

# Examining the Facets of Burden from Agricultural Injury: Policy Implications

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## Abstract

Agriculture is one of the most dangerous industries in the United States. Loss of life, injury, and illness estimates in the agriculture industry only measure a fraction of the total burden to society. The purpose of this review was to conduct a comprehensive scan of the peer-reviewed literature to catalog research that explores the burden of agricultural injury to synthesize what is currently known. In total, 116 full-text papers meeting eligibility criteria were reviewed. Publications documenting agricultural injury burden were scanned and observations were categorized using a priori themes previously identified by occupational safety and health researchers. Results from this review indicate the true burden of agricultural injury is more expansive and complex than previous narratives on injury burden would imply. Future research should consider policies that encourage the collection of more expansive injury burden data, as well as methods to incorporate them into standard injury surveillance efforts.

## Keywords

agriculture, occupation, injury, burden, surveillance

## Background

The vocation of farming is one of the world's oldest and most hazardous occupations. Today, agriculture remains one of the most dangerous industries in the United States.<sup>1</sup> Miscellaneous agricultural workers—which includes agricultural equipment operators as well as farmworkers and laborers working on crop, livestock, nursery, greenhouse, ranch, and aquaculture operations—had a fatal occupational injury rate of 20.0/100,000 full-time equivalents (FTE) in 2022.<sup>2</sup> This rate is over five times higher than the all-worker fatality rate of 3.7/100,000 FTE.<sup>2</sup> This rate describes the situation for agricultural workers, but does not represent other farm managers, owners, and bystanders who are also at risk of serious injury. Furthermore, those who live on farms are also in harm's way—every 3 days a child is killed in an agricultural injury event in the United States.<sup>3,4</sup>

Agriculture, as an industry, was granted many exemptions during the creation of the Occupational Safety and Health Act of 1970 (OSH Act).<sup>5</sup> The agrarian myth, where farming was framed as a virtuous endeavor, with farmers being owed a social debt by others, played a key role in sparing farmers from what was seen as unmanageable regulations.<sup>6</sup> Economic, cultural, and labor access challenges have also figured prominently in decisions to relax regulatory requirements for farmers.<sup>7</sup> Looking back, some lawmakers expressed regret in creating such a lasting exemption, later

suggesting that regulations should have been phased in over an extended period, eventually bringing agriculture in line with general industry requirements.<sup>6</sup> Unfortunately, given the inherent risks of farming and existing regulatory flexibility, nearly every farmer knows someone who has been severely injured or killed at work.<sup>8</sup>

Occupational injury burden, injury, illness, and loss of life, are generally numerated in terms of frequency, rate, and severity. However, these estimates only measure a fraction of the total burden to society and to injured workers.<sup>9</sup> In 1970, the OSH Act cited Congress' concern that personal injuries and illnesses affect interstate commerce, production, and productivity, and contribute to substantial wage loss, medical expenses, and disability compensation payments.<sup>5</sup> Nearly 50 years later, a RAND report on workers' compensation, stakeholder policy views, and research priorities<sup>10</sup> highlighted the need for more research on the shift of occupational injury and illness costs to social programs and families. The National Academy of Sciences' (NAS) recent

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occupational surveillance review noted that the “costs of a surveillance system include not only the costs of data collection, but also the costs associated with the health and productivity consequences of occupational exposures, injuries, illnesses, and mortality on workers, their families, and society.”<sup>11</sup> Capturing such vast and varied data points has proven difficult for agriculture.<sup>12</sup>

Understanding the economic impact of farm injuries is critical as it offers the necessary data to prioritize prevention investments and associated strategies for this at-risk industry. While agricultural workplace fatalities are generally captured in the Census of Fatal Occupational Injury (CFOI),<sup>13</sup> data relating to injury, especially in the Northeast USA, are problematic due to the underreporting in routine injury data collection systems.<sup>14</sup> An estimate published in 2001 showed that agricultural injuries cost roughly \$4.57 billion to the US economy (in 1992).<sup>15</sup> However, the authors acknowledged that injuries on farms with less than eleven employees were not captured in their method (though they attempted to adjust for it). Ninety percent of farms in the Northeast are exempt from OSHA regulations due to their small employment numbers (having 10 or fewer hired employees).<sup>16</sup> Even the injury and fatality estimates that do exist are limited.<sup>17–19</sup> For instance, work time loss calculations are often based on farm income, however, many farmers work several jobs, and lost off-farm income is rarely calculated.<sup>20</sup> Other factors that are infrequently included in calculations of injury burden include opioid addiction, transportation issues, and lack of access to rehabilitation services, particularly in rural areas where farms are located. In addition, researchers and economists have noted that the calculated injury costs often leave out pain, suffering, and the mental and emotional toll for workers and their families.<sup>21</sup>

As a result, the lack of adequate agricultural injury data has impeded efforts to develop more accurate economic evaluation estimates and has negatively impacted the prioritization of workplace health and safety in state and federal public health efforts.<sup>22</sup> The low prioritization of occupational health and safety is demonstrated by the National Institute of Occupational Safety and Health’s (NIOSH) share of the Centers for Disease Control and Prevention (CDC) federal budget. In 2023 allocations were approximately 0.04% of the entire budget.<sup>23</sup> Over a decade ago, J. Paul Leigh noted that the costs of occupational injury and disease exceeded those of cancer by \$30 billion, and at that time, the National Cancer Institute’s (NCI) budget was over sixteen times that of NIOSH’s funding allocation.<sup>21,24</sup> By 2023, that budget disparity has ballooned to the point where the NCI budget is twenty times larger than the NIOSH budget.<sup>23,25</sup>

Burden encompasses economic costs, lost quality of life, disability, death, injury, and illness, but also factors less easily quantified, such as mental and emotional hardships, and impacts on family and community.<sup>26</sup> The purpose of this literature review was to examine the peer-reviewed research to identify studies focused on characterizing the

burden of agricultural injury, financial and otherwise. The results of this review will inform US-focused agricultural injury surveillance methods, however, the scope of the review covered all English language materials, knowing that global work could inform and improve research in the United States. This review focused on the following approach for burden assessments recommended by Schulte et al.:<sup>27</sup> using multiple domains, including the worker, their family, the community, the employer, and society. These categories were used to create a priori themes for organizing the literature review results.

## Materials and Methods

This review was based on standardized protocols for evaluating existing research literature.<sup>28–31</sup> For simplicity, the term publication refers to an individual piece of scientific literature. The specific steps for this review are outlined in the section below.

### Steps of the Review

*Framing the research question*—How has the burden of agricultural injury been described in the English language literature? The research question was further refined to ensure the review fully captured what is currently known about agricultural injury, its challenges and shortcomings. If occupational illness was mentioned in conjunction with an injury-related article, it was considered within the scope of the research question. The review, results, and recommendations focus on a United States perspective, however, all English-language literature was included, to learn from best practices around the world.

*Identifying relevant studies*—The search strategy is shown in Table 1. This review included PubMed, American Psychological Association (APA) PsycInfo, Web of Science, Google Scholar, ProQuest Dissertations & Theses Global, U.S. Government Publications Catalog, and the NIOSH Resource Database (NIOSH TIC-2). The literature search included the capture of grey literature, such as doctoral dissertations and masters’ theses. These databases were chosen in consultation with an information specialist, who routinely assists with reviews on occupational health and safety topics.<sup>32</sup> The specific search terms used for each database are shown in detail in Table 1. EndNote X20 software (Clarivate Analytics, Philadelphia, PA) was used to manage all review records. Only literature in the English language was considered eligible. Literature published between 1980 and 2021 was considered within scope. This period was set as a reasonable window, as most U.S. occupational safety and health research in agriculture began in earnest during the 1980s.

*Study selection*—To be eligible, the publication had to originally address an aspect of agricultural injury burden, specifically the aftermath of the injury event. In particular,

**Table 1.** Search Strategy.

| Database                         | Search string                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        |                                  |                            |                  |                            |                                  |            |                                  |     |
|----------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------------------|----------------------------|------------------|----------------------------|----------------------------------|------------|----------------------------------|-----|
| PubMed                           | <p>#1—Farmers[Mesh] OR farmers[tiab] OR farmer[tiab] OR “farm worker”[tiab] OR “farm workers”[tiab] OR farmworker[tiab] OR farmworkers[tiab] OR “agricultural worker”[tiab] OR “agricultural workers”[tiab]</p> <p>#2—“Wounds and injuries”[mh] OR injury[tiab] OR injuries[tiab] OR injured[tiab] OR Accidents[mh] OR accidents[tiab] OR accident[tiab] OR accidental[tiab]</p> <p>#3—“agricultural injury”[tiab] OR “agricultural injuries”[tiab] OR “agricultural occupational injury”[tiab] OR “agricultural occupational injuries”[tiab] OR “farm injury”[tiab] OR “farm injuries”[tiab] OR “farmers’ injuries”[tiab] OR “agricultural accident”[tiab] OR “agricultural accidents”[tiab] OR “farm-related injury”[tiab] OR “farm-related injuries”[tiab] OR “farm-related accident”[tiab] OR “farm-related accidents”[tiab] OR “agriculture-related injury”[tiab] OR “agriculture-related injuries”[tiab] OR “agriculture-related accident”[tiab] OR “agriculture-related accidents”[tiab]</p> <p>#4—(#1 AND #2) OR #3</p> <p>#5—“costs and cost analysis”[mh] OR cost[tiab] OR costs[tiab] OR burden[tiab] OR burdens[tiab]</p> <p>#6—“Hospital charges”[mh] OR “hospital charges”[tiab] OR “hospital bill”[tiab] OR “hospital bills”[tiab] OR “hospital fee”[tiab] OR “hospital fees”[tiab]</p> <p>#7—“quality of life”[mh] OR “quality of life”[tiab]</p> <p>#8—efficiency[mh] OR efficiency[tiab] OR productivity[tiab]</p> <p>#9—“psychological trauma”[mh] OR psychological[tiab] OR psychologically[tiab] OR psychosocial[tiab] OR psychosocially[tiab]</p> <p>#10—“Workers’ compensation”[mh] OR “workers’ compensation”[tiab] OR “worker’s compensation”[tiab] OR “workers compensation”[tiab] OR “injury claim”[tiab] OR “injury claims”[tiab] OR “disease claim”[tiab] OR “disease claims”[tiab]</p> <p>#11—#5 OR #6 OR #7 OR #8 OR #9 OR #10</p> <p>#12—#4 AND #7</p> <table><tr><td>Controlled Language</td><td>Search Filters</td><td>Search Completed</td><td>Number of Records Returned</td></tr><tr><td>Medical Subject Headings (MeSH)</td><td>1980–2021</td><td>May 3, 2020, February 17, 2022</td><td>329</td></tr></table> | Controlled Language              | Search Filters             | Search Completed | Number of Records Returned | Medical Subject Headings (MeSH)  | 1980–2021  | May 3, 2020, February 17, 2022   | 329 |
| Controlled Language              | Search Filters                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       | Search Completed                 | Number of Records Returned |                  |                            |                                  |            |                                  |     |
| Medical Subject Headings (MeSH)  | 1980–2021                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            | May 3, 2020, February 17, 2022   | 329                        |                  |                            |                                  |            |                                  |     |
| EMBASE                           | <p>English</p> <p>#1 (‘agricultural worker’/exp OR ‘agricultural worker’) AND (‘occupational accident’/exp OR ‘occupational accident’) AND [1980–2020]/py</p> <p>#2 (‘cost benefit analysis’/exp OR ‘cost benefit analysis’ OR ‘quality of life’/exp OR ‘quality of life’ OR ‘productivity’/exp OR productivity OR ‘hospital cost’/exp OR ‘hospital cost’ OR ‘psychotrauma’/exp OR psychotrauma OR ‘workman compensation’/exp OR ‘workman compensation’) AND [1980–2020]/py</p> <p>#1 AND #2</p> <table><tr><td>Controlled language</td><td>Search filters</td><td>Search completed</td><td>Number of records returned</td></tr><tr><td>Emtree (Embase Subject Headings)</td><td>1980–2021</td><td>April 7, 2020, February 17, 2022</td><td>39</td></tr></table>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     | Controlled language              | Search filters             | Search completed | Number of records returned | Emtree (Embase Subject Headings) | 1980–2021  | April 7, 2020, February 17, 2022 | 39  |
| Controlled language              | Search filters                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       | Search completed                 | Number of records returned |                  |                            |                                  |            |                                  |     |
| Emtree (Embase Subject Headings) | 1980–2021                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            | April 7, 2020, February 17, 2022 | 39                         |                  |                            |                                  |            |                                  |     |
| SCOPUS                           | <p>English</p> <p>(TITLE-ABS-KEY (“agricultural worker”) AND TITLE-ABS-KEY (“occupational accident”) AND TITLE-ABS-KEY (“cost benefit analysis” OR “Quality of life” OR productivity OR “hospital cost” OR psychotrauma OR “workman compensation”))</p> <table><tr><td>Controlled language</td><td>Search filters</td><td>Search completed</td><td>Number of records returned</td></tr><tr><td>n/a</td><td>1980–2021</td><td>April 7, 2020, February 17, 2022</td><td>56</td></tr></table>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           | Controlled language              | Search filters             | Search completed | Number of records returned | n/a                              | 1980–2021  | April 7, 2020, February 17, 2022 | 56  |
| Controlled language              | Search filters                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       | Search completed                 | Number of records returned |                  |                            |                                  |            |                                  |     |
| n/a                              | 1980–2021                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            | April 7, 2020, February 17, 2022 | 56                         |                  |                            |                                  |            |                                  |     |
| PsycInfo                         | <p>English</p> <p>(occupational injury OR agricultural injury) AND farm Tx All Text</p> <p>burden of occupational injury TX All Text</p> <table><tr><td>Controlled language</td><td>Search filters</td><td>Search completed</td><td>Number of records returned</td></tr><tr><td>n/a</td><td>1997*–2021</td><td>April 7, 2020, February 17, 2022</td><td>14</td></tr></table>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         | Controlled language              | Search filters             | Search completed | Number of records returned | n/a                              | 1997*–2021 | April 7, 2020, February 17, 2022 | 14  |
| Controlled language              | Search filters                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       | Search completed                 | Number of records returned |                  |                            |                                  |            |                                  |     |
| n/a                              | 1997*–2021                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           | April 7, 2020, February 17, 2022 | 14                         |                  |                            |                                  |            |                                  |     |
| NIOSHTIC-2                       | <p>English</p> <p>*1997 earliest date that returned a hit for this search</p> <p>agricultural worker OR farmer OR farm worker OR farmworker AND injury AND burden</p> <table><tr><td>Controlled language</td><td>Search filters</td><td>Search completed</td><td>Number of records returned</td></tr><tr><td>n/a</td><td>1980–2021</td><td>March 5, 2020, February 23, 2022</td><td>42</td></tr></table>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             | Controlled language              | Search filters             | Search completed | Number of records returned | n/a                              | 1980–2021  | March 5, 2020, February 23, 2022 | 42  |
| Controlled language              | Search filters                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       | Search completed                 | Number of records returned |                  |                            |                                  |            |                                  |     |
| n/a                              | 1980–2021                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            | March 5, 2020, February 23, 2022 | 42                         |                  |                            |                                  |            |                                  |     |

(continued)

Table 1. Continued.

| Database                               | Search string                                                                                                                                                                                                                                                                                                                      |                |                                   |                            |
|----------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------|-----------------------------------|----------------------------|
| Web of Science                         | English                                                                                                                                                                                                                                                                                                                            |                |                                   |                            |
|                                        | burden of agricultural injury OR TOPIC: Agricultural injuries" AND TOPIC: Farmers OR farmworkers OR agricultural worker                                                                                                                                                                                                            |                |                                   |                            |
|                                        | Controlled language                                                                                                                                                                                                                                                                                                                | Search filters | Search completed                  | Number of records returned |
|                                        | n/a                                                                                                                                                                                                                                                                                                                                | 1980–2021      | April 1, 2020, February 17, 2022  | 166                        |
| Google Scholar                         | English                                                                                                                                                                                                                                                                                                                            |                |                                   |                            |
|                                        | intext: "agricultural injury" burden United States                                                                                                                                                                                                                                                                                 |                |                                   |                            |
|                                        | Controlled language                                                                                                                                                                                                                                                                                                                | Search filters | Search completed                  | Number of records returned |
|                                        | n/a                                                                                                                                                                                                                                                                                                                                | 1980–2021      | March 18, 2020, February 28, 2021 | 428                        |
| ProQuest Dissertations & Theses Global | English                                                                                                                                                                                                                                                                                                                            |                |                                   |                            |
|                                        | "occupational injury" OR "occupational injuries" OR "work injury" OR "work injuries" OR "farm injury" OR "farm injuries") AND (farmer OR farmers OR "farm worker" OR "farm workers" OR "agricultural worker" OR "agricultural workers" OR farmworker OR farmworkers) AND (burden OR burdens OR cost OR costs OR "quality of life") |                |                                   |                            |
|                                        | Controlled language                                                                                                                                                                                                                                                                                                                | Search filters | Search completed                  | Number of records returned |
|                                        | n/a                                                                                                                                                                                                                                                                                                                                | 1980–2021      | March 18, 2020, February 28, 2022 | 1,775                      |
| U.S. Government Publications Catalog   | English                                                                                                                                                                                                                                                                                                                            |                |                                   |                            |
|                                        | "burden of agricultural injuries"                                                                                                                                                                                                                                                                                                  |                |                                   |                            |
|                                        | Controlled language                                                                                                                                                                                                                                                                                                                | Search filters | Search completed                  | Number of records returned |
|                                        | n/a                                                                                                                                                                                                                                                                                                                                | 1980–2021      | March 18, 2020, February 28, 2022 | 0                          |
|                                        | English                                                                                                                                                                                                                                                                                                                            |                |                                   |                            |

articles had to explore injury burden beyond the mere discussion of injury trends or rates, either in their methods, results, discussion, or conclusion. This meant that articles could not merely cite a previously published example of burden. References of included literature were themselves reviewed, and crosschecked with studies that were returned using the search criteria in Table 2. Examples of agricultural injury burden that were considered within scope included costs to the patient, family, insurer, or community, emotional distress, subsequent disability, medication use and side effects, use of emergency services, impacts on coworkers/business, etc. For the purposes of this review, agricultural injury was defined as unintentional bodily harm occurring due to acute exposure to energy because of farm work, or farm hazards. For additional context, farming can include "a wide range of activities, hazards, and dispersed workplaces; a seasonal hired workforce that often has brief tenure, poor English skills, a distrust of officialdom; and a history of exemption regarding occupational health and safety regulations."<sup>33</sup>

*Charting the data*—A publication-cataloging database was built in Microsoft Access (Microsoft Corp. Redmond, WA), including fields for the title, abstract, author(s), year, study location, institution, funder, study population, methodology, and results. A notes column was included to capture relevant information that surfaces during the review, but which may not be captured in predefined variables. The

title and abstracts of all identified publications were reviewed by the information specialist (reviewer 1) to narrow the list of articles that required full-text review. Any ambiguous publications received full-text reviews at this stage. The final publications were identified, and the full-text review of each was completed by the primary reviewer (reviewer 2) using NVivo 12 (QSR International, Queensland, AUS) to manage the process (Figure 1). Each full-text publication was assigned as in scope or out of scope, and a priori nodes (or themes) were assigned for all in-scope documents. Additional new nodes were captured as they emerged from the review. The coauthor reviewed the nodes and organization of the qualitative data.

*Collating, summarizing, and reporting the results*—While the process of sorting through the literature was extensive, this review included only those studies that fit the criteria, a small fraction of the total reviewed. The spreadsheet that was described in the previous step served as the foundation for developing a flow chart showing the total publications reviewed, a description of the review process, and a table of studies included in the final review, along with their important attributes. Gaps in the literature were also described.

## Results

A total of 2,849 publications were identified through the review process, with six of the seven databases returning

**Table 2.** Major Domains of Burden-Related Nodes.

| Injured worker                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          | Worker's family                                                                                                                                                                                                                                                                                                                      | Employer                                                                                                                                                                                                                                                                                                                                                                                          | Society                                                                                                                                                                                                                                                                                                                                                                                 |
|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Adaptation <ul style="list-style-type: none"> <li>• Assistive equipment</li> <li>• Can't farm due to injury</li> <li>• Continue to farm</li> <li>• Physical environment change</li> <li>• Planning ahead (taking more time)</li> <li>• Safer after injury</li> <li>• Social leisure activities</li> </ul>                                                                                                                                                                                                                                                                                               | Faith <ul style="list-style-type: none"> <li>• Social support</li> </ul> Toll on family <ul style="list-style-type: none"> <li>• Anxiety</li> <li>• Depression</li> <li>• Economic losses</li> <li>• Impact on children</li> <li>• Impaired relationships</li> <li>• Loss of ability to perform family and societal roles</li> </ul> | Accident investigation <ul style="list-style-type: none"> <li>• Direct medical costs</li> <li>• Indirect costs (productivity)</li> <li>• Legal</li> <li>• Pension and wage replacement</li> <li>• Production interruption</li> <li>• Recruiting and training replacement workers</li> <li>• Retaliation</li> <li>• Vocational rehabilitation expenses</li> <li>• Workers' compensation</li> </ul> | Bureaucracy <ul style="list-style-type: none"> <li>• Community</li> <li>• Community strain</li> <li>• Economic losses</li> <li>• Government support</li> <li>• Social security disability insurance</li> </ul> Loss of human capital <ul style="list-style-type: none"> <li>• Unequal value of agriculture</li> <li>• Workers' compensation costs borne by medical insurance</li> </ul> |
| Disability <ul style="list-style-type: none"> <li>• Economic impact               <ul style="list-style-type: none"> <li>• Days away from work</li> <li>• Loss of housing</li> <li>• No insurance</li> </ul> </li> </ul>                                                                                                                                                                                                                                                                                                                                                                                |                                                                                                                                                                                                                                                                                                                                      |                                                                                                                                                                                                                                                                                                                                                                                                   |                                                                                                                                                                                                                                                                                                                                                                                         |
| Emotional impact <ul style="list-style-type: none"> <li>• Lack of independence</li> <li>• Loss of contribution of community life</li> <li>• Mental impact</li> <li>• Not taking responsibility</li> <li>• Persistence</li> <li>• Stress</li> </ul>                                                                                                                                                                                                                                                                                                                                                      |                                                                                                                                                                                                                                                                                                                                      |                                                                                                                                                                                                                                                                                                                                                                                                   |                                                                                                                                                                                                                                                                                                                                                                                         |
| Injury as a vacation from work <ul style="list-style-type: none"> <li>• Medical issues               <ul style="list-style-type: none"> <li>• Complications following injury</li> <li>• Death</li> <li>• Delays in care</li> <li>• Follow-up care                   <ul style="list-style-type: none"> <li>○ Rehab or nursing home care</li> </ul> </li> <li>• Health</li> <li>• Inability to follow medical advice</li> <li>• Living and working with pain</li> <li>• Medication</li> <li>• Not receiving adequate care</li> <li>• Specialty surgery</li> <li>• Time to recover</li> </ul> </li> </ul> |                                                                                                                                                                                                                                                                                                                                      |                                                                                                                                                                                                                                                                                                                                                                                                   |                                                                                                                                                                                                                                                                                                                                                                                         |
| Racial disparity <ul style="list-style-type: none"> <li>• Re-injury</li> <li>• Worker types               <ul style="list-style-type: none"> <li>• Children</li> <li>• Migrant farmworker</li> <li>• Adult</li> </ul> </li> </ul>                                                                                                                                                                                                                                                                                                                                                                       |                                                                                                                                                                                                                                                                                                                                      |                                                                                                                                                                                                                                                                                                                                                                                                   |                                                                                                                                                                                                                                                                                                                                                                                         |

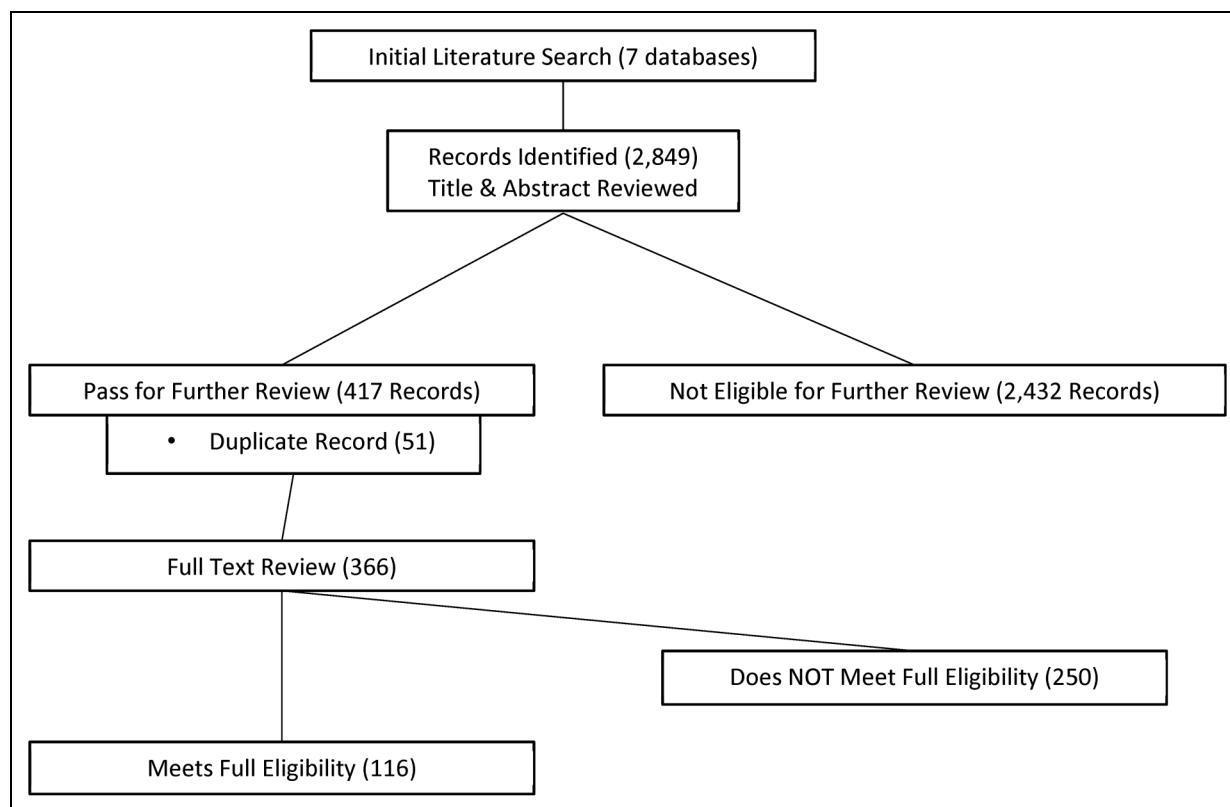
records. One database, the U.S. Government Publications Catalog, had no articles identified when using the search strategy documented in Table 1. The title and abstracts of the 2,849 publications were visually inspected and 2,432 were deemed ineligible for further review because they did not originally address an aspect of agricultural injury burden, as described in the methods. Of the 417 publications that passed on for full-text review, 51 publications were duplicates and were removed from consideration. Therefore, 366 publications were read in their entirety. Of these 366, 250 were ultimately not eligible (cited previous work), and the remaining 116 documented agricultural injury burden. Full results can be seen in Supplement 1, including the study population, type of burden described, and location for each study. Seventy-seven publications had research that was conducted in the United States, with Canada, Australia, and Finland contributing to the majority of international representation ((Figures 2 and 3)). When a study involved multiple locations, they were each listed separately on the map. Of the publications documenting agricultural injury burden, a priori themes were used to organize findings in relation to the injured person, the worker's family, the employer, and society. Throughout the literature review process, new nodes were added as needed to fully describe the various pathways of burden. When the review process was complete, these nodes were grouped into the

themes. Within them, there were differences in how the theme manifested itself depending on the role (injured worker, worker's family, employer, and society) shown in Table 2. The subsequent subheadings represent the major overarching themes.

### Financial Considerations

Direct injury costs, mostly in the form of medical costs, and the value of workers' compensation claims were commonly noted. Fifty of the 116 publications referred to these direct injury costs. The ability to calculate medical costs differed across geographic locations, with notable differences based on the country or U.S. state reporting and their data collection guidelines. Finland and Australia were well represented in the review with research that contained national medical cost estimates.<sup>34–40</sup> The financial impact of medical costs was discussed across each of the a priori themes, from the worker, to the family, employer, and society, at large.

One of the most complete assessments of financial costs came from a dissertation by Roger Tormoehlen in 1985.<sup>41</sup> Tormoehlen considered costs within the following categories: emergency services and rescue, hospital charges, medical expenses following leave from hospital, rehabilitation expenses, parking and mileage charges, follow-up medical care, loss of earnings, property damage, replacement

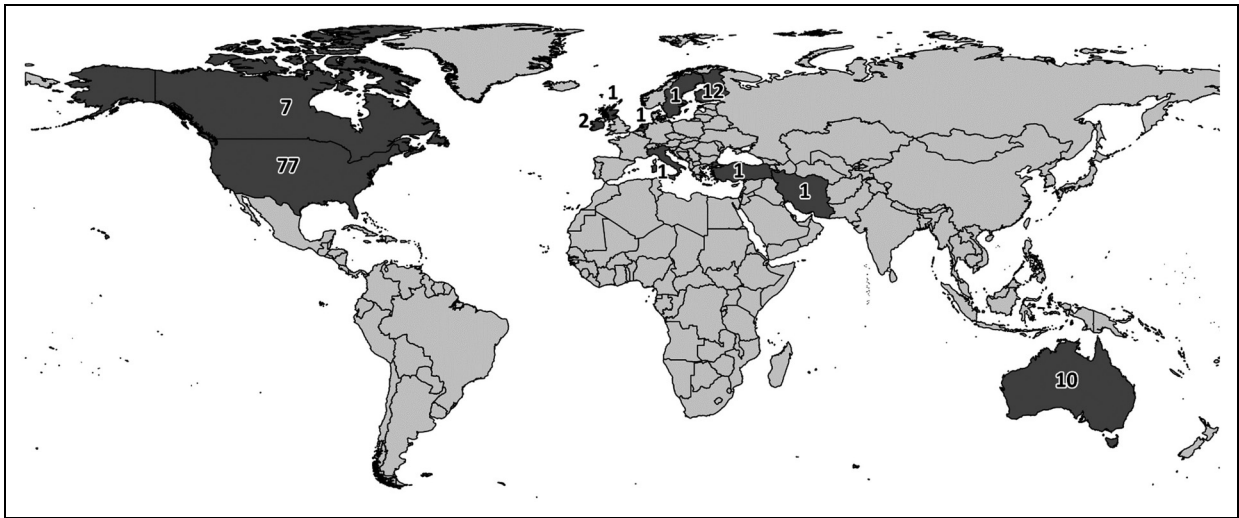


**Figure 1.** Flow diagram of the review process.

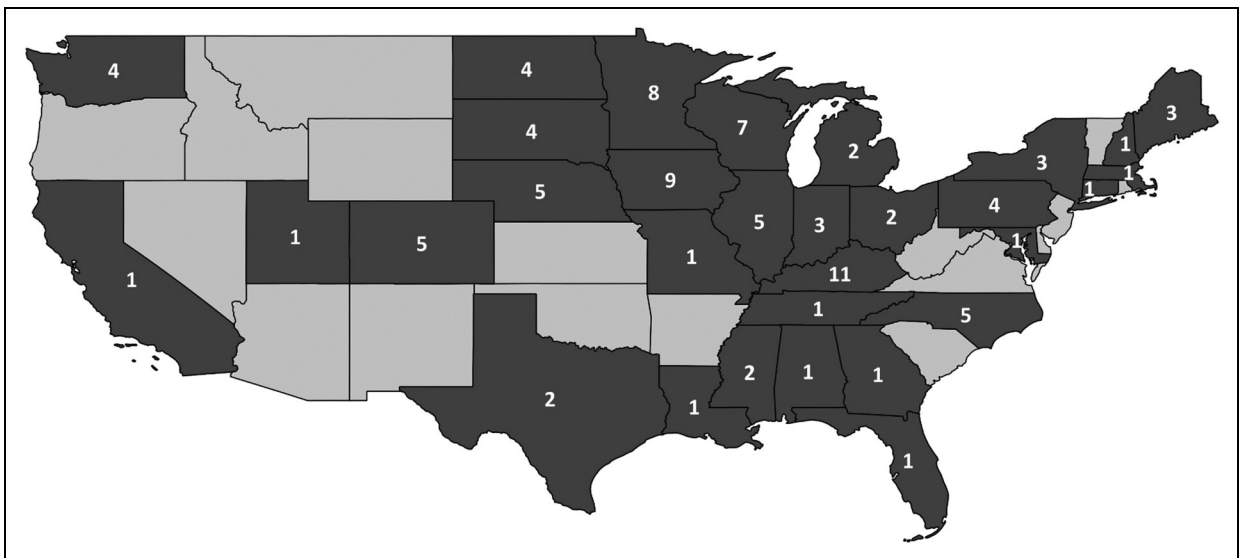
labor, lost productivity, modifications for home and farm, and legal expenses and/or income.<sup>41</sup> His calculations took into account seemingly small and often overlooked costs, like the price of clothing destroyed in an injury event. When these costs were taken together, they offered a sobering perspective on the substantial financial impact of an agricultural injury. While he provided a comprehensive look at economic considerations for farm injury, those costs have changed both in scope as well as in today's dollars.

There was also evidence of cost-shifting from what should have been workers' compensation to medical insurance, as well as private payers covering medical charges for a variety of reasons. In her analyses, Costich<sup>42</sup> noted that most farm

injury medical care was not paid for by workers' compensation but rather covered by commercial insurance or government payers, shifting substantial costs to public and private sources. Missikpode and colleagues<sup>43</sup> noted similar findings. Self-employment was a complicating factor in calculating costs for both the US and other countries, with Bittle and colleagues noting similar issues in Canada.<sup>44</sup> In these publications, migrant farmworkers discussed the pressure placed on them from supervisors to avoid using the workers' compensation system.<sup>45</sup> While cost shifting certainly occurred, substantial workers' compensation payments were also represented in the literature, with livestock handling and equipment injuries contributing most frequently to claims.<sup>46-51</sup>



**Figure 2.** Worldwide representation of the final publications.



**Figure 3.** States represented in the final publications.

Note. Eighteen studies from the United States did not specify a state but rather used national data.

Some financial considerations focused on farm and family economic losses due to the injury.<sup>52–54</sup> In an analysis of tractor-related injuries, Doupbrate and colleagues<sup>55</sup> noted that the largest lost-time burden was borne by the farm owner-operator and their family members. Researchers in Ireland<sup>56</sup> found that an injury event not only put a financial strain on the farm due to the loss of direct production, but farm family income was further reduced because it was more difficult for family caretakers to sustain off-farm employment when caring for their disabled or injured loved one. Medications,<sup>19,40,57</sup> rehabilitation care,<sup>58–62</sup> adaptive equipment and farm and home modifications,<sup>63–65</sup> were other common costs noted.

### Productivity Costs

Productivity costs and production interruption (e.g., days away from work) were another routine means to quantify the burden of agricultural injury. Identified research discussed productivity losses ranging from reducing farm operations, calling upon family, neighbors, and friends to fill work shifts, to the loss of the farm enterprise. While many farmers responded negatively about lost work time, there were a few reports, such as that by Rasinski (2007), where the farmer noted a work injury as the only time he ever had a “vacation.”<sup>66</sup> This subject had three teenage sons who filled in for much of the work. The implication was that while productivity may have not suffered on the farm, those children were spending much more time working with less time for their own activities.<sup>66,67</sup> Research also noted the difficulty in not only finding replacement help, but the difficulty in training them properly in a short period of time.<sup>64</sup> When farmers could return to work, many noted that the same tasks would take much longer on account of having to work slower or use adaptive equipment.<sup>41,64,65,68</sup> On a broader scale, the reduction in productivity was noted as an expense to society.<sup>9,55,69,70</sup>

### Emotional Impact

Many publications described injured farmers feeling guilty that they had become a burden to their family. Connected with the loss of productivity was the loss of purpose or identity, as well as a lack of independence. Murray and colleagues (2019) interviewed farmers who described, “I don’t ask for much help. I don’t like to try to burden anyone else” and “You lost all your independence....”<sup>71</sup> This lack of independence had wide-ranging mental health impacts and farmers noted disappointment over not being able to participate in family or community life to the extent they were used to.<sup>54,64,71</sup> Interestingly, returning to work following a traumatic injury was found to have both positive and negative mental health impacts. Research by Reed (1996) highlighted fear of returning to the location of the injury, “...Right on the start ... I’ll admit it. It [going back to work] scared the—out of me.”<sup>72</sup> For others, returning to work represented a return to

their core identity, and thus was considered to have a positive impact on their mental wellbeing.<sup>71</sup>

Emotional impacts were significant for farm families, as well. Several articles described the stress of farm injuries affecting the breakdown of familial relationships. Conrad described how traditional gender norms negatively impacted a farm son, after his father was injured on the farm, noting that his mother and sister could confide in each other, and he was left on the outside to process his feelings alone.<sup>54</sup> He also noted that after a particular fatal injury event, the remaining family struggled to fill the void, with this eventually leading to divorce, drug use, and prison time. While some relationships broke down, others strengthened based on the closeness that caretaking requires, but in some cases, it led to post-traumatic stress disorder on the part of the partner—fearing an injury event or a reoccurrence for their loved one.<sup>71</sup>

### Disability

The size and sheer force of farm equipment, animals, and other farm hazards mean that traumatic farm injury often results in lengthy recoveries and long-term disability. A population-based study in Kentucky found that 22 percent of older injured farmers made permanent changes in how they performed farm work due to lasting effects of their injury.<sup>57</sup> Another study in Kentucky calculated that for 56 farmers hospitalized due to a tractor rollover event, collectively they spent 1,118 days in the hospital and lost 6,742 days of work.<sup>73</sup> Ten of them were permanently disabled. As Doupbrate noted, tractor and livestock handling work were more costly and required more days away from work than other agricultural injuries.<sup>74</sup> Farmers living with disabilities discussed having to reimagine tasks related to leisure and work to accomplish day-to-day living. Some typical tasks of daily living, like bathing or dressing, were no longer possible alone. One participant in a study by Fintel described relying on help from his sister to do the laundry and clean the house, also noting that with his upper extremity amputation, he could not even tuck in his own shirt.<sup>64</sup> Also common among those recovering from injuries were extended sessions of intensive physical and occupational therapy, and the need to be fit with proper prosthesis and adaptive equipment. Some farmers were able to return to some or all farm work with adaptive equipment such as modified pedals in personal vehicles and farm equipment, and personal lifts to safely move into operator’s seats.<sup>75</sup> Finding the proper adaptive equipment that could withstand the wear and tear on the farm was an issue faced by many disabled farmers.<sup>65,72,75,76</sup>

## Discussion

### Gaps in the Literature

Notably absent from the literature were analyses on the navigation of bureaucratic processes related to traumatic farm

injury. Research touched on the frustration of dealing with insurance companies and paperwork related to disability assistance,<sup>64</sup> but evidence of a broader analysis could not be identified. After reviewing the 116 publications, it became clear that bureaucracy and delays in care and assistance were relatively common for injury victims, and these would greatly contribute to the overall assessment of burden, as well as opportunities for improving relevant services and programs. Trends in farming have also shifted during the period of this review, with fewer adult children staying on the farm to take over. As a result, there are currently fewer familial and social ties to step in should an injury occur. Given the clear role that the family plays in farm injury recovery and support, as described in this literature review, the consequences of fewer social ties in rural America need to be assessed. Further, migrant, seasonal, and H2A farm workers were underrepresented in the literature, being the focus of only nine of the 116 publications.

### Limitations

Many reviews take advantage of a second reviewer to verify the findings for all papers. However, due to time and resource constraints, this review was conducted primarily by the author, with our research librarian reviewing papers where classification was ambiguous. It is also possible that some publications were not identified due to the style of the text search string and how literature is indexed. For instance, in PubMed, Medical Subject Headings (MeSH) terms were used to identify potential records. These MeSH terms include many additional terms under their “umbrella”; however, these may not entirely encompass all keywords chosen by a given author. As a result, there may be papers more broadly related to the burden of occupational injury, that have not been included in the scope of this paper.

### Policy Implications

The existing collection of occupational injury data for agriculture in the U.S. remains inadequate to fully realize traumatic injury burdens (financial and otherwise). Policies related to agricultural regulatory exemptions have directly contributed to the dearth of available information. What information is available is often skewed toward larger farm operations that are required to maintain OSHA 300 logs, or could be included in the Survey of Occupational Injury and Illnesses (SOII).<sup>5,77</sup>

While databases exist that maintain injury and illness information, such as hospital discharge data, the inability to routinely subset these data by industry and occupation has severe consequences.<sup>78</sup> This negatively impacts agricultural injury surveillance, but also the overall ability to understand the impact of all types of work on morbidity and mortality. Requiring industry and occupation variables to be included in hospital discharge data reporting, for example, would be

revolutionary for occupational epidemiology. For example, some states have embraced adding industry and occupation modules for public health surveys such as the Behavioral Risk Factor Surveillance Survey (BRFSS), opening new possibilities for understanding the burden of work on health, injury, and wellbeing.<sup>79</sup> Thus, adding work-related variables to other existing health datasets would allow researchers to stratify and analyze many outcomes in relation to work status, or even the lack thereof.

Furthermore, we must think creatively about how to capture data using alternative methods. Beyond healthcare datasets and surveys, we need to consider non-traditional sources of data in fully describing the burden of occupational injury in the agriculture industry. In particular, measures to estimate the severity and type of mental and emotional distress and length of time to navigate social supports should be a focus of future research. Obtaining feedback from the agricultural community and industry stakeholders should be an integral component of this process. In addition, tax and financial records could be important sources of information related to long-term monetary consequences of agricultural injury.

Current estimates of burden are underrepresenting the toll injuries have on this vital industry and more attention should be paid to fully enumerating these, and further, making agriculture safer. The informant feedback could provide inputs for a framework recommending additional variables, highlighting new data sources, potential changes in surveillance practices, and data requirements.

To help ease this situation, federal agencies such as the United States Department of Agriculture (USDA) and the Centers for Disease Control and Prevention (CDC) should consider ways to implement new or maintain current memorandums of understanding (MOUs) for data-sharing agreements. Even better, would be to implement policies that allowed outside researchers to apply for, and use such datasets more widely and ideally without traveling to specific data centers around the country.

Lastly, within the United States, the resultant framework should be shared widely among injury surveillance and agricultural industry experts at both the state and federal levels, and through professional organizations such as the Council of State and Territorial Epidemiologists (CSTE) and the American Public Health Association (APHA) to garner support for such changes.

### Conclusions

A review of the literature uncovered many facets of burden that are not routinely noted when discussing agricultural injury surveillance. The tracking of occupational injuries often focuses on the number, rates, and characteristics of injury events, such as the type of event and source of injury. Increasingly, calculations of medical costs have been included in such analyses. However, it is clear from

this review, that the true burden of agricultural injury is more nuanced and complex than previous literature has described. Future work should consider identifying avenues of better collecting these data and methods to incorporate them into injury surveillance to provide more accurate estimates of agriculture injury burden. In particular, these should focus on data sources related to mental and emotional health, as well as assessments of bureaucracy associated with social support programs.

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### Supplemental Material

Supplemental material for this article is available online.

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