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COVID-19 risk perception and food security in the MENA region: evidence from a multi-wave household survey

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Abstract

The COVID-19 pandemic had disruptive consequences for MENA countries' agri-food value chains that exacerbated poverty and jeopardized food security. This study examines the relationship between individuals' perception of contracting COVID-19 and their experience of food insecurity, using longitudinal data from the Combined COVID-19 MENA Monitor Household survey. It also investigates the underlying mechanisms of COVID-19 concerns and explores coping strategies employed by households to identify vulnerabilities in food security. The results provide compelling evidence of a strong association between individuals' concern about the virus and various dimensions of food security, particularly reduced purchasing power and decreased meal frequency. Notably, this association follows an inverted U-shaped curve, with food insecurity initially increasing as worry grows, but declining after individuals contract the virus. High levels of concern were also linked to significant income decreases and worsening economic conditions. Moreover, individuals with higher concerns were more likely to rely on specific coping strategies, particularly spending savings and obtaining funds from relatives or friends. These findings underscore the need for government interventions during disease outbreaks and economic downturns to focus on alleviating individuals' worry and fear to facilitate informed decision-making that minimizes food insecurity consequences. Additionally, the findings emphasize the need to strengthen social protection systems during public health and economic challenges to ensure food security for vulnerable populations.

Keywords Covid-19 · Risk perception · Consumer nutrition · Food security · MENA region

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1 Introduction

The outbreak and global spread of the COVID-19 pandemic from 2019 to 2022 had disruptive consequences for food security in low- and middle-income countries (LMICs) (Béné, 2020; Sawadogo & Ouoba, 2023). A plethora of research has documented and quantified the impacts of the pandemic on various dimensions of food security, including food supply and availability (e.g. Balana et al., 2023; Bitzer et al., 2024), physical and economic accessibility to food (e.g. Ceballos et al., 2020; Laborde et al., 2021), food utilization and nutritional outcomes (e.g. Devereux et al., 2020; Picchioni et al., 2022), and food stability (e.g. Rozaki, 2021). Overall, the literature provides abundant evidence that adjusting diet and decreasing the quality and quantity of food consumption have been a primary strategy for LMICs' households to cope with food shortages, food price inflation, and loss of income and employment (Laborde et al., 2021; Tabe-Ojong et al., 2022).

Perception of COVID-19 risks, *i.e.*, the degree of an individual's worriedness about COVID-19 infection, is

likely to predict individual's food insecurity (Mueller et al., 2022). Theoretical health-behavior models hypothesize that the extent to which an individual believes that a disease, such as Covid-19 infection, is severe and likely to affect his or her health should predict their actual behaviors which may influence their earning potential (Skinner et al., 2015; Weinstein, 2007). This is because an individual's perceived susceptibility to contracting COVID-19 is indicative of the role of potential factors that may influence earning potential, and subsequently deteriorate the individual's food security (Rudin-Rush et al., 2022; Wang et al., 2021a, b). These factors include, for example, perceived transmission risk, strictness of local risk prevention and mitigation measures, and the effectiveness of social structures that enable risk sharing. In this regard, Faour-Klingbeil et al. (2021) and Abu Hatab et al. (2023) find that perception of COVID-19 risk among the population of selected countries from the Middle East region predicted individuals' compliance behavior with COVID-19 containment measures, which caused adverse impacts on household income and employment, and deteriorated their food security levels (Hobaika et al., 2022; Hoogeveen & Lopez-Acevedo, 2021).

Despite the extensive literature that has investigated the food security outcomes of the COVID-19 pandemic in LMICs (e.g., Arndt et al., 2020; Jaacks et al., 2021), there is scant evidence on the association between COVID-19 risk perception and food security (e.g., Wang et al., 2021a, 2021b), especially in the MENA region (e.g., Elshahry et al., 2020). Existing studies have explored the association between COVID-19 risk perception and consumers' food stockpiling behavior (e.g. Wang et al., 2020), food waste behavior (e.g. Deliberador et al., 2023), or household coping mechanisms with food price inflation (e.g. Coulthard et al., 2021). A better understanding of this association between risk perception during the times of crises and food insecurity is crucial to formulate effective strategies for ensuring food security and mitigating their consequences on the poverty and hunger among the vulnerable groups of the population, and to build resilient food systems in LMICs to achieve the Sustainable Development Goals (SDGs), particularly SDG #2 and SDG #12 (Galanakis, 2020; WFP, 2020).

To gain insight into the persistence of household food insecurity amidst the COVID-19 pandemic, we utilized longitudinal data from five waves of the Combined COVID-19 MENA Monitor Household survey (CCMMHH), which was carried out by the Economic Research Forum (ERF) in Egypt, Jordan, Morocco, Tunisia and Sudan between November 2020 and August 2021. Specifically, we examine the association between one's perception of the risk of contracting COVID-19 and their experiences with food insecurity. Then, we delve into the factors that prevented households from mitigating the economic consequences of the elevated risk of contracting the virus, as well as the decline

of informal support networks and coping mechanisms. The advantage of our dataset for measuring the effects of the pandemic on food security is that it provides a disaggregated panel information about COVID-19 risk exposure; food insecurity; employment, incomes, and expenditures; received food, cash and other support from government and others; and household mitigation strategies of the effects of the pandemic on their incomes and food consumption. Specifically, we apply linear regression models to estimate the association between perceived COVID-19 risk and food insecurity. To better understand the underlying causes of food insecurity, we analyzed the mechanisms that contribute to worry about COVID-19 infection and investigated the coping strategies used to alleviate worriedness about COVID-19 risk.

The present study makes three important contributions to the literature. First, unlike previous studies which used rather subjective measures of risk perception by asking - for example - whether an individual personally knows someone who contracted coronavirus (e.g., Mueller et al., 2022), we use a more indicative measure of COVID-19 risk perception by focusing on individuals' own assessment of their level of concern about contracting the virus. This way, we account for an array of other factors that may shape an individual's risk perception personal and collective efficacy, personal knowledge, trust in the government, science, and healthcare systems, individual values and belief, and direct and indirect experience of the virus through one's own network (Lanciano et al., 2020).

Second, in contrast to the majority of previous studies (e.g., Ahn & Norwood, 2021; Fitzpatrick et al., 2021; Gaitán-Rossi et al., 2021), which narrowly defined food security and measured it from a single dimension (e.g. food shortage or food prices), our study acknowledges the multifaceted nature of an individual's food security status, and therefore develops a multidimensional index of food security to examine the association between individuals' COVID-19 risk perception and their food security outcomes. Recently, the adoption of multidimensional food security measures has increasingly been recommended for evaluating household food insecurity, as they provide a more comprehensive understanding of individuals' food security status by encompassing various dimensions related to food supply and demand (Jaacks et al., 2021). In this context, several development organizations and think tanks have developed indices for measuring food security, including the Economist's Global Food Security Index (GFSI), the IFPRI's Global Hunger Index (GHI), and the FAO's Food Insecurity Experience Scale (FIES). For instance, GFSI captures four dimensions of food security: affordability, availability, quality and safety, and sustainability and adaptation (The Economist Intelligence Unit, 2022). The GHI measures hunger based on four indicators: undernourishment, child wasting, child stunting,

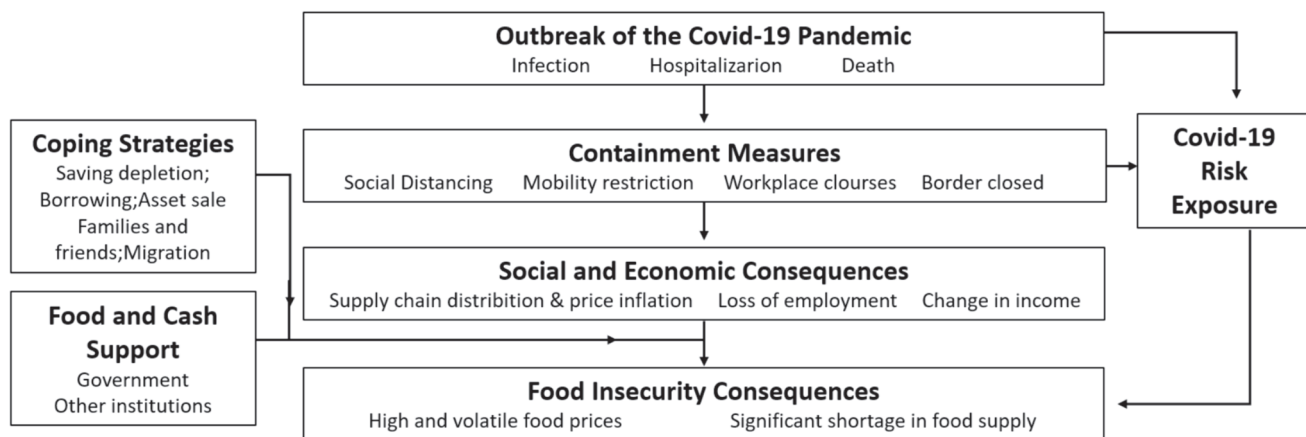


Fig. 1 Conceptualization of the linkages between the COVID-19 pandemic and food security

and child mortality (IFPRI, 2022). Similarly, the FIES comprises experience-based measures of household or individual food security, calculated using eight questions concerning individuals’ access to adequate food due to resource constraints (FAO, 2018). Overall, these indices provide a holistic approach for measuring food security among individuals and households and allow for regional and cross-country comparisons (Jaacks et al., 2021). The food security index utilized in the present study draws upon elements from these multidimensional indices and devises a unique measurement based on five questions included in the CCMMHH survey. Specifically, our food security index comprises five interrelated dimensions pertaining to the availability, accessibility, and affordability of food commodities, quality and utilization of food, and stability in food supply. Consequently, it provides a more comprehensive measure of an individual’s food security compared to the measures utilized in prior studies, by being multifaceted and accounting for various dimensions relating to food supply and demand.

Third, most previous studies relied on survey-based evidence from a single point in time related to a single COVID-19 wave (that is, cross-sectional data). This only provides a snapshot of the association between COVID-19 risk and food insecurity consequences; but does not uncover the dynamic elements of this relationship which were subjected to substantial changes over the pandemic’s time and across various waves (Abdelrahman, 2022). Among these elements are infection rates, media coverage as well as public policy and communication regarding the implementation of mitigation measures (Rattay et al., 2021). The present study used multiple waves of the CCMMHH survey spanning from November 2020 to August 2021, controlled for country-specific and time trends. This enabled us to account for changes within a country over time that may be associated with the changes in individuals’ risk perceptions and concern about food security among the population. In

addition, we believe that analyzing the consequences of an exogenous shock, such as the Covid-19 pandemic, on the consumption stage of the food value chain would offer an interesting and pertinent perspective, while many of existing studies in the context of LMICs focus on the impact of exogenous shocks on food production, distribution and retailing, analyzing the effects of such shocks on the consumption stage, including its impact on food security outcomes, is crucial.. Consumers represent the ultimate recipients of the value generated by the various stages and actors within the chain. Therefore, the findings of this study hold significant implications for policy interventions aiming at addressing the broader impacts of exogenous shocks on agri-food value chains in LMICs and mitigate their consequences on consumer nutrition and food security.

2 COVID-19 risk perception and food security in the MENA region: A conceptual model

Figure 1 illustrates our conceptualization of the links between the COVID-19 pandemic and food security in the MENA region while considering the impact of risk perception on food security. With the first COVID-19 case reported in the region in February 2020, the virus rapidly spread through MENA countries, causing more than 220,000 confirmed cases and nearly 8,500 deaths by May 2020 (WHO, 2022). As of February 2023, the WHO Coronavirus Dashboard shows that MENA countries have reported more than 26 million confirmed cases and over 323,000 deaths. In the initial absence of an effective vaccine and as the COVID-19 pandemic unfolded in the region, MENA governments implemented a mix of non-pharmaceutical measures for prevention and control measures to contain the spread of the virus and mitigate its public health impacts. These measures

included partial or full lockdown, mobility restrictions, social distancing and avoidance of public gatherings, mandatory use of face masks, and repeated handwashing (UNDP, 2020). In tandem with these prevention and mitigation measures, most of MENA countries banned entry to foreigners during the first phases of the pandemic, reduced or placed air traffic on hold, introduced mandatory testing for COVID-19 as an entry requirement, and launched public awareness campaigns through social media and TV to educate citizens of the region about hygienic preventive measures (OECD, 2020).

The implementation of these measures has raised individuals' awareness and consciousness about the risks associated with the virus and heightened their risk perception in relation to the pandemic's seriousness and personal susceptibility (Melki et al., 2022). While these measures initially aided MENA governments in managing the first wave of the pandemic, it became evident that their effectiveness diminished as the pandemic advanced into 2021 (Alzaatreh et al., 2022). This was largely attributed to public non-compliance, as people were reluctant and unwilling to follow measures that had negative impacts on their employment, income, and livelihoods (Hobaika et al., 2022). Consequently, this turned many MENA countries into hotspots for viral transmission, resulting in high mortality rates (Fawcett, 2021), and in turn, reignited people's fears about contracting the virus, amplifying their perceived susceptibility and level of concern. Being a representative of the role of potential factors that influence earning potential, risk perception is likely to predict individual's food insecurity (Mueller et al., 2022).

From a food security perspective, the region, which hosts 20% of the world's acutely food insecure individuals, has traditionally been facing longstanding food insecurity challenges and has especially been susceptible to the impact of exogenous shocks including disease outbreaks (Belhaj & Soliman, 2021). The vulnerability of MENA countries to shocks is attributed to their unique characteristics in terms of population density, regional instability, and the facts that the region is distinctly conflict- and displacement affected (Abu Hatab et al., 2021). As shown in Fig. 1, COVID-19 containment measures implemented both nationally and internationally have exacerbated food insecurity in the MENA region primarily through their consequences on food accessibility both physically and economically, and their adverse impacts on employment and livelihood (Chiwona-Karlton et al., 2021). That is, the pandemic disrupted logistics and other downstream activities in the food supply chain, leading to ripple effects on upstream activities and further risks of disruption to the entire food supply chain (Abu Hatab et al., 2021). Consequently, there have been sharp and abrupt fluctuations in food prices, and significant shortages in the food supply, resulting in decreased resilience for impoverished individuals and an aggravation of the already precarious

food insecurity situation. In addition, food supply chains in the MENA region are richly integrated in the global food system and most of the countries are import-dependent and rely heavily on global food chains for meeting the food needs of the population. Therefore, these peculiarities of the region and the strong connections that exist between health, food, and other socioecological systems quickly transform the COVID-19 pandemic from a health crisis to one with much broader societal hazards and food insecurity consequences (UNDP, 2020).

Another channel through which the pandemic is affecting food security in the MENA region is via the effects of COVID-19 mitigation measures on household livelihoods (Béné et al., 2021; Picchioni et al., 2022). Evidence shows that the pandemic adversely impacted employment, wages, and household disposable income due to economic recession, coronavirus-related job loss or pay cuts, which caused financial distress for households and widened already-existing inequalities, and worsened food insecurity levels (Alzaatreh et al., 2022; OECD, 2020). For instance, Abu Hatab et al. (2021) show that the COVID-19 containment measures, particularly the lockdowns, have drastically compromised the essential flow of commodities produced by agrifood small- and medium-sized enterprises in Egypt, which generate more than 90% of employment in the food system. Thus, layoff was a key strategy that these enterprises relied on to minimize their operating costs with more than half of the enterprises surveyed laid off up to 30% of their workforce during the pandemic. In addition, the significant importance of the food system for economic activity, employment and livelihood in MENA countries meant that many other sectors of the economy, not only those concerned with processing and distributing agricultural products, experienced indirect effects through impacts on income and consumption.

According to Fig. 1, high threat perception to COVID-19 and its socioeconomic consequences ultimately guides individuals toward particular responses and defensive strategies that deter and mitigate the perceived impacts on their livelihoods and wellbeing, and thus on food security. Previous research has identified several coping strategies that households in LMICs adopted during the COVID-19 pandemic including depleting own savings; curtailing consumption; receiving support from families and friends within country; receiving remittances from family members and friends abroad; moving to other areas; borrowing from financial institutions, and selling assets (Giovanis & Ozdamar, 2021; Harris et al., 2020). Besides these household-level mitigation strategies, MENA governments took several measures to support vulnerable households including emergency cash transfers, food aid, and food price subsidies, with the aim to redistribute wealth, shield lower-income households from income shocks, and prevent the deterioration of their food

security (Mandour, 2021). However, the effectiveness of these measures has been criticized for insufficient coverage and targeting errors by not effectively reaching the intended beneficiaries, resulting in the exclusion of some eligible households and the inclusion of ineligible ones (El-Shal et al., 2022).

It should be noted that the linkages between COVID-19 and food security shown in Fig. 1 are also contingent on a suite of sociodemographic factors. The dominant narrative in previous studies suggests that the pandemic disproportionately affected low-income households, who typically live in precarious circumstances (Padmaja et al., 2022). In addition, certain professions were linked to a significant reduction in earnings and a decline in the purchasing power, specifically those that depend more on human effort than on technology and involve direct human interaction, such as construction, manufacturing, and service industries, along with low-skilled and informal employment, and laborers employed in small to medium-sized businesses (Abu Hatab et al., 2021; Amare et al., 2021). Previous studies also show that females are generally more vulnerable than their male counterparts to livelihood loss and food insecurity (Mahmah & Amar, 2021). Likewise, several studies in the context of LMICs reveal that the prevalence of food insecurity during the COVID-19 period was much higher among young individuals than the elderly (Elsahoryi et al., 2020). Geographic factors were found to determine food insecurity in LMICs where urban households who rely on food purchases were affected the most from the disruption of food supply chains (Kesar et al., 2021). Finally, previous studies reveal distinct differences among MENA countries in relation to vulnerability to food insecurity which is typically attributed to governance, institutional and socioeconomic factors along with the varying and uneven responses by governments in terms of the implementation of risk management strategies and adopted measures to support vulnerable households during the pandemic (Krafft et al., 2022; Woertz, 2020).

3 Data

3.1 The CCMMHH survey and sample composition

The study utilized data from the Economic Research Forum's Combined COVID-19 MENA Monitor Household survey (CCMMHH), which included five waves of panel telephone surveys rolled out approximately every two months between November 2020 and August 2021 (ODAMI, 2021). The base wave of the survey was conducted in November 2020, while the subsequent four waves were conducted in February 2021, April 2021, July 2021, and August 2021. The interviews were implemented by experienced survey research and polling companies in Egypt, Jordan, Morocco,

Tunisia, and Sudan using computer-assisted telephone interviewing techniques. The CCMMHH survey covered a wide range of topics including household demographics, labor market and employment status, income and earnings, perception and attitudes towards COVID-19 risks and adherence to mitigation measures. It also included questions about the food security experiences of respondents during the pandemic, which encompassed factors like food affordability, availability, and access barriers. Additionally, the questionnaires asked about household coping strategies, access to social safety nets, and access to government and non-governmental support provided to help households cope with the pandemic's impact on their employment, income, and food security.

A stratified sampling design based on mobile operators' country-specific market shares was used, and the sample was designed to cover at least 2,000 unique households and individuals who were mobile phone users aged 18–64. Respondents from previous waves were contacted again for a follow-up interview only if they had agreed to this in the earlier wave. In order to reduce sampling bias, an inverse probability weighting was applied based on various factors including the market shares of the telephone operators, the number of telephones by operator for individuals and household members, and the representative in-person survey data with comparable demographic and household characteristics. For each country and wave, the corresponding sample is shown in Table S1 in the supplementary material to this study. While we recognize that it is important to know the attrition rates to better interpret the results, the information provided by the Economic Research Forum does not specify the attrition rates by country. However, more information on the sampling design and response and attrition rates can be found in the Economic Research Forum's documentation for the CCMMHH survey, available online.¹

The countries covered by the CCMMHH survey are fairly representative of the MENA region, especially in capturing a range of geographic, socioeconomic, and political conditions. They are also reflective of typical development challenges, such as unemployment, poverty, conflict, and political instability, which align closely with the experiences of other LMICs. Specifically, they represent North Africa (Egypt, Morocco, Tunisia) and the Middle East (Jordan, Sudan), thus providing a broad geographic representation of the two main sub-regions within MENA that traditionally face food security challenges and were adversely affected by the economic and food security impacts of the COVID-19 pandemic (Abu Hatab et al., 2023).

¹ See the data portal of the ERF: <http://www.erfdataportal.com/index.php/catalog/230/download/3459>

From a socioeconomic development perspective, these countries occupy varied positions in terms of their annual progress towards achieving the SDG targets. For instance, among the 193 UN countries covered by the SDG Index (Sachs et al., 2023), Tunisia is in a more advanced position (ranked 50), compared to Morocco (70), Jordan (77), and Egypt (81), which hold middle positions, and Sudan (160), which ranks lower on the index. In terms of food security indicators, the five countries also hold varied positions on the Global Hunger Index (GHI) of the International Food Policy Research Institute (IFPRI), which comprehensively measure and track hunger at country levels using three dimensions of hunger (insufficient availability of food, shortfalls in the nutritional status of children, and child mortality) (IFPRI, 2022). Tunisia ranks advanced (26), followed by Morocco (47), Jordan (53), Egypt (57), and lastly, Sudan (106), out of the 136 assessed countries. Therefore, varying degrees of social and economic and development of the CCMMHH countries create diversity that helps capture a range of household behaviors and economic conditions.

While the absence of Gulf countries (Bahrain, Kuwait, Iraq, Oman, Qatar, Saudi Arabia, and the United Arab Emirates) from the CCMMHH survey means the dataset may not fully represent the entire MENA region, the selected countries remain valuable for understanding common development issues faced by the majority of MENA countries and LMICs. The seven Gulf countries have significantly higher average household incomes and living standards, a different population composition with a large proportion of expatriates, and distinct social welfare systems and political and institutional contexts. Including Gulf countries, with their highly distinctive economic structures and heavy reliance on oil and gas revenues, could have posed challenges in drawing meaningful comparisons or generalizing findings across the MENA region. Their exclusion, therefore, does not significantly detract from the dataset's relevance, as the selected countries provide a representation of the broader economic and social dynamics in the MENA region. In addition, the empirical findings and policy lessons derived from our analysis using the CCMMHH survey should be applicable to countries with similar economic and social contexts not only in the MENA region but also in other LMICs.

3.2 Descriptive statistics

The descriptive statistics of the variables used in this study are shown in Table 1. In the case of food security dimensions, respondents were asked to indicate whether they or any of their household members have experienced any of following in the past seven days prior to the survey: i. difficulties in going to food markets due to mobility restrictions imposed by government/closure (*Market barrier*); ii. Unable to buy the amount of food they usually buy because

of shortages of food in markets (*food shortage*); iii. Unable to buy the amount of food they usually buy because the price of food increased (*high food prices*); iv. Unable to buy the amount of food they usually buy because of a decline in household income (*decreased income*); and v. had to reduce the number of meals and/or the portion of each meal they would usually eat (*reduced meal/portion*).

Among the five food security dimensions, “high food prices” and “decreased income” constitute a high level of food insecurity in the MENA region. Thus, about 59% and 57% of respondents indicated that they have been unable to buy the amount of food they usually buy because of price increase and decreased income, respectively. About 78% and 75% of Sudanese and Tunisian respondents, respectively, experienced high food insecurity due to increased food prices. Egypt somewhat reported a relatively lower proportion of food insecurity attributed to high food prices (that is, 46.6%). In the case of food insecurity attributed to decreased income, the proportion of respondents experiencing that ranges from 45.5% to 68% with Sudan and Tunisia having the lowest and highest proportion, respectively. A relatively lower proportion of respondents, about 19%, indicated “Market barrier” dimension as a constituent of food insecurity in the MENA region. In the case of worriedness about COVID-19 infection, relatively high proportion of respondents indicated they are not worried about being infected by COVID-19, with Sudan having the highest percentage. On average, about 4% of respondents in the MENA region indicated they have already been infected by COVID-19 based on the survey. In Jordan, about 8% respondents have been infected by COVID-19, however, only 1% indicated they have already been infected by the virus in Sudan. About 41% of the respondents are female and 73% of the sample lives in urban areas. The average household size is about five and the average age of respondents is about 36 years. Around 51% of the respondents are actively employed, 23% are unemployed and 26% are out of the labor force.

4 Empirical strategy

Based on the conceptual framework illustrated in Fig. 1, we explore the relationship between COVID-19 risk perception and food insecurity following the specification by Mueller et al. (2022). Thus, we specify a linear model of the form:

$$y_{ijkt}^m = \beta_0 + \beta_1 Covid_worries_{ijkt} + X_{ijkt}\beta + \mu_{jk} + \eta_k + \gamma_t + \varepsilon_{ijkt} \quad (1)$$

where y_{ijkt}^m is the probability of an individual (i) in a community (j) residing in a country (k) experiencing an indicator l dimension (m) of food insecurity at a particular period “ t ”, m is the specific food insecurity dimension which comprises of “Market barrier”, “Food shortage”,

Table 1 Descriptive statistics

VARIABLES	(1)	(2)	(3)	(4)	(5)	(6)	(7)
	All Mean	Std.	Jordan Mean	Morocco Mean	Sudan Mean	Tunisia Mean	Egypt Mean
<i>Food insecurity</i>							
Market barrier	0.187	(0.390)	0.121	0.182	0.123	0.326	0.133
Food shortage	0.246	(0.431)	0.132	0.0962	0.344	0.490	0.201
High food prices	0.585	(0.493)	0.488	0.474	0.781	0.752	0.466
Decreased income	0.565	(0.496)	0.583	0.548	0.455	0.680	0.477
Reduced meal/portion	0.407	(0.491)	0.420	0.279	0.437	0.506	0.430
Household size	5.124	(2.433)	5.381	5.010	6.265	4.521	4.743
Age	36.46	(12.14)	36.53	37.19	30.20	40.00	35.15
Female	0.414	(0.493)	0.473	0.359	0.480	0.403	0.365
Urban	0.723	(0.447)	0.812	0.714	0.831	0.691	0.518
<i>COVID-19 worriedness</i>							
Not at all worried	0.388	(0.487)	0.319	0.426	0.479	0.377	0.356
Little worried	0.216	(0.411)	0.188	0.264	0.145	0.267	0.152
Rather worried	0.151	(0.359)	0.212	0.0750	0.157	0.143	0.203
Very worried	0.207	(0.405)	0.202	0.212	0.209	0.177	0.256
Already infected	0.0385	(0.192)	0.0780	0.0224	0.0102	0.0358	0.0337
<i>Educational attainment</i>							
Less than basic	0.223	(0.416)	0.105	0.380	0.105	0.268	0.171
Basic ^a	0.184	(0.388)	0.281	0.183	0.104	0.169	0.127
Secondary	0.325	(0.468)	0.326	0.183	0.411	0.353	0.466
Higher education	0.267	(0.443)	0.288	0.254	0.380	0.211	0.236
<i>Marital status</i>							
Never Married	0.319	(0.466)	0.248	0.326	0.538	0.295	0.240
Currently Married	0.635	(0.481)	0.698	0.625	0.431	0.661	0.715
Widowed/divorced	0.0460	(0.209)	0.0537	0.0495	0.0316	0.0438	0.0444
<i>Employment status</i>							
Employed	0.511	(0.500)	0.439	0.508	0.401	0.616	0.581
Unemployed	0.234	(0.423)	0.272	0.193	0.306	0.213	0.207
Out of labour force	0.255	(0.436)	0.289	0.299	0.294	0.171	0.212
<i>Income quartile</i>							
First quartile	0.253	(0.435)	0.257	0.363	0.0941	0.199	0.299
Second quartile	0.255	(0.436)	0.350	0.257	0.167	0.200	0.271
Third quartile	0.199	(0.399)	0.193	0.107	0.184	0.294	0.234
Fourth quartile	0.175	(0.380)	0.159	0.0470	0.395	0.233	0.113
Don't know	0.106	(0.308)	0.0323	0.206	0.147	0.0690	0.0674
Refused to answer	0.0125	(0.111)	0.00816	0.0204	0.0134	0.00592	0.0157
Observations	31,436		7,471	8,120	4,401	7,437	4,007

^aFor Egypt basic education comprises primary covering grades 1–9. In Jordan it entails grades 1–10. In Morocco- it comprises of grades 1–9. In Sudan-it comprises of primary education of eight years (that is, grades 1–8). In Tunisia-it entails pre-school and grades 1–9

Std. represents standard deviation

“High food prices”, “Decreased income” and “Reduced meal/portion”. Each of the dimensions of food insecurity is a binary variable, which takes the value of 1 if the individual indicates that he/she or the household is experiencing food insecurity due to any of the dimensions. The variable of interest, *Covid_worries_{ijkt}*, represents the

degree of an individual’s perceived worriedness about COVID-19 infection. Individuals were asked to indicate their degree of worriedness about being infected with COVID-19. The options provided to respondents are “not worried”, “little worried”, “rather worried”, “very worried” and “already infected”.

We acknowledge that the “already infected” category of the perceived worriedness variable ($Covid_worries_{ijkt}$) may not necessarily indicate a higher level of worriedness compared to the “very worried” category of the variable. However, the authors have limited control over that, since they were not involved in the survey design and implementation. In addition, and importantly, the authors argue that including the “already infected” individuals allows for a more comprehensive understanding of the full spectrum of experiences related to the risk of contracting COVID-19. This inclusion is particularly important given the evidence showing that many who contracted COVID-19 have been re-infected, and thus may still perceive worriedness even after contracting the virus (Wang et al., 2021a, b). Those individuals might have different worries or attitudes towards the risk compared to those concerned about potential infection. Furthermore, this categorization enables comparisons between those worried about potential infection and those who have already faced the risk, highlighting differences in perception and subsequent actions taken to mitigate economic and food security consequences. Therefore, it was assumed that including “already infected” individuals would provide deeper insights and a more complete picture of risk perception and its impacts on food security for the participants.

Socioeconomic and demographic factors, and other control variables are captured by the vector X_{ijkt} . These controls include gender, age, household size, location (urban/rural), education, marital, employment status, and income quartile. Further, we account for community/administrative (μ_{jk}), country (η_k) and survey wave (γ_t) fixed effect in our model. The error term in our model is represented by ε_{ijkt} .

Although each food insecurity dimension is binary, we estimate Eq. (1) using seemingly unrelated regression in a linear probability model (LPM) framework. The seemingly unrelated regression helps us to simultaneously estimate the five dimensions of food insecurity and account for possible correlation among them. We preferred seemingly unrelated regression to non-linear estimators such as multivariate probit due to the following reasons: i. seemingly unrelated regression allows identification of impact without necessarily having to impose a specific functional form such as normal distribution as required multivariate probit, ii. unlike multivariate probit model which requires transformation of the parameters into marginal effects to give economic interpretations of results, coefficients of the seemingly unrelated regression can be directly interpreted as marginal effects. Although predicted probabilities from seemingly unrelated regression model can fall outside the interval, 0 to 1, this limitation will be relevant if the objective of the estimation is, for instance, to predict the probability of the outcome variable. However, our aim is to estimate the relationship between COVID-19 risk perception and food insecurity.

In addition to using each of the dimensions as an outcome variable in our model, we generate a composite index of food insecurity using the five food insecurity dimensions and principal component analysis (PCA). Before proceeding with the PCA, we first tested the internal reliability or consistency of the five food insecurity indicators/dimensions. The Kaiser-Meyer-Olkin (KMO) which shows a measure of sampling adequacy gives a value of 0.75 and the Cronbach’s alpha (measure of internal reliability) gives a value of 0.71. In addition, the chi-square statistic from Bartlett’s test of sphericity gives a value of 28,146.3 and is statistically significant ($p < 0.01$), meaning the null hypothesis that the variables are not inter-correlated is rejected. Based on these test values, there is a common factor among the five food insecurity indicators and therefore usage of principal component analysis (PCA) is appropriate.

From Table S2 in the supplementary material, the eigenvalue shows that one of the components passes the criteria since the eigenvalue is greater than one. This component explains about 46.5% variations in the food insecurity dimension. Thus, this component represents the food insecurity index to be used in our second stage of the analysis. Using ordinary least squares estimation, we regress the food insecurity index on $Covid_worries_{ijkt}$ and the other regressors in Eq. 1. Given that food insecurity could differ across various socioeconomic and demographic dimensions, we explore heterogenous effects of the relationship between food insecurity and COVID-19 risk perception.

5 Results

5.1 COVID-19 risk perception and food insecurity

Table 2 presents the econometric results of the six models that were estimated to examine the association between the level of individuals’ concern about contracting COVID-19 and various dimensions of food insecurity. Specifically, results of models 1 to 5 are based on seemingly unrelated regression with assumed correlation among dependent variables. The dependent variable of each of these models represent a certain dimension of the food security concept as follows: Model 1, labeled “Market Barrier”, pertains to issues related to difficulties that households encountered in going to food markets due to mobility restrictions imposed by government or closures. Model 2, labeled “Food Shortage” relates to households’ inability to purchase the usual amount of food due to shortages in the market. Model 3 (High Food Prices) relates to households’ inability to buy the amount of food they usually buy due to food price spikes. The results of Model 4 (Decreased Income) relate to households’ inability to buy the amount of food they usually buy because of a decline in household income. Model 5 (Reduced Meal/

Table 2 Relationships between food insecurity and concern about COVID-19 infection

Variables	Seemingly unrelated regression model					OLS
	(1)	(2)	(3)	(4)	(5)	(6)
	Market barrier	Food shortage	High food prices	Decreased income	Reduced meal/portion	FII
Concern about infection (ref: Not worried)						
A little worried	0.017*** (0.006)	0.021*** (0.006)	0.027*** (0.007)	0.011 (0.007)	0.025*** (0.007)	0.099*** (0.020)
Rather worried	0.033*** (0.007)	0.046*** (0.007)	0.054*** (0.008)	0.038*** (0.008)	0.052*** (0.008)	0.215*** (0.023)
Very worried	0.089*** (0.006)	0.087*** (0.006)	0.095*** (0.007)	0.091*** (0.007)	0.096*** (0.007)	0.442*** (0.021)
Already infected	0.016 (0.011)	0.005 (0.012)	0.019 (0.014)	-0.011 (0.014)	0.006 (0.014)	0.034 (0.040)
Household size	0.003*** (0.001)	0.004*** (0.001)	0.006*** (0.001)	0.013*** (0.001)	0.006*** (0.001)	0.031*** (0.003)
Age	0.001*** (0.000)	-0.000 (0.000)	0.001*** (0.000)	0.001*** (0.000)	0.003*** (0.000)	0.004*** (0.001)
Gender (ref: Male)	-0.005 (0.005)	0.003 (0.005)	0.047*** (0.006)	0.009 (0.006)	0.030*** (0.006)	0.081*** (0.018)
Locality (ref: Rural)	-0.023*** (0.005)	-0.012** (0.006)	0.001 (0.007)	0.007 (0.007)	0.007 (0.007)	-0.019 (0.020)
Education (ref: Less than basic)						
Basic	-0.026*** (0.007)	-0.029*** (0.007)	-0.011 (0.008)	-0.024*** (0.009)	-0.044*** (0.009)	-0.129*** (0.025)
Secondary	-0.060*** (0.007)	-0.066*** (0.007)	-0.060*** (0.008)	-0.082*** (0.008)	-0.109*** (0.008)	-0.361*** (0.024)
Higher education	-0.078*** (0.007)	-0.104*** (0.007)	-0.105*** (0.009)	-0.174*** (0.009)	-0.167*** (0.009)	-0.603*** (0.025)
Marital status (ref: Never Married)						
Married	-0.012** (0.006)	-0.006 (0.006)	0.056*** (0.007)	0.067*** (0.007)	0.041*** (0.007)	0.139*** (0.021)
Widowed/divorced	0.008 (0.012)	0.006 (0.012)	0.050*** (0.014)	0.066*** (0.014)	0.063*** (0.014)	0.183*** (0.042)
Constant	0.268*** (0.016)	0.218*** (0.017)	0.444*** (0.020)	0.572*** (0.020)	0.408*** (0.020)	-0.099* (0.059)
Observations	31,436	31,436	31,436	31,436	31,436	31,436
R-squared	0.087	0.174	0.163	0.157	0.143	0.242
Controls	YES	YES	YES	YES	YES	YES
Country&Admin FE	YES	YES	YES	YES	YES	YES
Wave FE	YES	YES	YES	YES	YES	YES
Breusch–Pagan test of independence: $\chi^2(10)=23842.963^{***}$						

Columns (1)–(5) are based on seemingly unrelated regression with assumed correlation among dependent variables. While column (6) is based on OLS estimation. Column (1)-Market barrier: Difficulties in going to food markets due to mobility restrictions imposed by government/closures. Column (2)-Food shortage: Unable to buy the amount of food we usually buy because of shortages of food in markets. Column (3)- High food prices: Unable to buy the amount of food we usually buy because the price of food increased. Column (4)- Decreased income: Unable to buy the amount of food we usually buy because our household income has dropped. Column (5)- Reduced meal/portion: Had to reduce the number of meals and/or the portion of each meal we would usually eat. For column (6), we developed FII based on columns (1)-(5) using principal component analysis. Standard errors in parentheses in the case of the seemingly unrelated model. For the OLS model, robust standard errors are in parentheses

We controlled for employment status, income quartile, wave, country, and administrative fixed effect in all the models

*p < 0.1; **p < 0.05; ***p < 0.01

Portion) relates to the likelihood that a household would cut down on the number of meals or the portion size of each meal they usually consume. Finally, Model 6 was estimated using OLS regression based on the FII that we developed.

Overall, the results present compelling evidence of an association between an individual's concern about contracting COVID-19 and household's overall food insecurity, while a higher FII was positively and significantly correlated with greater degrees of concern about contracting COVID-19, ranging from "a little worried" to "rather worried" to "very worried" (Model 6). Likewise, across the five dimensions of food security (Models 1–5), most coefficients related to varying levels of worry from "a little worried" to "very worried", were positively significant and highly statistically significant at the 1% level. Especially, a greater concern about catching the virus was strongly associated with a household's reduced ability to purchase their typical amount of food due to food price increases (Model 3 – "higher food prices") and a tendency to decrease meal frequency or portion sizes (Model 5 – "reduced meal/portion").

Notably, a look at the coefficients of all the six estimated models reveals that the association between an individual's concern about contracting COVID-19 and household food insecurity can be represented graphically with an inverted U-shaped curve. Specifically, the magnitude of the estimated coefficients increased as individuals' worries about contracting the virus rose, until reaching a peak value for the "very worried" category of the independent variable, and then decreased markedly after they had been infected with the virus. For instance, the results of Model 2 demonstrate that the coefficient value relating to households' inability to buy the amount of food they usually buy because of a decline in household income grew from 0.011 for the "a little worried" category to 0.38 and 0.91 for the "very worried" and "rather worried" categories, respectively, and then returned to 0.011 for the "already infected" category. Similarly, the coefficient value for exhibiting difficulties in going to food markets due to mobility restrictions increased from 0.017 to 0.033 for the "a little worried" and "rather worried" categories, respectively, to a maximum value of 0.089 for the "very worried" category, before falling below the baseline level ("a little worried") for the "already infected" category of the sample.

Turning to individual attributes, the estimated models suggest that respondents' food security outcomes during the COVID-19 pandemic were generally influenced by their age, gender, education level, and marital status. In terms of age, the results reveal a positive and highly statistically significant association between a respondent's age and all dimensions of food security, with the exception for Model 2 (Food Shortage) where the coefficient is negative but not statistically significant. When compared to their male counterparts, our results suggest that female respondents were

generally found to have a significantly higher likelihood of experiencing food insecurity, specifically in relation to being unable to purchase their usual amount of food due to spikes in food prices and having to reduce the number or portion size of their meals. Regarding the influence of educational attainment on food insecurity, an interesting observation is that both the FII model and the disaggregated models consistently indicate that the probability of experiencing food insecurity decreases significantly as the level of educational attainment increases. In comparison to respondents who have never been married, individuals who are currently married or experienced widowhood or divorce encountered notably more food insecurity challenges during the pandemic, which were primarily related to increased exposure to food price inflation, a decrease in disposable income, and reduced food consumption.

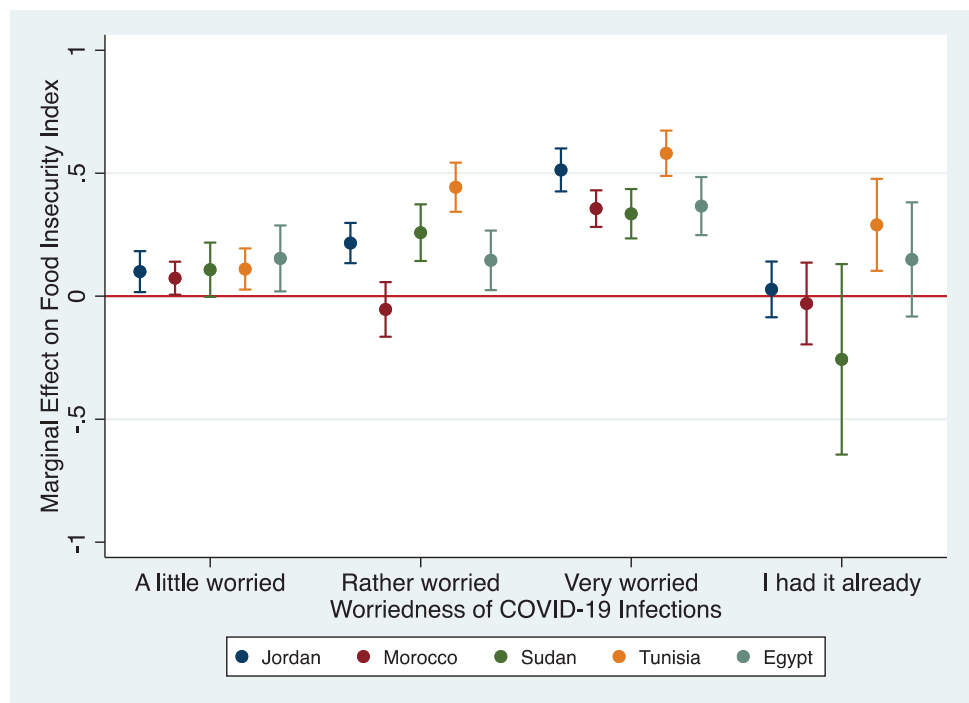
With a highly statistically significant coefficient in all models, the results demonstrate a significant and consistent relationship between household size and food insecurity consequences during the COVID-19 pandemic. The coefficient of household size was highly statistically significant in all models, indicating that larger household sizes were associated with greater food insecurity challenges for the surveyed households. Finally, our findings suggest that overall, there is no significant difference between rural and urban households in terms of their overall FII. However, urban households were notably more likely to report specific food security challenges related to physical access to food markets and unavailability of food products in the markets.

Given the possible variation in the association between concern about COVID-19 infection and food insecurity, we further explored this relationship across the respondents' gender, age group, marital status, employment status, income quantiles, and geographic location of the residential area (urban vs. rural). The results of these analyses are reported in Tables S3 through S10 in the Supplementary Material. In general, the sign and magnitude of the effect of these factors on the association between worriedness of COVID-19 infection on food insecurity are qualitatively similar- with few exceptions- to those of the pooled model (Table 2).

5.2 Cross-country analysis

Figure 2 displays the findings of our cross-country analysis of the link between individuals' COVID-19 infection concerns in the five MENA countries and the FII. The results confirm a positive and statistically significant correlation between COVID-19 concerns and FII. This correlation generally increases in an ascending trend from individuals who are less worried to those who are highly worried, and then the correlation weakens and becomes

Fig. 2 Coefficient plot of regression estimates of worriedness of COVID-19 infection on food insecurity index by country. Spike plot is at 95% confidence interval



insignificant in all cases except for Tunisia when individuals contract the virus. Furthermore, the estimated coefficients show that the association was most substantial in Tunisia and Egypt compared to the rest of the sampled MENA countries. In these countries, the coefficients rose from 0.11 and 0.15, respectively for the “little worried” category of respondents, to 0.58 and 0.46 for the “very worried” group.

Upon examining the results of the analysis concerning the sociodemographic characteristics of the respondents across the countries (see Table S11 in the Supplementary Material), we find that the FII score tends to decrease with higher educational levels and increase with larger household sizes. In Morocco and Egypt, FII was found to correlate positively and significantly with being female, whereas this correlation was statistically insignificant for other countries. Respondents’ age was found to have a negative and statistically significant effect on FII for Egyptians and Moroccans, but this effect was significantly positive for other countries. Additionally, married, widowed, and divorced Jordanians, Moroccans, and Egyptians had higher FII scores compared to those who have never been married. However, the effects were insignificant for other countries. Moreover, we observed that the FII is positively associated with being unemployed and negatively associated with being out of the labour market, as opposed to being employed, across all the sampled countries.

5.3 Analysis of mechanisms of worriedness about COVID-19 infection

5.3.1 Change in income and concerns about COVID-19 infection

Table 3 shows our results regarding the association between change in income and worriedness of COVID-19 infection. On the one hand, the calculated marginal effects reveal that individuals who had some concerns about contracting COVID-19 were more likely to report no change or even an increase in their income of up to 25% or more, compared to those who were completely unworried. On the other hand, they were less likely to report a decrease in their income. These differences were statistically significant. In contrast to these finding, the results suggest that individuals who were highly concerned about contracting COVID-19 were significantly more likely to experience substantial income decreases of up to or exceeding 25%, compared to those who had lesser concerns about the infection.

In addition, they were significantly less likely to report either any stability or an increase in their income of up to 25% or more, in contrast to those who had no worries at all. Furthermore, the results are noteworthy in that they demonstrate no statistically significant differences between respondents who were completely unworried and those who either had moderate worries or had already been infected. This suggests that the significant differences in the relationship between income changes and COVID-19 concerns are primarily evident among individuals with low or high levels of concern about contracting the virus.

Table 3 Association between change in income and concerns about COVID-19 infection

Concern about infection ^a	Ordered probit model	Marginal effect on income				
		Decreased > 25%	Decreased 1–25%	No change	Increased 1–25%	Increased > 25%
A little worried	0.069*** (0.018)	-0.024***	-0.002***	0.016***	0.006***	0.003***
Rather worried	-0.017 (0.020)	0.006	0.001	-0.004	-0.002	-0.001
Very worried	-0.062*** (0.019)	0.021***	0.002***	-0.015***	-0.006***	-0.003***
Already infected	-0.011 (0.035)	0.004	0.000	-0.003	-0.001	-0.001
Observations	27,014	27,014	27,014	27,014	27,014	27,014
Controls	YES	YES	YES	YES	YES	YES
Country&Admin.FE	YES	YES	YES	YES	YES	YES
Wave FE	YES	YES	YES	YES	YES	YES

^aReference group is “not worried”. Column (1) represents ordered probit estimation and columns (2)–(6) are the marginal estimation based on column (1). The dependent variable is the change in total monthly income compared to Feb 2020; i. Decreased by > 25%, ii. Decreased by 1–25%, iii. No change in income, iv. Increased by 1–25%, and v. Increased by > 25%

We controlled for gender, age, household size, location, education, marital, employment status, income quartile, wave, country and administrative fixed effect in all the models

Robust standard errors in parentheses * $p < 0.1$; ** $p < 0.05$; *** $p < 0.01$

5.3.2 Worriedness about economic situation and concerns about COVID-19 infection

Table 4 displays the results of the ordered probit model, indicating a strong positive correlation between an

individual's concerns about COVID-19 infection and worries about economic concerns. This association is consistently significant across all levels of COVID-19 concern. In the CCMMHH survey, the assessment of worriedness about economic situation was done using the question of

Table 4 Association between worry about economic situation and concerns about COVID-19 infection

Concern about infection ^a	Ordered probit model	Marginal effect on worry about economic situation			
		Not at all worried	A little worried	Rather worried	Very worried
A little worried	0.262*** (0.017)	-0.056***	-0.029***	-0.011***	0.096***
Rather worried	0.473*** (0.019)	-0.101***	-0.052***	-0.020***	0.173***
Very worried	0.938*** (0.021)	-0.201***	-0.103***	-0.040***	0.343***
Already infected	0.372*** (0.036)	-0.080***	-0.041***	-0.016***	0.136***
Observations	31,436	31,436	31,436	31,436	31,436
Controls	YES	YES	YES	YES	YES
Country_Admin FE	YES	YES	YES	YES	YES
Wave FE	YES	YES	YES	YES	YES

^aReference group is “not worried”. Column (1) represents ordered probit estimation and columns (2)–(5) are the marginal estimation based on column (1). The dependent variable is how worried respondents are about the economic situation; i. not at all worried, ii. a little worried, iii. rather worried and iv. very worried

We controlled for gender, age, household size, location, education, marital, employment status, income quartile, wave, country, and administrative fixed effect in all the models

Robust standard errors in parentheses * $p < 0.1$; ** $p < 0.05$; *** $p < 0.01$

Table 5 Association between coping strategies and COVID-19 risk

Concern about infection ^a	(1) Coping strategy	(2) Spending savings	(3) Families & friends in-country	(4) Families & friends abroad	(5) Return migration	(6) Borrowing money	(7) Selling assets
A little worried	0.022*** (0.007)	0.021*** (0.007)	0.014** (0.007)	-0.001 (0.004)	-0.004 (0.004)	0.009* (0.005)	-0.005 (0.005)
Rather worried	0.032*** (0.008)	0.032*** (0.008)	0.040*** (0.008)	0.010** (0.004)	0.010** (0.005)	0.016*** (0.006)	0.004 (0.006)
Very worried	0.035*** (0.007)	0.006 (0.007)	0.035*** (0.008)	0.014*** (0.004)	0.015*** (0.004)	0.031*** (0.005)	0.025*** (0.006)
Already infected	0.032** (0.013)	0.042*** (0.015)	0.018 (0.014)	0.009 (0.008)	-0.006 (0.007)	0.039*** (0.012)	0.019* (0.010)
Constant	0.768*** (0.019)	0.282*** (0.021)	0.467*** (0.021)	0.030*** (0.010)	0.138*** (0.011)	0.135*** (0.015)	0.154*** (0.015)
Observations	31,436	31,436	31,436	31,436	31,436	31,436	31,436
R-squared	0.037	0.082	0.055	0.036	0.074	0.047	0.054
Controls	YES	YES	YES	YES	YES	YES	YES
Country_Admin FE	YES	YES	YES	YES	YES	YES	YES
Wave FE	YES	YES	YES	YES	YES	YES	YES

^aReference group is “not worried”. Spending savings = taking money out of savings; Families & friends in-country = Taking money from family, relatives, or friends; Families & friends abroad = Taking money from family, relatives, or friends abroad; Return migration = going back to the village or family; Borrowing money = Borrowing from a bank, employer, or private lender; and Selling assets = sale of household assets. The dependent variable in each of the models is binary, and all models are estimated by linear probability models

We controlled for gender, age, household size, location, education, marital, employment status, income quartile, wave, country, and administrative fixed effect in all the models

Robust standard errors in parentheses *p < 0.1; **p < 0.05; ***p < 0.01

“How worried are you about the economic situation? On a scale from 1 to 4 from not at all worried (1) to very worried (4) where would you put yourself?”. Upon reviewing the calculated marginal effects, it is evident that individuals with varying levels of COVID-19 concern, ranging from minimal to high levels of concern and even those who have already been infected, were significantly more likely than those who were completely unconcerned to be classified under the category of the dependent variable associated with elevated economic concerns.

Especially, individuals who expressed elevated levels of worry regarding contracting COVID-19 were found to be more prone to exhibit apprehensions about their economic circumstances (marginal effect = 0.343), when compared to those with lower levels of concern about COVID-19 infection. Interestingly, a “first-up-then-down” trend, akin to the observed relationship between food insecurity and concern about COVID-19 infection, is also evident in Table 4. The magnitude of the marginal effect of an individual's worries regarding their own economic situation became increasingly significant as their concerns about contracting the virus intensified. However, this significance diminished significantly after they had contracted the virus.

5.4 Coping strategies for mitigating worriedness about COVID-19 risk

In this part of the analysis, we hypothesize that coping strategies and level of concern are correlated, because worriedness determines the strategies individuals would adopt in order to cope with the negative impact of the infection (Abu Hatab et al., 2023). As shown in Table 5, households in the surveyed MENA countries applied six primary coping strategies to manage the repercussions of the COVID-19 pandemic: *i*) withdrawing funds from savings, *ii*) obtaining money from family, friends, or acquaintances, *iii*) obtaining money from overseas family or friends, *iv*) returning to the village or family, *v*) borrowing from banks, employers, or private lenders, and *vi*) selling assets.

Overall, the results presented in Table 5 reveal a positive and statistically highly significant association between the level of an individuals’ concern about contracting the virus and their adoption of coping strategies (column 1). Upon examining the outcomes pertaining to different coping mechanisms, it was observed that the most notable correlation was found in the “spending savings” strategy, succeeded by acquiring funds from relatives, friends, or acquaintances.

The coefficients linked to these two strategies were persistently positive and statistically significant at %1 level at all levels of individuals' concern about contracting the virus. With regards to the other four strategies presented in columns 4 through 7 in Table 5, the findings indicate that only individuals with moderate and high levels of concern about contracting COVID-19 were significantly more inclined to adopt them, as opposed to those who were entirely unconcerned about infection.

6 Discussion

Recent years have witnessed a rise in the simultaneous occurrence and severity of external shocks, such as disease outbreaks, geopolitical conflicts, and natural disasters. These events have laid bare the vulnerability and fragility of global and regional agri-food value chains (Das & Roy, 2022). While the impact of these shocks has been felt globally, it is the food supply chains in LMICs that have been most affected due to their inherent characteristics, resource constraints, and limited governance capacity, which hindered their ability to respond effectively. The repercussions of these shocks extend beyond the immediate impacts on agri-food value chains, posing a threat to already fragile food systems, exacerbating poverty, compromising food security, and even undermining sociopolitical stability (Barrett, 2020). Abu Hatab (2022) highlights the combined effects of recent shocks, such as the COVID-19 pandemic and the Russian aggression in Ukraine, present a significant risk to derailing national and global efforts towards achieving sustainable development goals in LMICs, particularly those related to promoting sustainable consumption and production patterns, and eradicating hunger.

To gain deeper insights into the relationship between these exogenous shocks and household food insecurity in LMICs, this study utilized longitudinal data from the Combined COVID-19 MENA Monitor Household survey (CCM-MHH), conducted between November 2020 and August 2021 in five MENA countries to examine how individuals' concern about contracting COVID-19 relates to their experiences with food insecurity. In addition, the study delved into the underlying causes of food insecurity by analyzing the mechanisms contributing to concerns about COVID-19 infection and the coping strategies employed by households to alleviate their worries about the risk of COVID-19.

Overall, our results are consistent with previous research on the impact of COVID-19 on food insecurity in MENA and LMICs countries in Jordan (Elsahoryi et al., 2020), Iran (Pakravan-Charvadeh et al., 2021), Kenya and Uganda (Kansiime et al., 2021), all corroborating the detrimental effects of the pandemic on households' food security (Mandour, 2021; Woertz, 2020). However, the findings of this study hold

significant implications for the design and implementation of policy interventions that can effectively address the broader impacts of exogenous shocks, including disease outbreaks and mitigate their consequences on consumer nutrition and food security. The following paragraphs discuss our main findings and their policy implications.

6.1 Greater levels of concern about contracting COVID-19 were strongly associated with food insecurity

The results of this study substantiate the conclusions drawn by Mueller et al. (2022), confirming the association between an individual's concerns about contracting a disease like COVID-19 and their likelihood of experiencing food insecurity. The results comport also with those by Tabé-Ojong et al. (2022) and Deressa et al. (2021) showing correlations between the COVID-19 pandemic and individuals' worries about the affordability and access to food. Ben Hassen and El Bilali (2022) illustrate that the implementation of preventive measures by governments brought about substantial lifestyle changes, exacerbating worries, stress, anxiety, and other related issues, which had a profound impact on individuals and their relationship with food. Hence, our findings suggest that government interventions aimed at addressing food insecurity during disease outbreaks should encompass extensive public awareness campaigns to direct individuals towards trusted sources and accurate evidence-based information regarding disease transmission and control to ensure that individuals are well-informed and equipped to make informed decisions that minimize food insecurity consequences (van Burgel et al., 2023).

The results revealed that individuals' worries about contracting COVID-19 influences the five dimensions of food security that were examined, although the extent of influence may vary. This finding underscores the importance of adopting more holistic and comprehensive approaches empirical examinations of food security to account for the multidimensional nature of food security, which encompasses various dimensions, including availability, accessibility, utilization, and stability of food. Comprehensive approaches would enable the examination of these collectively and the analysis of their interconnections, providing a more nuanced understanding of the intricate dynamics and the underlying factors that contribute to food insecurity (Abu Hatab et al., 2021).

Remarkably, the results showed that the association between individuals' worries about contracting COVID-19 and food insecurity was particularly pronounced in two dimensions: individuals' reduced ability to purchase their usual amount of food due to food price increases, and the tendency to decrease meal frequency or portion sizes. In this regard, Hoogeveen and Lopez-Acevedo (2021) show

that the pandemic escalated households' stress levels regarding access to food, forcing individuals in developing countries to change their daily food consumption patterns. These changes were particularly evident among respondents from low-income households, where individuals relied more heavily on food-related strategies to cope with the consequences of the pandemic, such as the consumption of less expensive foods, skipping meals or reducing portion sizes (e.g. Das et al., 2020; Pakravan-Charvadeh et al., 2021).

6.2 An inverted U-shaped pattern explains the association between individuals' concerns about contracting COVID-19 and the dimensions of food security

Interestingly, the coefficients obtained from the six estimated models reveal a distinctive pattern in the association between individuals' worry about contracting COVID-19 and food security, which can be graphically represented by an inverted U-shaped curve. That is, the magnitude of the estimated coefficients exhibited an upward trend as individuals' worries about contracting the virus increased, reaching the highest point for the "very worried" category of the independent variable, and then sharply decreasing after individuals had been infected with the virus. One possible explanation for this pattern is that individuals' worries about infection have diminished as they have become more familiar with the pandemic, including through personal experiences of contracting the virus. This increased familiarity may lead to a perception of reduced health risks, motivating individuals to engage in activities that improve their earnings or have a positive impact on their food consumption. This suggests that while heightened worries can lead to increased challenges in accessing and affording food, the situation may improve once individuals have experienced the virus. Abu Hatab et al. (2023) found a similar pattern, where the association between individuals' worries about COVID-19 infection and their compliance with mitigation measures in the MENA region, i.e., wearing face mask and maintaining social distance, took a "first-up-then-down" trend, rising as individuals' worries about contracting the virus increased, and then remarkably decreasing after being infected. In this regard, Laborde et al. (2020) and Alzaatreh et al. (2022) point out that the COVID-19 mitigation measures implemented by the surveyed countries' governments have created a dilemma for vulnerable segments of the population, such as migrant laborers, daily wage workers, and street vendors, forcing them to navigate a challenging trade-off between the risks posed by COVID-19 and the threat of hunger.

Therefore, our finding provides valuable insights into the dynamic nature of the relationship between COVID-19 concerns and food insecurity, and it underscores the importance of reorienting public policy discussions surrounding disease

outbreaks in MENA countries, particularly during the early stages. While health concerns rightfully received significant attention, there was a lack of focus on the economic and food security consequences of the implemented mitigation measures. While the implemented mitigation measures may have unintentionally reduced short-term food insecurity outcomes, there is a potential risk of decreased acceptance among individuals and undesired consequences in terms of infection spread and long-term food security deterioration (Chiwona-Karltun et al., 2021). This highlights the importance of policy interventions that consider the broader impacts of disease control measures, considering dimensions beyond biomedical risks to better understand and address the complex dynamics and potential trade-offs associated with these measures, including socio-economic factors, such as income disparities and food security.

6.3 Individuals' sociodemographic characteristics influence the association between COVID-19 worries and food security

The results presented in Table 2, Fig. 2, and Tables S3–S10 in the supplementary material reveal that food security outcomes during the COVID-19 pandemic were significantly influenced by individual attributes and socioeconomic characteristics. Factors such as age, gender, education level, income, marital status, and household size played a crucial role in shaping individuals' experiences of food security. These results align with previous studies conducted in the MENA region, highlighting the diversity of food security challenges across countries and communities due to varying socio-economic, cultural, and environmental contexts (e.g., Mahmah & Amar, 2021; Omidvar et al., 2019). This emphasizes the importance of conducting context-specific investigations that consider the local realities and factors that shape food security to develop targeted and effective policies for addressing and promoting food security in a more tailored and impactful manner in diverse settings.

In analogy with the findings of previous studies (e.g., Chudik et al., 2021), our cross-country analysis revealed significant variations in the relationship between COVID-19 risks and food security across the five examined countries, with the association being particularly pronounced in Tunisia and Egypt compared to the other MENA countries included in the sample. These differences indicate that the impact of COVID-19 on food security is not uniform and can be influenced by country-specific factors such as socio-economic conditions, cultural norms, and policy responses (Shilomboleni, 2020). Previous studies have also attributed these differences to a suite of governance and institutional factors, such as the nature of the political system, the public discourse, the stringency of the measures, their length of implementation, and the degree of social trust in

governments (Chudik et al., 2021; Laborde et al., 2021), and a range of socioeconomic factors, such as the demographic composition of the population, including age and gender, social capital, the degree of ethnic diversity, income level, and political beliefs, and news channel viewership, and other cultural beliefs and social characteristics of the population (Dasgupta & Robinson, 2021). By recognizing and addressing these variations, policymakers and development partners can better allocate resources, collaborate with local stakeholders and design appropriate targeted interventions to address the diverse needs and vulnerabilities of different populations within each country regarding the effects of COVID-19 on food security.

6.4 Two mechanisms for worriedness about COVID-19 infection

The analysis of the relationship between worriedness about COVID-19 infection and its mechanisms revealed that individuals with high levels of worry about contracting COVID-19 were significantly more likely to experience substantial income decreases, reaching or exceeding 25%, compared to those with lower levels of concern. Additionally, we found a strong positive correlation between an individual's worries about COVID-19 infection and their economic situation. These findings align with the findings of Hou et al. (2021), which highlight the connection between income loss and increased anxiety and worries during the COVID-19 pandemic. Studies conducted by Amare et al. (2021) and Hamadani et al. (2020) have consistently demonstrated a strong correlation between reduced income, particularly during lockdowns, and an increase in household food insecurity in LMICs. These findings are further supported by the works of Doraiswamy et al. (2021) and Manfrinato et al. (2021), who reported high levels of worry and anxiety among food-insecure individuals as a result of job loss and economic hardships. The MENA region alone experienced a staggering loss of over 10 million full-time jobs due to the pandemic, resulting in dire consequences for people's livelihoods and contributing to a global increase in food insecurity (Hamadani et al., 2020). These significant declines in living standards, driven by reduced wages and unemployment, have forced individuals to make difficult financial choices, leading to a compromised quality of life and nutrition (Giovanis & Ozdamar, 2021). Unemployment, in particular, has been identified as one of the key drivers of food insecurity in the Mediterranean region, as it significantly diminishes individuals' ability to afford adequate and nutritious food (Hoteit et al., 2021). These findings suggest that to alleviate the economic hardships faced by individuals worried about contracting the virus, it is crucial to prioritize economic support measures such as income protection schemes, targeted financial assistance, and job creation initiatives for affected

households. Additionally, targeted interventions should be implemented to cater for specific needs of different population groups and ensure access to affordable and nutritious food. This can be achieved by strengthening social safety nets, expanding food assistance programs, and supporting local food production and distribution systems. Alongside these economic measures, policymakers should consider implementing mental health programs, counseling services, and community support networks to address the psychological impact of the pandemic and alleviate anxiety and worries among the population.

6.5 Positive and statistically significant association between individuals' worry about contracting the virus and the adoption of specific coping strategies

Finally, the findings underscore the strong association between the level of individuals' worry about contracting the virus and the adoption of specific coping strategies to manage the repercussions of the COVID-19 pandemic. Notably, six primary coping strategies were identified, namely withdrawing funds from savings, obtaining money from family, friends, or acquaintances, obtaining money from overseas sources, returning to the village or family, borrowing from banks, employers, or private lenders, and selling assets. Among these strategies, spending savings and acquiring funds from relatives, friends, or acquaintances stood out as particularly significant. Previous studies on coping strategies with COVID-19 have shown that social support has contributed to decreased individuals' worry and fear of getting infected (Moore & Lucas, 2021). In particular, individuals who were food insecure relied primarily on coping strategies like getting financial support from family, relatives, or friends (Hoogeveen & Lopez-Acevedo, 2021), spending of savings and selling assets (Giovanis & Ozdamar, 2021), or going back to the village or family (Chiwona-Karlton et al., 2021) to compensate for the negative impacts of the pandemic. Given the significant association between obtaining funds from family or acquaintances and coping with COVID-19 concerns, policies should promote and strengthen social support networks through initiatives that facilitate community assistance programs and encourage solidarity among individuals to alleviate individuals' worriedness, and promote their resilience in the face of future challenges.

7 Conclusion

In conclusion, our study contributes to the existing literature on the impact of external shocks, such as the COVID-19 pandemic, on household food security in LMICs. We provide evidence of a significant association between

individuals' concerns about contracting COVID-19 and various dimensions of food security, notably reduced purchasing power and decreased meal frequency. Our findings highlight the necessity of adopting comprehensive approaches to food security analysis, considering the multidimensional and complex nature of an individual's food security status. In addition, our findings illuminate the mechanisms linking COVID-19 worries to income decreases and worsening economic conditions, underscoring the urgency of implementing economic support measures and targeted interventions to mitigate financial strain and ensure households' access to nutritious food during crises. Furthermore, our study reveals a notable correlation between COVID-19 concerns and the adoption of coping strategies, particularly those leveraging social support networks. Ultimately, our findings emphasize the importance of reframing public policy discourse surrounding disease outbreaks to account for their broader socioeconomic ramifications. Implementing targeted interventions to address food security consequences and strengthen social protection systems is crucial for safeguarding vulnerable populations' access to food security amidst crises.

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Declarations

Conflict of interest The authors declared that they have no conflict of interest.

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