (0.43–44,888.78)	0.68	.409	0.32 (0.02–4.81)
RANOUT	+15.7%	0.06	.815	0.78 (0.98–6.24)	0.14	.71	0.61 (0.05–8.1)
HUNGRY	+16.7%	2.2	.138	12 (0.45–320.13)	0.2	.652	2.03 (0.09–43.9)
WHOLEDAY	+16.4%	5.98	.015	22.88 (4.61–10)	0.047	.828	0.82 (0.13–5)

(+) sign indicates increment of the food insecurity or increment of the 'yes' answers following COVID-19 emergence.

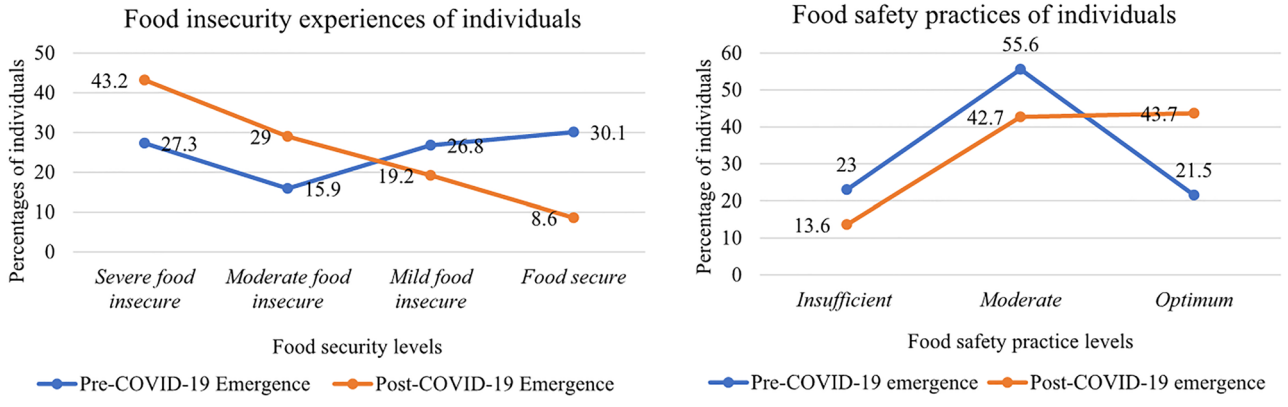

Figure 2. Impact of COVID-19 on individuals' food security and food safety: pre and post comparative analysis.

Discussion

Although food security and food safety are different measures, they are nonetheless closely interrelated (Esfarjani et al., 2019; King et al., 2017). This study was conducted assuming that the impact of COVID-19 on individuals' food security would similarly affect their food safety practices. However, the findings revealed that the relationship between food security and food safety was disrupted due to COVID-19. This result aligns with research conducted in China (Ma et al., 2021) and findings from a global study (Maqbool et al., 2024). The result of the present study showed that the participants' food safety practice was improved due to the COVID-19 preventive and control measures. At the same time, the food security experiences of individuals were negatively impacted by the pandemic.

Before the emergence of the pandemic, the participants' location had a statistically significant association with their food safety practices ($p = .006$, odds = 4.91) and food security experience ($p = .002$, odds = 0.37). This suggests that individuals residing in the metropolitan city of Addis Ababa demonstrated 4.91 times higher food safety practices than those in Debre Birhan. However, food security among individuals in the metropolitan city was 0.37 times lower than that of individuals living in Debre Birhan. However, the location was not statistically associated with food safety practice and food insecurity experience post-pandemic emergence. It is hypothesized that this disruption may be attributed to differences in information access, the introduction of new COVID-19-related restrictions and advocacy efforts, and variations in awareness levels among participants from different localities. For instance, individuals residing in metropolitan areas and large cities are generally perceived to have greater access to food safety and security information through social media, television, radio, guidelines, and policies than those in remote areas. This explanation aligns with research conducted in Bangladesh (Ishra et al., 2022) and a study from the United States (Dave et al., 2024).

However, since the COVID-19 pandemic affected individuals regardless of their place of residence and government messaging was disseminated nationwide, the findings of this study indicate no significant location-based differences in food safety practices and food security experiences. These results are consistent with studies conducted in Saudi Arabia (Alsultan et al., 2023) and South Korea (Jung et al., 2022). However, a study in Thailand (Jainonthee et al., 2022) found a statistically significant association between individuals' locations and their food safety practices.

Participants without formal education exhibited insufficient food safety practices both before ($p = .001$, odds = 0.017) and after ($p = .001$, odds = 0.002) the emergence of COVID-19 compared to those with higher education qualifications. This suggests that the food safety practices of individuals without formal education were 0.017 and 0.002 times lower than the recommended food safety standards compared to those with higher education. These findings might be due to differences in the individuals' awareness levels (Tamiru et al., 2022) and the individual capacity in using information sources and technologies. Similar to the current finding, the study conducted by Keleb et al. (2022) confirmed that the participants with higher education qualifications have optimum/good food safety practices as compared to participants with lower education levels. Contrary to the current finding, the study conducted in the United Kingdom (Pool & Dooris, 2022) showed that the educational status of the participants was not associated with their food safety practices. This difference might be due to differences in community awareness levels and variabilities in demographic and socioeconomic factors.

The participants' living arrangements (family size) and the type of work for income generation were significantly associated with their food safety practices and food insecurity experiences before and after the pandemic. Based on the current findings, the association of these two demographic factors (family size and work for income generation) with the participants' food safety practices and food insecurity experiences were not affected by COVID-19. Comparably, the study conducted in Kenya and Uganda, (Kansiime et al., 2021) confirmed that the effect of family size and source of income on the individuals' food security status were unchanged due to the COVID-19 emergence. In addition, the study in Malawi (Pool & Dooris, 2022) indicated that the participants' family size and educational status were important drivers of food insecurity both before and after the emergence of COVID-19. All eight FIES items (*see additional file 1*) showed an increase following the emergence of COVID-19 compared with the pre-pandemic FIES responses. This indicates that the food insecurity of the participants increased due to the emergence of COVID-19.

Other studies (Gebeyehu et al., 2023b; Kakaei et al., 2022; Picchioni et al., 2022; Sumsion et al., 2023; Zafar & Zehra, 2022) corroborated that the food security of individuals was compromised due to the emergence of COVID-19. The increase in food insecurity during COVID-19 was argued to be due to the restrictions and measures laid down to prevent and control COVID-19 (Gebeyehu et al., 2023b; Louie et al., 2022; Ma et al., 2021). Among the FIES items, lack of money or resources related to 'worries' and passing the 'whole day' without food had statistically significant associations with the food safety practice of individuals before the emergence of the COVID-19 pandemic, but this relationship was not observed following COVID-19 occurrence. While different studies confirmed the negative impact of COVID-19 on the food security of individuals, the study conducted by Trmčić et al. (2021) indicated that the food safety practices of individuals were improved due to strict applications of COVID-19 prevention practices. As shown in *Additional File 2* of this study, participants' cleaning-related practices, particularly handwashing, improved more during COVID-19 than other food safety measures such as separation, cooking, and chilling. This could be attributed to the advocacy and enforcement efforts of health regulators, including the World Health Organization, which prioritized hygiene and handwashing over other food safety practices (AlGhobaishi et al., 2022; Alwan et al., 2023; Alzyood et al., 2020). As a result, the current findings and the results of previous studies confirmed that COVID-19 had the opposite impact on the food safety (positive impact) and food security (negative impact) of individuals.

Policy implications

As identified by previous research (King et al., 2017) and confirmed by the current study, a linear relationship existed between food security and food safety before the COVID-19 pandemic. However, this association was disrupted due to the measures implemented to prevent and control the virus. This disruption is attributed to the dual impact of COVID-19 and its associated prevention measures, which positively influenced individuals' food safety practices while negatively affecting their food security experiences.

The varying effects of these measures on food safety and food insecurity highlight the need for policymakers and food safety and security regulators to focus on improving food access while maintaining safety standards. The following sections outline policy implications related to food security resilience and food safety sustainability to provide a clearer understanding of how to sustain food safety practices and address the COVID-19-induced food security crisis.

Development of food security resilience strategies

Contrary to food safety practices, the restrictions and measures taken to prevent COVID-19 have negatively impacted the food security of individuals. Transport bans, lockdown measures, job losses, social distancing, and closure of agricultural and food manufacturing factories significantly and detrimentally impacted the food security of individuals during the pandemic (Abay et al., 2023; Devereux et al., 2020; Gebeyehu et al., 2023b; Kansiime et al., 2021; Louie et al., 2022; Ma et al., 2021; Picchioni et al., 2022). It is not easy to re-bounce for individuals and households from pandemic-induced and catastrophic food insecurity unless long-term and continuous resilience strategies are formulated and implemented. The COVID-19 pandemic is continued as a food security challenge due to its never-ending mutation and creation of virulent strains. Implementing integrated food aid and safety net programs targeted at those most in need can help food-insecure individuals navigate the economic instability caused by the pandemic. Given the likelihood of future pandemics due to global challenges such as climate change, urban expansion, population growth, human-animal encroachment, and increased global trafficking (Shafaati et al., 2023), proactive preparedness strategies are essential. Learning from the COVID-19 crisis and developing early intervention measures can help mitigate the impact of inevitable pandemics. Additionally, policymakers should consider the effects of disease prevention measures on food security when designing Infection Prevention and Control (IPC) strategies.

Supporting the sustainability of food safety practices

As reported by different scholars, (Abolmaaty et al., 2022; Djekic et al., 2021; Hoseini et al., 2022; Jung et al., 2022; Luo, Ni, et al., 2021; Luo, Chen, et al. 2021; Tamiru et al., 2022) the infection prevention and control (IPC) measures that were advocated, enforced, and implemented for the prevention of the COVID-19 pandemic indirectly improved the food safety practices of individuals. As shown by the previous studies (Alemayehu et al., 2021; Teferi et al., 2021) and confirmed by the current study, individuals' practice on food safety items such as cooking their foods before consumption and washing their hands before, during, and after food preparation and before and after eating were improved, post COVID-19 emergence. The unexpected food safety practice improvements due to COVID-19-related measures should be supported with policies and guidelines to be sustained after the pandemic era. Maintaining the recommended food safety practices (Centre for Diseases Prevention and Control, 2024) (proper cleaning procedures, separating different food items, thorough cooking before consumption, and appropriate chilling technique) that were boosted due to COVID-19-related measures are crucial for the prevention and control of communicable diseases, not limited to the prevention and control of COVID-19. Consecutive community awareness creation, formulation of food safety guidelines and continuous training regarding the implementation of food safety guidelines, and further studies on the sustainability of food safety practices are the targets of food sustainability-related policy.

Limitation of the study

Individuals who did not purchase food themselves or obtained it through other means, such as supermarkets or food aid programs, and were not present in the open-air market at the time of data collection were excluded from this study. Consequently, some individuals critically affected by COVID-19 may have been missed.

Since the study relied on participants' past experiences with food insecurity and food safety practices, the data may be subject to recall bias. Additionally, as it is based on self-reported information, there is a potential for self-reporting bias, where participants might exaggerate, underreport, or selectively provide socially desirable responses.

The data were collected from four Ethiopian cities with Amharic-speaking participants, meaning results may differ in other regions. It is acknowledged that food security is a complex issue influenced by multiple factors, including biological, socio-economic, and political elements, making it challenging to ensure a fully representative sample. However, the random sampling approach used in this study is considered the most appropriate for selecting participants.

Conclusion

This study confirmed that COVID-19's opposing effects on individuals' food safety practices and food insecurity experiences resulted in no indirect impact of COVID-19 on food safety through the food security crisis. While COVID-19 and its associated measures negatively affected the food security sector, they simultaneously improved individuals' food safety practices. Consequently, the previously positive relationship between food safety and food security shifted in the opposite direction.

The infection prevention and control measures implemented during the pandemic indirectly enhanced food safety practices, while these measures and restrictions compromised various dimensions of food security. Despite its widespread negative impacts, COVID-19 unexpectedly led to some positive health outcomes, such as improved food safety practices among individuals (Gebeyehu et al., 2023a). Given the distinct effects of COVID-19 on food security and food safety, this study did not identify an indirect negative impact of the pandemic on food safety via the food security crisis.

Based on these findings, it is recommended to support the sustainability of optimal food safety practices in the post-pandemic era, develop and implement food security resilience strategies, establish emergency preparedness task forces, and learn from COVID-19 to enhance readiness for future pandemics. Additionally, further research is encouraged to explore ways to sustain food safety practices and support individuals facing food insecurity. Given the ongoing mutation of SARS-CoV-2, with new variants such as FLiRT and XEC emerging, extra caution should be taken to prepare for potential future waves of COVID-19.

Acknowledgements

The authors appreciated the University of New England for assistances related with the data collectors' expenses. Moreover, the food buyers and food sellers who were participated in the survey and interview of this research project are appreciated for their willingness to participate and their valuable data input.

Ethical approval

Research ethics approval was gained from the University of New England Human Research Ethics Committee (HREC), with approval number: HE22-173. The research was conducted based on the 'Australian National Statement on the Ethical Conduct of Human Research 2007' standards. After the project received ethical approval from the University of New England Human Research Ethics Committee (UNE-HREC), we requested additional ethics approval from the first author's home institution in Ethiopia (Wollo University). The first author was granted a short-term attachment to Wollo University for the duration of the data collection, and the 'Wollo University Institutional Research Ethics Review Committee' approved the ethics clearance granted by UNE-HREC. To secure their confidentiality, individuals' identifiers, like their names, were not requested or recorded anywhere. Prior to the commencement of the data collection, the purpose of the research was briefed to individuals, who then signed an informed consent form to participate in the survey.

Authors contributions

DTG participated in data collection, entry, manipulation, and analysis; result interpretation; manuscript draft writing and editing. SW, LE and MSI has supervised the activities conducted by DTG, revised, and edit the draft manuscript, language, and quality checks; and all authors have participated in reading and final approval of the manuscript.

Disclosure statement

No potential conflict of interest was reported by the author(s).

Funding

No Funding received for the study.

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Data availability statement

All data related to this research is included in the result section of the manuscript. If any further data is needed it can be accessible via the corresponding author on request.

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