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Understanding the impacts of COVID-19 on the determinants of food insecurity: A state-specific examination

Eva Nelson, Candice Bangham, Shagun Modi, Xinyang Liu, Alyson Codner, Jacqueline Milton Hicks, Jacey Greece*

Boston University, School of Public Health, 801 Massachusetts Avenue, Boston, MA, USA

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ABSTRACT

This paper examines risk factors influencing food insecurity during the first year of the COVID-19 pandemic in a state in the U.S. heavily impacted by it and offers recommendations for multi-sector intervention.

The U.S. Census Bureau Household Pulse Survey was analyzed to evaluate the impacts of COVID-19 on food security in Massachusetts from April 2020 through March 2021 using a study sample of 57,678 participants. Food security was defined as a categorical variable (food security, marginal food security, low food security, very low food security) and binary variable (food security and food insecurity). Known or suspected factors that contribute to it, such as childcare, education, employment, housing, and transportation were examined in multivariate logistic regression models. Data imputation methods accounted for missing data.

Sociodemographic characteristics, including lower education level and living in a household with children, were determinants of food insecurity. Another factor that influenced food insecurity was economic hardships, such as unemployment, being laid off due to COVID-19, not working due to concerns about contracting or spreading COVID-19, or not having enough money to buy food. A third factor influencing food insecurity was food environment, such as lack of geographic access to healthy foods. Some of these factors have been exacerbated by the pandemic and will continue to impact food security. These should be addressed through a comprehensive approach with public health efforts considering all levels of the social ecological model and the context created by the pandemic.

1. Introduction

Food insecurity is a multi-faceted issue, influenced by a variety of environmental and personal determinants that requires a comprehensive solution. *(USDA, 2021)* Numerous local and national programs and policies within the U.S. aim to change the availability and accessibility of foods for vulnerable populations. *(Clay et al., 2018)* Even with these efforts, food insecurity increased among certain populations, such as Black and Hispanic people, households with children, and single-parent households over the first year of the COVID-19 pandemic. *(Coleman-Jensen et al., 2020)*

Food security is a combination of a person’s access to sufficient food at all times, knowledge to make appropriate food choices, and availability of resources (i.e., money) to obtain and purchase nutritious foods. *(Savoie-Roskos et al., 2016; USDA Food Insecurity, 2021)* It is complicated to measure because it is usually self-reported, people perceive survey questions differently, and stigma surrounds food insecurity. *(USDA Food Insecurity, 2021)* Food insufficiency occurs when a household sometimes or often does not have enough food to eat. *(USDA Food Insecurity, 2021)* Food insufficiency is tracked for surveillance and intervention efforts and often used as a proxy for food insecurity. While the definition of food security focuses on a household’s ability to acquire food, the definition of food insufficiency encompasses the total availability of adequate food for consumption, regardless of how it is acquired. *(USDA Food Insecurity, 2021)* These concepts overlap considerably so surveillance efforts that categorize people as food secure also categorize them as food sufficient. While food security is a more precise measure, food sufficiency is easier to collect and interpret so it has been used in COVID-19 surveillance.

COVID-19 has exacerbated many of the well-documented...
Table 1
Demographic characteristics for a sample of survey respondents in Massachusetts to the Census Household Pulse Survey, March 2020–March 2021 (n = 57678)1.

| Age Category | Food Security 3 (n = 39134) | Marginal Food Security 3 (n = 12620) | Low Food Security 3 (n = 2086) | Very Low Food Security 3 (n = 467) | Total 3 (n = 54307) | p-value |
|--------------|-----------------------------|--------------------------------------|-------------------------------|-----------------------------------|---------------------|---------|
| 18–29        | 2868 (7.3)                  | 1099 (8.7)                           | 241 (11.6)                    | 54 (11.6)                         | 4623 (7.8)          | <0.0001 |
| 30–39        | 6887 (17.6)                 | 2499 (19.1)                          | 456 (21.9)                    | 109 (23.1)                        | 9861 (18.2)         | <0.0001 |
| 40–49        | 7034 (18.0)                 | 2466 (19.5)                          | 503 (24.1)                    | 117 (25.0)                        | 10,120 (18.6)       | <0.0001 |
| 50–59        | 7672 (19.6)                 | 2619 (20.8)                          | 461 (22.1)                    | 105 (22.5)                        | 10,857 (20.0)       | <0.0001 |
| 60–69        | 8148 (20.8)                 | 2499 (19.8)                          | 330 (15.8)                    | 59 (12.6)                         | 11,036 (20.3)       | <0.0001 |
| 70+          | 6525 (16.7)                 | 1528 (12.1)                          | 95 (4.6)                      | 23 (4.9)                          | 8171 (15.1)         | <0.0001 |

Sex

| | Male | Female |
|---|------|-------|
| Sex | 16340 (41.8) | 22794 (58.3) |
| Male | 650 (36.4) | 760 (36.4) |
| Female | 168 (36.0) | 299 (64.0) |

Ethnicity

| | Non-Hispanic, Latino, or Spanish origin | Hispanic, Latino, or Spanish origin |
|---|----------------------------------------|-----------------------------------|
| Sex | 37073 (94.7) | 20613 (5.3) |
| Male | 11342 (89.9) | 1278 (10.1) |
| Female | 1630 (78.1) | 456 (21.9) |

Race

| | White | Black | Asian | Multiracial |
|---|------|------|------|------------|
| Race | 34745 (88.8) | 13711 (3.5) | 20793 (5.3) | 9397 (2.4) |
| White | 10391 (82.3) | 328 (15.7) | 91 (4.4) | 593 (4.7) |
| Male | 107 (72.4) | 50 (10.7) | 16 (3.4) | 63 (13.5) |
| Female | 46906 (86.4) | 2638 (4.9) | 2933 (5.4) | 1830 (3.3) |

Education

| | Less than high school | Some high school | High school graduate or equivalent |
|---|-----------------------|-----------------|-----------------------------------|
| Education | 97 (0.3) | 277 (0.7) | 2670 (6.8) |
| Male | 97 (0.8) | 198 (1.6) | 1472 (11.7) |
| Female | 53 (2.5) | 102 (4.9) | 445 (21.3) |

Marital Status

| | Married | Widowed | Divorced | Separated | Never married | Unknown |
|---|---------|---------|----------|-----------|---------------|---------|
| Marital Status | 24106 (61.6) | 1724 (4.4) | 4422 (11.3) | 498 (1.3) | 8214 (21.0) | 170 (0.4) |
| Married | 6428 (50.9) | 598 (4.7) | 2043 (16.2) | 332 (2.6) | 3137 (24.9) | 82 (0.65) |
| Widowed | 667 (32.0) | 85 (4.1) | 453 (21.7) | 118 (5.7) | 752 (36.1) | 11 (0.53) |
| Divorced | 107 (22.9) | 27 (5.8) | 96 (20.6) | 35 (7.5) | 200 (42.8) | 2 (0.43) |
| Separated | 131 (28.1) | 19 (3.9) | 22 (4.9) | 37 (7.9) | 19,310 (35.6) |

Household Size

| | 1 person | 2 people | 3 people | 4 people | 5 people | 6 + people |
|---|----------|----------|----------|----------|----------|-----------|
| Household Size | 6321 (16.2) | 15180 (38.9) | 6809 (17.4) | 6926 (17.7) | 2669 (6.8) | 1229 (3.1) |
| 1 person | 2179 (17.3) | 4113 (32.6) | 2450 (19.4) | 2192 (17.4) | 1055 (8.4) | 631 (5.0) |
| 2 people | 381 (18.3) | 552 (26.5) | 421 (20.2) | 341 (16.4) | 202 (9.7) | 189 (9.1) |
| 3 people | 112 (24.0) | 92 (19.7) | 91 (19.5) | 75 (16.1) | 46 (9.9) | 51 (10.9) |
| 4 people | 255 (54.6) | 88 (18.8) | 71 (15.2) | 75 (16.1) | 3972 (7.3) |
| 5 people | 36,209 (66.7) | 8062 (14.8) | 7243 (13.3) | 2159 (3.9) |

Number of Children in Household

| | 0 | 1 | 2 | 3 | 4 | 5 |
|---|---|---|---|---|---|---|
| Number of Children in Household | 26761 (58.4) | 25462 (14.0) | 5166 (13.2) | 1392 (3.6) | 271 (0.7) | 82 (0.2) |
| 0 | 8061 (63.9) | 2078 (16.5) | 1684 (13.3) | 607 (4.8) | 133 (1.1) | 57 (0.5) |
| 1 | 1122 (54.3) | 434 (20.8) | 322 (15.4) | 137 (6.6) | 40 (1.9) | 21 (1.0) |
| 2 | 255 (54.6) | 88 (18.8) | 71 (15.2) | 23 (4.9) | 15 (3.2) | 15 (3.2) |
| 3 | 36,209 (66.7) | 8062 (14.8) | 7243 (13.3) | 2159 (3.9) |

Phase of Survey Administration

| | Phase 1 (April 23, 2020 – July 21, 2020) | Phase 2 (August 19, 2020 – October 26, 2020) | Phase 3 (October 28, 2020 – March 29, 2021) |
|---|---------------------------------------|----------------------------------------|----------------------------------------|
| Phase of Survey Administration | 18,966 (48.5) | 9244 (23.6) | 10,924 (27.9) |
| 0 | 6805 (53.9) | 2840 (22.5) | 2975 (23.6) |
| 1 | 924 (44.3) | 525 (25.2) | 637 (30.5) |
| 2 | 172 (36.8) | 134 (28.7) | 161 (34.5) |
| 3 | 26,867 (49.5) | 12,743 (23.5) | 14,697 (27.1) |

Analyses were conducted using frequencies and Wald’s chi-square statistical test, significance = 0.05.
1. Descriptive analyses were conducted before data imputation. Missing values (n = 3371) are due to missed questions in the outcome variable (i.e., food security status).
2. Definitions include: food security (enough of the kinds of food I/we wanted to eat); marginal food security (enough, but not always the kinds of food I/we wanted to eat); low food security (sometimes not enough to eat); very low food security (often not enough to eat).
3. Age categories derived from the U.S. Census Bureau, 2019.
The outcome of interest was food insecurity, which was measured through food insufficiency. Food insecurity is typically measured through ten questions describing food eaten in the household in the past 12 months, while food insufficiency is measured in a single question that asks respondents to describe the food eaten in their household in the past seven days and is commonly used as a proxy for food insecurity. In consultation with the USDA’s Economic Research Service, the questions on food sufficiency were constructed to align with questions on other surveys to address food insecurity during the pandemic. (Fields et al., 2020) Food insecurity was defined by the question that asked participants if they often did not have enough to eat, sometimes did not enough to eat, had enough but not always the kinds of foods they wanted to eat, or had enough of the kinds of food they wanted to eat within the last seven days. (USDA Food Insecurity, 2021; Bureau UC Household Pulse Survey Data Tables, 2021) The study explored this as a categorical variable [food security (enough of the kinds of food the household wanted to eat), marginal food security (enough food to eat, but not always the kinds of food the household wanted to eat), low food security (sometimes not enough to eat), and very low food security (often not enough to eat)] (USDA Food Insecurity, 2021; Census Bureau, 2021) and a binary variable [food secure (having “enough of the kinds of food I/we wanted to eat” and “enough, but not always the kinds of foods I/we wanted to eat”) or food insecure (“sometimes not enough to eat” and “often not enough to eat”).] (USDA Food Insecurity, 2021; Census Bureau, 2021).
Table 2: Economic and food-related characteristics by food security status for a sample of survey respondents in Massachusetts to the Census Household Pulse Survey, March 2020 – March 2021 (n = 57678)

| Food Security | Marginal Food Security | Low Food Security | Very Low Food Security | p-value |
|---------------|------------------------|-------------------|------------------------|---------|
| EMPLOYMENT STATUS |                        |                   |                        |         |
| Loss of employment | <0.0001               |                   |                        |         |
| Yes | 13,102 (33.5) | 6649 (52.7) | 1498 (71.8) | 354 (75.8) |
| No | 25,985 (66.4) | 5948 (47.1) | 587 (28.1) | 111 (23.8) |
| Unknown | 47 (0.1) | 23 (0.2) | 1 (0.1) | 2 (0.4) |
| Expecting loss of employment | <0.0001               |                   |                        |         |
| Yes | 6893 (17.6) | 4733 (37.5) | 1191 (57.1) | 290 (62.1) |
| No | 32,161 (82.2) | 7840 (62.1) | 890 (42.7) | 172 (36.8) |
| Unknown | 80 (0.2) | 47 (0.4) | 5 (0.2) | 5 (1.1) |
| Any work for pay/profit | <0.0001               |                   |                        |         |
| Yes | 25,721 (65.7) | 7154 (56.7) | 906 (43.4) | 149 (31.9) |
| No | 13,377 (34.2) | 5446 (43.2) | 1173 (56.2) | 315 (67.5) |
| Unknown | 36 (0.1) | 20 (0.2) | 7 (0.3) | 3 (0.6) |
| Employment Type | <0.0001               |                   |                        |         |
| Government | 3238 (12.6) | 1041 (14.6) | 115 (12.7) | 22 (14.8) |
| Private company | 14,437 (56.1) | 3959 (55.3) | 529 (58.4) | 90 (60.4) |
| Non-profit organization | 4852 (18.9) | 1262 (17.6) | 145 (16.0) | 14 (9.4) |
| Self-employed | 2578 (10.0) | 671 (9.4) | 70 (7.7) | 16 (10.7) |
| Family business | 363 (1.4) | 115 (1.6) | 24 (2.7) | 4 (2.7) |
| Unknown | 253 (1.0) | 106 (1.5) | 23 (2.5) | 3 (2.0) |
| Main source for not working for pay/profit | <0.0001               |                   |                        |         |
| Did not want to be employed | 597 (4.5) | 102 (1.9) | 9 (0.8) | 5 (1.6) |
| Sick with coronavirus symptoms | 99 (0.7) | 108 (1.8) | 40 (3.4) | 12 (3.8) |
| Caring for someone with coronavirus symptoms | 23 (0.2) | 23 (0.4) | 9 (0.8) | 5 (1.6) |
| Caring for children not in school/daycare | 588 (4.4) | 401 (7.4) | 125 (10.7) | 34 (10.8) |
| Caring for an elderly person | 125 (0.9) | 91 (1.7) | 17 (1.5) | 9 (2.9) |
| Concerned about getting/spreading coronavirus | 394 (3.0) | 392 (7.2) | 139 (11.9) | 41 (13.0) |
| Retired | 6925 (51.8) | 1594 (29.3) | 107 (9.1) | 19 (6.0) |
| Employer experienced reduction of business or furlough due to pandemic | 926 (6.9) | 542 (10.0) | 115 (9.8) | 26 (8.3) |
| Laid off due to pandemic | 723 (5.4) | 514 (9.4) | 148 (12.6) | 34 (10.8) |
| Employer closed temporarily during pandemic | 749 (5.6) | 521 (9.6) | 124 (10.6) | 30 (9.5) |
| Employer went out of business during pandemic | 82 (0.6) | 81 (1.5) | 33 (2.8) | 18 (5.7) |
| Other reason | 1680 (12.6) | 819 (15.0) | 244 (20.8) | 67 (21.3) |
| I was concerned about getting or spreading the coronavirus | 356 (2.7) | 224 (4.1) | 59 (5.0) | 12 (3.8) |
| Unknown | 110 (0.8) | 34 (0.6) | 4 (0.3) | 3 (1.0) |
| Telework | <0.0001               |                   |                        |         |
| At least one adult substituted typical work with telework | 11,973 (59.4) | 2656 (45.7) | 282 (24.3) | 40 (13.6) |
| No adults substituted typical work with telework | 5192 (25.7) | 2125 (36.5) | 588 (50.6) | 163 (55.3) |
| No change in telework | 2421 (12.0) | 815 (14.0) | 231 (19.9) | 80 (27.1) |
| Unknown | 582 (2.9) | 219 (3.8) | 61 (5.3) | 12 (4.1) |
| FOOD ENVIRONMENT AND ACCESS |                        |                   |                        |         |
| Receiving benefits from SNAP | <0.0001               |                   |                        |         |
| Yes | 762 (3.8) | 767 (13.3) | 400 (35.0) | 121 (41.7) |
| No | 19,208 (95.5) | 4958 (86.1) | 733 (64.1) | 167 (57.6) |
| Unknown | 147 (0.7) | 34 (0.6) | 11 (1.0) | 2 (0.7) |
| Fewer trips to the grocery store due to pandemic in the last 7 days | <0.0001               |                   |                        |         |
| Yes | 13,981 (69.3) | 4947 (85.1) | 963 (82.9) | 225 (76.3) |
| No | 6088 (30.2) | 847 (14.6) | 182 (15.7) | 67 (22.7) |
| Unknown | 99 (0.5) | 21 (0.4) | 17 (1.5) | 3 (1.0) |
| People in household receive free groceries or a free meal in the last 7 days | <0.0001               |                   |                        |         |
| Yes | 1500 (3.8) | 1115 (8.9) | 341 (16.5) | 83 (18.0) |
| No | 37,497 (95.9) | 11,360 (90.7) | 1715 (82.9) | 372 (80.7) |
| Unknown | 85 (0.2) | 56 (0.5) | 12 (0.6) | 6 (1.3) |
| Locations where people in household received free groceries or a free meal in the last 7 days | <0.0001               |                   |                        |         |
| Free meals through the school or other programs for children | 715 (47.7) | 498 (45.0) | 149 (44.4) | 25 (30.9) |
| Food pantry or food bank | 259 (17.3) | 343 (31.0) | 121 (36.0) | 41 (50.6) |
| Home delivered meal service (ex. Meals on Wheels) | 84 (5.6) | 68 (6.1) | 26 (7.7) | 8 (9.9) |

(continued on next page)
Demographic characteristics examined included sex, race/ethnicity, age (calculated based on date of birth and survey completion), education level, marital status, household size, and number of children in the household. Employment status was characterized as “work for pay” (i.e., employed), “loss of employment,” and “expecting loss of employment,” with unemployment defined by combining the latter two categories. For those who “work for pay,” the survey asked for type of employment and telework status; for those not working, the survey asked for reasons for not working in the last 7 days. Other determinants explored included receiving SNAP benefits, taking fewer trips to the grocery store in the last 7 days, and receiving free meals or groceries in the last 7 days, while participants were asked questions on access and affordability of food over the next four weeks including being able to afford enough food for children and where those free meals/groceries were accessed (i.e., school programs, food pantries/food banks, religious institutions, soup kitchens, home delivered meals, friends and family).

2.5. Statistical Analyses

Weekly and bi-weekly phase data was combined into a single dataset. Per protocols used by the U.S. Census Bureau and relayed to the study team in direct correspondence, and after descriptive statistics were conducted, data imputation was conducted on all missing outcome and exposure variables of interest using Markov Chain Monte Carlo (MCMC) algorithm with chained equations where the data was imputed across 20 datasets. Analyses were performed across all 20 imputed datasets and the results were combined to provide inferential statistics. (Allison, 2012; Allison, 2005; Enders, 2010).

Descriptive analyses were conducted on demographic characteristics and determinants and significance was examined across food security status using Wald’s chi-square test with an alpha level of 0.05. Multi-variable logistic regression models were used to assess variables associated with the dichotomous food security outcome. Multinomial logistic regression models were used to control for known and suspected covariates in adjusted analyses for the categorical food security outcome. Variable selection in the multivariable models was a combination of 1) variables shown to be associated with the outcome (p-value threshold of 0.05), and 2) potential confounding variables based on prior knowledge of the outcome variable. Certain variables were removed from the multivariable analysis due to collinearity with other variables in the model (assessed using a VIP threshold of 10) and potential reverse causality problems, determined by knowledge of the outcome variable, which would make it difficult to interpret the measure of effect. Statistical analyses were conducted using SAS Version 9.4 (SAS Institute Inc.).

3. Results

3.1. Descriptive Findings

A variety of variables were assessed across food security status including for demographic characteristics (Table 1) and economic and food-related characteristics (Table 2). The majority of Massachusetts survey participants were younger than 60 years old (64.6%); female (59.2%); not of Hispanic, Latino, or Spanish origin (92.8%); White (86.4%); and, had no children in their household (66.7%) (Table 1). Younger people experienced food insecurity at higher proportions, with nearly one-quarter of 18–24 year olds experiencing very low food

Table 2 (continued)

| Food Security² (n = 39134) | Marginal Food Security² (n = 12620) | Low Food Security² (n = 2086) | Very Low Food Security² (n = 467) | p-value |
|---------------------------|-----------------------------------|-------------------------------|---------------------------------|---------|
| n (%)                     | n (%)                             | n (%)                         | n (%)                           |         |
| Church, synagogue, temple, mosque, or other religious organization | 92 (6.1) | 106 (9.6) | 46 (13.7) | 15 (18.5) | <0.0001 |
| Shelter or soup kitchen   | 6 (0.4) | 14 (1.3) | 14 (4.2) | 8 (9.9) | <0.0001 |
| Other community program   | 307 (20.5) | 232 (21.0) | 68 (20.2) | 19 (23.5) | 0.9186 |
| Family, friends, neighbors | 296 (19.8) | 267 (24.1) | 110 (32.7) | 28 (34.6) | <0.0001 |
| The children were not eating enough because we just couldn’t afford enough food in the last 7 days³⁸,¹¹ | Often true | N/A | 38 (1.1) | 74 (10.0) | 64 (38.3) | <0.0001 |
| Sometimes true            | N/A | 437 (13.2) | 383 (51.6) | 55 (32.9) |         |
| Never true                | N/A | 2804 (84.4) | 275 (37.1) | 46 (27.5) |         |
| Unknown                   | N/A | 45 (1.4) | 10 (1.4) | 2 (1.2) |         |
| Why didn’t you not have enough to eat³⁸,¹² | Couldn’t get out to buy food | N/A | 3297 (26.3) | 1620 (78.3) | 384 (83.3) | <0.0001 |
|                          | N/A | 1604 (12.8) | 375 (18.1) | 105 (22.8) |         |
|                          | N/A | 4327 (34.5) | 501 (24.2) | 112 (24.3) | <0.0001 |
|                          | N/A | 1003 (8.0) | 210 (10.2) | 69 (15.0) | <0.0001 |
|                          | N/A | 6518 (52.0) | 399 (19.3) | 84 (18.2) | <0.0001 |

Analyses were conducted using frequencies and Wald’s chi-square statistical test, significance = 0.05.
1. Descriptive analyses were conducted before data imputation. Missing values are due to missed questions in the outcome variable (i.e., food security status).
2. Definitions include: food security (enough of the kinds of food I/we wanted to eat); marginal food security (enough, but not always the kinds of food I/we wanted to eat); low food security (sometimes not enough to eat); very low food security (often not enough to eat).
3. These variables were combined in subsequent analyses to indicate “not working”.
4. Unknown responses indicate the survey respondent left the response for that question blank on the survey.
5. Respondents who answered “yes” to working for pay received the question asking for the type of work. Respondents who answered “no” to working for pay received the question asking for the main source for not working.
6. This question was only asked for people who responded that they did work for pay in the previous question.
7. This question was only asked for people who responded that they did not work for pay in the previous question.
8. This question was “select all that apply” and proportions may equal greater than 100% indicating multiple responses were selected.
9. This question was not asked in Phase 1 of the survey.
10. This question was asked only of people who reported receiving a free meal or food within the last 7 days.
11. This question was asked only of people who indicated that the children in the household could not afford enough to eat.
12. This question was not asked of people who indicated food insecurity in the last 7 days and based on the definition of “food secure” would not have values for this question.
Table 3
Crude and adjusted associations of determinants of food insecurity (binary and categorical) for a sample of survey respondents in Massachusetts to the Census Household Pulse Survey, March 2020 – March 2021 (n = 57,678)^1

| Age Categories | Binary Food Insecurity Adjusted Odds Ratio^2 (95% CI) p-value | Categorical Food Insecurity Low Food Security^2 Adjusted Odds Ratio^3 (95% CI) p-value | Very Low Food Security^2 Adjusted Odds Ratio^3 (95% CI) p-value |
|---------------|----------------------------------------------------------|---------------------------------------------------------------------------------|---------------------------------------------------------------|
| 18–29 (ref)   | 1.0                                                       | [reference]                                                                    | [reference]                                                    |
| 30–39         | 1.25 (1.05, 1.48)                                         | [reference]                                                                    | [reference]                                                    |
| 40–49         | 1.65 (1.35, 2.00)                                         | [reference]                                                                    | [reference]                                                    |
| 50–59         | 2.00 (1.61, 2.46)                                         | [reference]                                                                    | [reference]                                                    |
| 60–69         | 2.55 (2.16, 3.00)                                         | [reference]                                                                    | [reference]                                                    |
| Sex           |                                                          |                                                                                |                                                               |
| Male (ref)    | 1.0                                                       | [reference]                                                                    | [reference]                                                    |
| Female        | 1.10 (0.96, 1.25)                                         | [reference]                                                                    | [reference]                                                    |
| Ethnicity^4   |                                                          |                                                                                |                                                               |
| Non, not of Hispanic, Latino, or Spanish origin (ref) | 1.0                                                       | [reference]                                                                    | [reference]                                                    |
| Yes, of Hispanic, Latino, or Spanish origin       | 1.33 (1.13, 1.58)                                         | [reference]                                                                    | [reference]                                                    |
| Race^5        |                                                          |                                                                                |                                                               |
| White, alone  | 1.0                                                       | [reference]                                                                    | [reference]                                                    |
| Black, alone  | 1.13 (0.96, 1.32)                                         | [reference]                                                                    | [reference]                                                    |
| Asian, alone  | 1.34 (1.09, 1.64)                                         | [reference]                                                                    | [reference]                                                    |
| Education Level^6 |                                                        |                                                                                |                                                               |
| Less than or some high school                      | 1.0                                                       | [reference]                                                                    | [reference]                                                    |
| High school   | 1.14 (0.98, 1.33)                                         | [reference]                                                                    | [reference]                                                    |
| Associate's degree | 1.0                                                   | [reference]                                                                    | [reference]                                                    |
| Bachelor's degree | 1.0                                                    | [reference]                                                                    | [reference]                                                    |
| Graduate degree (ref)                           | 1.0                                                       | [reference]                                                                    | [reference]                                                    |

Table 3 (continued)

| Marital Status^6 | Binary Food Insecurity Adjusted Odds Ratio^2 (95% CI) p-value | Categorical Food Insecurity Low Food Security^2 Adjusted Odds Ratio^3 (95% CI) p-value | Very Low Food Security^2 Adjusted Odds Ratio^3 (95% CI) p-value |
|------------------|----------------------------------------------------------|---------------------------------------------------------------------------------|---------------------------------------------------------------|
| Now married (ref) | 1.0                                                       | [reference]                                                                    | [reference]                                                    |
| Widowed          | 1.0                                                       | [reference]                                                                    | [reference]                                                    |
| Divorced         | 1.0                                                       | [reference]                                                                    | [reference]                                                    |
| Separated        | 1.0                                                       | [reference]                                                                    | [reference]                                                    |
| Never married    | 1.0                                                       | [reference]                                                                    | [reference]                                                    |

Household Size

1. Analyses were conducted after data imputation to account for missing values.
2. Analyses were conducted using binomial and multinomial logistic regression, significance = 0.05.
3. Adjusted analyses were controlled for the other variables in the table.
4. Categories were determined by the categories listed on the Census Pulse Household Survey.

Analyses were conducted using binomial and multinomial logistic regression, significance = 0.05. Adjusted analyses were controlled for the other variables in the table. Categories were determined by the categories listed on the Census Pulse Household Survey.

security. The highest proportion of food secure people had a graduate degree (40.4%) and the highest proportion of very low food secure people had some college (28.1%). Most food secure and marginal food secure people were married (61.6% and 50.9%, respectively) while the majority of low food secure and very low food secure people were never married (36.1% and 42.8%, respectively). The majority of food secure people lived in a two-person household (38.9%) while the majority of very low food secure people lived in a one-person household (24%). The proportion who reported being food secure decreased across the three phases of survey administration.

The proportion of participants who experienced loss of employment or who were expecting loss of employment increased across food security levels with 75.8% of very low food secure people experiencing loss of employment compared to 33.5% of food secure people and 62.1% and
17.6% expecting loss of employment, respectively (Table 2). The proportion that experienced loss of employment increased as food security decreased. Of those who were employed, across all food security categories the majority worked in a private company followed by government or non-profit organization. The main reasons people who experienced low or very low food security did not work for pay or profit, aside from other unspecified reasons, were caring for children (10.7% and 10.8%, respectively), concern about spreading or contracting COVID-19 (12.6% and 10.8%, respectively), or their employer temporarily closed due to the pandemic (10.6% and 9.5%, respectively). These relationships were consistent across phases (data not shown).

The proportion of people receiving SNAP benefits in low and very low food secure people was low with 35.0% and 41.7%, respectively receiving these benefits. Across all food security categories, the majority of participants reported fewer trips to the grocery store due to the pandemic and the majority across food security categories also reported not receiving a free meal or food in the last 7 days. Even still, almost one-fifth of low (16.5%) and very low food secure (18.0%) people reported receiving a free meal or food from a variety of sources. The majority of low and very low food secure people reported that it was sometimes or often true that their children were not eating enough because they could not afford food (61.6% and 71.2%, respectively) with the most common reasons being that they could not afford or were afraid to go out to buy more food.

### 3.2. Adjusted Models

In adjusted models, those aged 40–49 had 1.54 (1.31, 1.82) times the odds of food insecurity compared to those aged 18–29; those who were Hispanic had 1.62 (1.44, 1.82) times the odds of food insecurity compared to non-Hispanic people; and, being Black or a combination of races put people at higher odds of food insecurity compared to White people (2.26 and 2.38, respectively). Additionally, participants who had education less than or some high school had 7.96 (6.37, 9.94) times the odds of food insecurity compared to those who had a graduate degree after adjusting for other predictors. Being widowed, divorced, separated or never married, or divorced resulted in increased odds of food insecurity than those who were married. Living in a household with 5 or 6 or more individuals was associated with increased odds of food insecurity (OR = 1.20 and 1.86, respectively). Those who were not working for pay or profit had 2.53 times the odds of food insecurity compared to those working for pay or profit after adjusting for all other predictors (p-value < 0.0001) (Table 3).

Categorical food security increased with certain determinants. Those who were of Hispanic, Latino, or Spanish race consistently had increased odds of having marginal food security (OR = 2.01, p-value < 0.0001), low food security (OR = 1.83, p-value < 0.0001) or very low food security (OR = 1.36, p-value < 0.0001) after adjusting for other predictors (p-value < 0.0001). While the odds of food insecurity did not increase consistently across levels, being Black or a combination of races put people at significantly higher odds of food insecurity (OR = 2.26, p-value < 0.0001 and OR = 2.38, p-value < 0.0001) and across all categories compared to Whites after adjusting for all other predictors. In addition, lower education levels resulted in greater odds of low food security than higher education levels (Table 3).

Those who were not working for pay/profit had significantly increased odds of having marginal food security (OR = 4.59, p-value < 0.0001), having low food security (OR = 2.75, p-value < 0.0001) and having very low food security (OR = 1.58, p-value < 0.0001) after adjusting for all other predictors (OR = 4.59, 2.75, and 1.58, respectively) (Table 3).

### 4. Discussion

Understanding the determinants of food insecurity is essential for creating better policies and programs, especially as the pandemic progresses and its long-term impacts are realized. Determinants affecting food insecurity during COVID-19 may have an effect on levels of the social ecological model (SEM) and can be organized by broader factors including food environment and access, economic hardship, and sociodemographic characteristics. (Kilanowski, 2017) This study aims to 1) understand some of the most immediate determinants within these factors, and 2) highlight best practices for intervention at all levels of the SEM and within the context of COVID-19 (Fig. 1), guided by these findings and evidence in the field. The importance of this is paramount given 4.4% of people in Massachusetts were food insecure in this study with recent projections indicating even larger proportions of food insecure people in Massachusetts (9.9%). (Little and Rubin, 2002).

During the pandemic, there have been barriers to accessing food and challenges with applying for and receiving SNAP benefits. (Feeding America, 2021) Consistent with the literature, this study found that during the first year of the pandemic, there was a proportion of those who had low or very low food security who were receiving SNAP benefits remained low (35% and 41.7%, respectively). While services exist, there is a need to promote existing services, such as SNAP, at the local and national level through more targeted and tailored communication about SNAP benefits to those eligible to increase utilization (Fig. 2).

To further promote food access and alleviate transportation barriers, community organizations can deliver meals directly to or near people’s homes (ex. mobile markets and home food delivery programs). (Food Trust, 2019) The successful government-funded program, Pandemic Electronic Benefit Transfer (P-EBT), allows states to provide funds directly to households with children who lost access to school lunch programs during COVID-19 to reduce food insecurity and improve nutritional uptake in children. (Mui et al., 2022) While invaluable, many food banks do not provide culturally-relevant food options for clients. Effective community-based strategies to improve resources and support for food pantry clients include increasing the diversity of available foods and providing education about storage and preparation (Fig. 2). (Hetrick et al., 2020) Future studies should explore transportation barriers and the impact on accessing food, particularly as access to and comfort with public transportation may change with the pandemic (Aiyer et al., 2019).
In our study, people experiencing economic hardship during COVID-19, such as loss of employment, were more likely to experience very low food security. This finding is consistent with other literature, which shows that prior to the pandemic, financial instability was associated with food insecurity and that during the pandemic, food insecurity increased due to higher rates of unemployment. (Hernandez, 2015; Wolfson and Leung, 2020) This study also found that not having enough money and being afraid to go out to buy food are often reported as the primary reasons people experience food insecurity (Table 2) (Aiyer et al., 2019). Other factors related to economic hardship include housing instability, transportation barriers, job loss, and unemployment (Decker and Flynn, 2018; Reimold et al., 2021). While not exhaustive, some example strategies to address economic hardship include job coaching for those who are unemployed, increasing food access at public housing sites, addressing food insecurity and housing instability together, and expanding SNAP benefits (Fig. 2) (Reimold et al., 2021; Lee et al., 2021; Quintiliani et al., 2021; Mass Legal Services, 2021).

Households with children, youth, elderly people, people with disabilities, and people of color are more likely to experience food insecurity than those who do not belong to those groups (Hernandez, 2015; Wolfson and Leung, 2020; Fan et al., 2021; Mass Legal Services, 2021). In this study, living in a household with five or more people, being Black, having a lower education level, or being unmarried were sociodemographic determinants impacting food insecurity (Table 3). Many people who are in these demographic groups experienced worse impacts from COVID-19. (Wolfson and Leung, 2020) Some strategies to address these determinants include food pantries providing culturally appropriate food and services and addressing the

| Factor                        | Determinants Exacerbated by COVID-19                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     | Study Findings                                                                                                                                                      | Strategies to Address Factors Organized by the Social Ecological Model (Kilianowski, 2017) |
|-------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------|
| Food Environment and Food Access | - Many people who are eligible for SNAP do not apply due to: (Feeding Trust, 2018) • Difficulty of the application process • Being unaware they are eligible for SNAP benefits • Lack of knowledge about the SNAP expansion during COVID-19 (Fang et al., 2021) - Barriers to obtaining food during COVID-19 include: (Reimold et al., 2021) • Worry about being exposed to COVID-19 • Worry about exposing others to COVID-19 • Not enough food at the store • Difficulty traveling to the store - People experiencing food insecurity often do not have options regarding quality, type, and diversity of food they are able to access (Aiyer et al., 2019) | - The proportion of low and very low food secure people who received SNAP benefits remained low (35% and 41.7%, respectively). - Across all food security levels, the overwhelming majority of respondents reported fewer trips to the grocery store due to the pandemic - Almost one-fifth of low (16.5%) and very low food secure (18%) people reported receiving a free meal or food with the sources ranging from food pantry (36% and 50.6%, respectively), school (44.4% and 30.9%, respectively), family, friends, and neighbors (32.7% and 34.6%, respectively), other community programs (20.2% and 23.5%, respectively), and religious organizations (13.7% and 18.5%, respectively) | Individual: - People experiencing food insecurity understand that precautions against COVID-19, such as mask wearing and social distancing, are effective measures in preventing the spread of COVID-19 so they feel more comfortable accessing food from public places Interpersonal: - Food bank workers have positive interactions with clients (American Academy of Pediatrics, 2021) Community: - Community organizations and food banks provide resources for people who are food insecure to assist SNAP-eligible people in the community (Feeding Trust, 2018) - Mobile food trucks travel to low income areas to provide fresh foods for people in communities who have limited access to transportation to obtain food (Mui et al., 2021) - Community organizations implement and expand programs that alleviate transportation barriers in rural communities, such as free or reduced price weekly mailed meal boxes to eligible children (Hetrich et al., 2020) - Community food banks provide education for clients about how to store and cook foods (Aiyer et al., 2019) Institutional: - Grocery stores make their policies regarding mask wearing and social distancing more clear to increase trust among customers - Government, community organizations, and food banks tailor appropriate communication about SNAP to |
needs of youth experiencing housing and food insecurity (Mass Legal Services, 2021). This study found that caring for children was one of the major reasons why people experiencing very low food security were unable to work during COVID-19 (10.8%), compared to those who were food secure (4.4%) (Table 2). When physicians screen their patients for food insecurity, they should also inquire about childcare needs and connect parents to services that can help address the barriers to affordable childcare. (Ziliak, 2021) Schools should also maintain free breakfast and lunch programs that may have been interrupted due to COVID-19 to ensure that children who receive food from school do not lose those meals (Fig. 2) (Aiyer et al., 2019; Mass Legal Services, 2021; Ziliak, 2021). For elderly people who may experience mobility issues that impact their ability to go to grocery stores or carry groceries back to their homes, home delivery meal programs are an effective intervention (Fig. 2) (Food Trust, 2019).

Determinants can be addressed through intervention including individualized programs, community-based efforts, and national policies. Some of these services are already in place, but a more thorough understanding of the context resulting from the pandemic will allow interventions to promote maximum utilization, to be tailored to meet the needs of the most vulnerable populations, and to successfully expand to other areas that can benefit from these approaches. Evidence-
informed strategies focused on one or more levels of the SEM (Fig. 2) to address the myriad of factors of food insecurity will achieve the most advantageous outcomes.

This study illustrates that there is still an ongoing and urgent need to address food insecurity in normal and emergency situations, such as COVID-19. Understanding the factors affecting this issue – whether through new studies or examination of ongoing surveys and surveillance – is essential to finding solutions through comprehensive and sustainable approaches. While this paper highlights some examples of those strategies, there are many others that should be explored with the understanding of the new context resulting from the pandemic. As public health responds to food insecurity during and in the aftermath of the pandemic, it is critical to create interventions that target populations most at risk and that address multiple levels of the SEM due to the interconnected individual and environmental determinants of food insecurity.

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| Sociodemographic Characteristics | - Households with children are at increased risk of experiencing food insecurity and this has been exacerbated due to school closures and loss of school lunch programs (Hetrick et al., 2020; Fan et al., 2020)  
- Elderly individuals, who have higher rates of morbidity and mortality due to COVID-19, are also at an increased risk of experiencing food insecurity. (Ziliak, 2020) This is due to:  
  - Not going to grocery stores to obtain food in fear of contracting or spreading COVID-19 (Mui et al., 2021)  
  - Stigma related to use of benefits, such as SNAP (Pak and Kim, 2020)  
- People of color have higher rates of food insecurity and have had worse health outcomes due to COVID-19 (Wolfson, 2020)  
- The majority of low and very low food secure people reported that it was sometimes or often true that their children were not eating enough because they could not afford food (61.5% and 71.3%, respectively)  
- Those who were Hispanic had 1.62 (95% CI=1.44, 1.82 p<0.001) times the odds of food insecurity compared to non-Hispanic people; and, being Black or a combination of race put people at higher odds of food insecurity compared to White people.  
- Lower education levels resulted in higher odds of food insecurity than higher levels of education  
- Being separated (OR=3.71, 95% CI= 2.49, 5.84 p<0.001) times the odds of low food security, and 1.58 (95% CI=1.51, 1.66 p<0.001) times the odds of very low food security than people who did work  
- For those who were employed, 65.7% were food secure, while 31.9% had very low food security and the proportion that were unemployed increased as food security decreased | - Food banks provide food for those who are financially unstable, especially in locations that have public housing (Quintiliani, 2021)  
*Policy/Society:*  
- Federal government expands SNAP benefits during COVID-19 to reach more people (Mass Legal Services, 2021)  
- Government and community organizations combine resources and funding that address food insecurity with support for housing insecurity (Lee et al., 2021)  
*Individual:*  
- People practice social distancing and mask wearing while at work and at home  
*Interpersonal:*  
- Assisted living facilities provide social support for the elderly to provide help for them if they are experiencing food insecurity (Pak and Kim, 2020)  
*Community:*  
- Ensure that food pantries accommodate all culture preferences within a community, such as tailoring available food items to the diets of common cultures in the community (Ayer et al., 2019)  
- Assisted living facilities make food available (ex. mobile markets) at public housing sites, especially for the elderly (Mui et al., 2021; Caouette et al., 2020)  
- Tailor supportive housing interventions to address the needs of youth experiencing housing insecurity and include interventions that address food insecurity (Brothers et al., 2020)  
*Institutional:*  
- Public stores ensure that essential workers are protected from COVID-19 by enforcing mask wearing, social distancing, and vaccines among workers

**Fig. 2. (continued).**
3.02, 4.56
p<0.0001), never married (OR=2.40, 95% CI=2.13, 2.71
p<0.0001), or divorced (OR=2.85
95% CI=2.51, 3.23
p<0.0001) resulted in higher odds of food insecurity than those who were married

- Living in a household with four or less people had a protective effect with less odds of being food insecure compared to a 1. person household; however, the odds of food insecurity increased with households with five or more people

and customers (Bir and Widmar, 2021)

- Schools maintain free breakfast and lunch programs that emerged during COVID-19 (Hetrick et al., 2020)

**Policy/Society:**

- Government continues to use Community Eligibility as a tool to allow schools that serve children in lower SES communities to offer free breakfast and lunch to students (Hunger Poverty in America – Food Research Action Center, 2020)

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### Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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