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Review Article

Gender in Occupational Health Research of Farmworkers: A Systematic Review

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Background *Farmwork is one of the most hazardous occupations for men and women. Research suggests sex/gender shapes hazardous workplace exposures and outcomes for farmworkers. This paper reviews the occupational health literature on farmworkers, assessing how gender is treated and interpreted in exposure-outcome studies.*
Methods *The paper evaluates peer-reviewed articles on men and women farmworkers' health published between 2000 and 2012 in PubMed or SCOPUS. Articles were identified and analyzed for approaches toward sampling, data analysis, and use of exposure indicators in relation to sex/gender.*
Results *18% of articles reported on and interpreted sex/gender differences in health outcomes and exposures. Sex/gender dynamics often shaped health outcomes, yet adequate data was not collected on established sex/gender risk factors relating to study outcomes.*
Conclusion *Research can better incorporate sex/gender analysis into design, analytical and interpretive approaches to better explore its mediation of health outcomes in light of emerging calls to mainstream gender research.* Am. J. Ind. Med. 57:1344–1367, 2014.

KEY WORDS: gender; sex; gender-sensitive research; farm; farmworker; agriculture; women; men; systematic review

INTRODUCTION

Researchers have argued the occupational health literature has inadequately accounted for gender in the formative, implementation, and analytical stages of study [Niedhammer et al., 2000; Messing et al., 2003; Coen and Banister, 2012]. They suggested as recourse the adoption of gender-sensitive research strategies, which addresses men's and women's health problems by identifying physiological, ergonomic and socio-cultural gender characteristics that shape study outcomes [Messing and Mager Stellman, 2006]. This research produces better empirical understandings of health and results in tangible outputs that equitably serve men and women.

In mainstream discourse, agriculture has been conceptualized as a male space [Peter, 2000; Brandth, 2002; Saugeres, 2002], yet women compose about 43% of the labor force in developing countries and at least 20% in developed economies [FAO, 2011b]. Despite this reality, occupational health literature addressing farmworkers has not focused on the instrumentality of gender in shaping health outcomes.

Research suggests that gender is elemental in constructing exposures in and outside the workplace that determine health. A recent report by the Canadian Institute for Health Research defines gender as "socially constructed roles, relationships, behaviours, relative power, and other traits that

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societies ascribe to women and men;" while sex is characterized by "biological and physiological characteristics that distinguish females from males" [CIHR, 2010]. In this article, sex and/or gender (abbreviated herein as 'sex/gender') is used because of the inseparability of the two concepts in women's and men's lived experience. Sex/gender has been found as a determinant for agricultural work in task assignment, work hours, pay, workplace conditions and exposure to other occupational and non-occupational risks [Stallones and Beseler, 2004; Arcury and Quandt, 2007; Villarejo and McCurdy, 2008].

These differences are highly variable based on the context in which a farm industry is situated. Men on farms are generally disproportionately represented in land ownership and labor [Deere and Leon, 2001; Doss et al., 2013], while certain tasks (i.e. machine operation) are also overwhelmingly men-dominant [Brandth, 2006]. There is also evidence that women farm homemakers (often referred to in the literature as "farmer spouses") frequently engage in farm tasks from field irrigation to driving tractors [Reed et al., 1999; FAO, 2011b]. Meanwhile, women in sub-Saharan Africa and in Asia take on more prominent roles in agricultural labor, as in Nigeria where women perform between 60%-90% of agricultural tasks – from land clearing, tilling, planting and maintenance, harvesting, food processing, transportation and marketing [Lawanson, 2008].

Indicators and Outcomes in Agricultural Research

The types of occupational morbidity in agriculture vary widely, from debilitating physical injuries to chemical poisonings and fungal, bacterial and viral illness [ILO, 2003]. Some health problems result from acute events, as when worker fall from heights or are bitten by snakes, while others like cancer may develop over prolonged periods of time [Quandt et al., 2013]. The variety of hazards and health problems prevalent in agricultural work suggests a complex occupational practice and environment—inclusive of ecosystems, farm and health technologies, individual physiology and psychology and the social context indigenous to each farming industry.

The literature has detailed the social, economic and occupational conditions that have made agricultural work among the most hazardous in the world [ILO, 2003; Wang et al., 2011; Shipp et al., 2013; Zheng et al., 2013]. Many workers are migrant and/or casually employed reflecting relative disadvantage compared to other occupational groups—in terms of pay, legal protections, housing, medical coverage and access to other resources [Arcury and Quandt, 2007]. These issues all feature as frequent indicators for assessing the determinants of agricultural worker health.

The occupational factors typically studied include work hours, task assignment, workplace conditions, off-farm employment and exposure to other occupational hazards. Task assignment and work responsibilities have been identified as a conspicuously gendered practice. Without reasonable physiological or social justifications, women are regularly excluded from many tasks, affecting their health and men's as well. For example, women rarely benefit from the perks of higher paying and more secure jobs as machine operators, but are also excluded from the higher risk of injury associated with these jobs [Xiao et al., 2013]. Meanwhile, the men-dominated task of machine operation is a major source of occupational injury. The ability of occupational health research to attend to sex/gender differences, both in health outcomes and the factors that shape their presentation, has staggering implications for the agricultural workforce.

Objective

This paper reviews the occupational health literature on farmworkers, assessing how gender is treated and interpreted in exposure-outcome studies of agricultural workers.

METHODS

Criteria for Considering Studies for This Review

Types of studies

Reviewed articles were limited to quantitative studies on farmworkers' health published in peer-reviewed journals between January 1, 2000 and December 31, 2012. They assessed health outcomes (such as injuries, mortality, pesticide poisoning, dermatitis, respiratory, neurological functioning), employing either cross-sectional, case-control or longitudinal epidemiological designs and were published in English. Articles reporting only descriptive analyses were excluded from the review.

This review focuses on studies of workers in crop-producing agricultural industries, including work related to harvesting, seeding, planting, farm maintenance, cultivation, picking, and sorting. Articles exclusively on animal-product farming were excluded. No restrictions were made on the country or region of study.

Types of participants

Articles were included that analyzed data for men and women workers actively or once engaged in agricultural work. Studies were not excluded if they collected data on non-agricultural working populations, as in comparative studies or studies including farmers' spouses. Study participants encompassed a diverse labor force: farm owners and their spouses, contract workers, seasonal workers, day-laborers, migrant workers and small-scale farmers who own

or rent the land where they produce. Among these were boys and girls and adult workers on part- or full-time schedules.

Search Methods for Identification of Studies

Electronic searches

This review drew articles from the SCOPUS and PubMed archival databases. These databases were chosen because of their expansive indexing of journals publishing epidemiological studies in medical and occupational health fields. The search included a wide range of terms covering key concepts of occupational health and agricultural work. Table I includes the strings used in PubMed and SCOPUS tailored to their search protocols.

Data Collection and Analysis

Selection of studies

Articles were first identified and screened through SCOPUS and then through PubMed, with duplicates found and removed. Articles were excluded at the abstract level that did not address crop-related farm work, if they had exclusively men or women samples (since these do not identify gender differences in exposures/outcomes) or if health was not the primary study outcome.

A standardized procedure was developed to assess the inclusion and exclusion of full-text articles and to categorize them based on their approaches towards sex/gender in research design, statistical analysis, and interpretation. Figure 1 below illustrates the steps taken for article identification and selection. This identified whether: (i) men and women were pooled together for statistical analysis, (ii) if sex/gender was used as a covariate or adjusted for in the analysis, or if sex/gender was analyzed independently for study outcome (analysis by gender stratification). Articles pooling men and women together in analysis were excluded, because they are unable to produce gender-sensitive findings. Articles that used sex/gender as a covariate and also interpreted sex/gender findings in their discussion were included in the final stages of full-text review. Those studies using sex/gender as a covariate that did not interpret sex/gender in their discussions were excluded.

Data extraction and management

The extraction and management protocol for categorizing data drawn from each reviewed article followed a standardized procedure obtaining the following information: (1) year of publication; (2) country of publication; (3) study participants: number, men/women proportion; (4) methods: study design (prospective/retrospective or cross-sectional), data collection/data source; (5) study outcomes: findings on health outcomes by gender; (6) exposure assessment: indicators of exposure to any work hazards, task assessment (none; yes, without sex/gender differentiation; yes, with sex/gender differentiation), actual exposure measurements.

Data analysis

Studies were assessed for their sampling strategy, data analysis approach and the use of exposure indicators in

TABLE I. Search Criteria

	Search engine	
	SCOPUS	**PubMed**
Search criteria 2000–2012	TITLE-ABS-KEY-AUTH((men OR male) AND (women OR female) AND (hygiene OR occupational health OR occupational injury OR occupational illness OR occupational disease) AND (farm OR agriculture)) AND (LIMIT-TO(DOCTYPE,"ar") OR LIMIT-TO(DOCTYPE,"re")) AND (LIMIT-TO(LANGUAGE,"English")) AND (LIMIT-TO(SRCTYPE,"j")) AND (LIMIT-TO(PUBYEAR, 2012) OR LIMIT-TO(PUBYEAR, 2011) OR LIMIT-TO(PUBYEAR, 2010) OR LIMIT-TO(PUBYEAR, 2009) OR LIMIT-TO(PUBYEAR, 2008) OR LIMIT-TO(PUBYEAR, 2007) OR LIMIT-TO(PUBYEAR, 2006) OR LIMIT-TO(PUBYEAR, 2005) OR LIMIT-TO(PUBYEAR, 2004) OR LIMIT-TO(PUBYEAR, 2003) OR LIMIT-TO(PUBYEAR, 2002) OR LIMIT-TO(PUBYEAR, 2001) OR LIMIT-TO(PUBYEAR, 2000)) AND (LIMIT-TO(LANGUAGE,"English")) AND (LIMIT-TO(SRCTYPE,"j"))	((men OR male) AND (women OR female) AND (hygiene OR occupational health OR occupational injury OR occupational illness OR occupational disease) AND (farm OR agriculture) NOT methodological ("2000/01/01"[Date - Publication]: "2012/12/31"[Date - Publication]) Filters: Humans; English

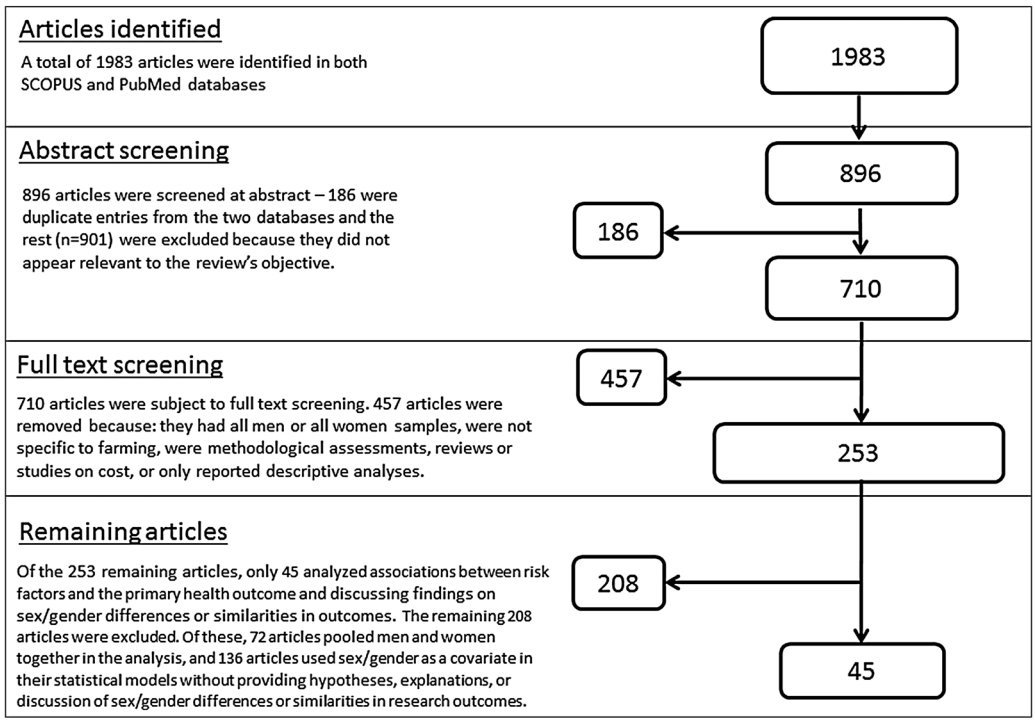

FIGURE 1. Article identification and selection process.

relation to outcomes. The following protocol outlines issues emphasized within each study component:

1. Sampling strategy: studies were assessed whether they recruited a sufficient number of women participants to study sex/gender differences and if clear consideration was given to sampling strategy.
2. Data analysis: articles were evaluated for their analytical treatment of the study population (i.e., use of sex/gender stratification; use of sex/gender as a covariate).
3. Exposure assessment methods: studies were assessed for the type of exposure assessment carried out in relation to study outcomes and how sex/gender was considered in exposure assessment.
4. Sex/gender differences in outcomes: how did men and women farmers differentially experience health outcomes.
5. Interpretation of sex/gender findings: did articles hypothesize, explain, or discuss why there may have been sex/gender differences or similarities in outcomes.

RESULTS

Results of the Search

The search initially found a total of 1983 articles: 682 articles in SCOPUS and 1,301 articles in PubMed, with 186 duplicates identified and removed. Upon first screening, 710 articles were selected: 315 articles through SCOPUS and 395 through PubMed.

These 710 articles were then reviewed as full-texts, 457 of which were excluded for not meeting the basic inclusion criteria (did not study a health outcome, were not specific to farmer populations and crop-production; were not epidemiological studies or only reporting descriptive analyses).

Excluded Studies

The overwhelming majority of excluded studies were eliminated because of vagueness surrounding the participants' work status as farmers in the study. These studies had samples in rural areas said to largely work in agriculture, yet did not collect information to identify the workers as farmers or non-farmers. Several studies were not explicit whether participants were livestock or crop farmers, while a number of other studies identified women in their samples as only 'farmer spouses,' making no qualification of their participation in farming activities. Research that identified farmer spouses as engaging in farm work were included if meeting the other criteria.

The final screening yielded 253 articles for full-text review, with only 45 (18%) analyzing associations between risk factors and the primary health outcome and discussing findings on sex/gender differences or similarities in outcomes. In the remaining 208 articles that were excluded, 72 articles pooled men and women together in the analysis, or sex/gender was used as a covariate in statistical models

(n = 136) without the authors providing hypotheses, explanations, or discussions as to why there may have been sex/gender differences or similarities in research outcomes.

Included Studies

Of the 45 articles that were analyzed in full text, 30 studies used a sex/gender-stratified model in the analysis, and 15 used gender as a covariate. Table II summarizes data extracted from these articles.

The geographic distribution of studies reflects an increasingly international literature. While many studies were conducted in the United States (n = 17, 38%), the review included research from northern Europe (n = 11, 24%), Canada (n = 4, 9%), Brazil (n = 3, 7%), South Korea (n = 3, 7%), China (n = 2, 4%), and one from France, India, El Salvador, Thailand, and Vietnam respectively.

The majority of studies analyzed the data cross-sectionally (n = 26), with the rest employing longitudinal (n = 10) or case-control (n = 9) designs. The longitudinal studies included: (1) farm injuries in the US [McCurdy et al., 2003; Carlson et al., 2005; Marcum et al., 2011], in Finland [Virtanen et al., 2003], and in South Korea [Lee et al., 2012], (2) cancer survival among Latino farmers in California [Dodge et al., 2007], pesticide poisoning in the US [Calvert et al., 2008; Kasner et al., 2012], (3) Parkinson's disease in Denmark [Tuchsen and Jensen, 2000] and (4) hearing loss in the US [Humann et al., 2012]. The case-control studies included: (1) glioma cases in the US [Lee et al., 2005; Ruder et al., 2009], (2) pesticide exposure in the US [Bell et al., 2006] (3) lymphohematopoietic cancers incidence in the US [Mills et al., 2005], (4) risk of uveal melanoma in 9 European countries [Behrens et al., 2012], (5) incidence of osteoarthritis in Sweden [Holmberg et al., 2004], respiratory symptoms in Sweden [Lembke et al., 2004], green tobacco sickness in India [Parikh et al., 2005] and (6) incidence of skin ailments in Vietnam [Trang et al., 2007].

Sample, Design, and Exposure Assessment

Sample sizes varied dramatically in this diverse literature: at the low end, a study of the neurological effects of pesticides in Brazil ran extensive testing batteries with 66 youth [Eckerman et al., 2007] while the research with the largest sample analyzed data from 267,479 US farmers' death certificates, comparing proportionate mortality of crop and livestock farmers [Lee et al., 2002]. The majority of studies, however, ranged between 600 and 8,000 participants, with some injury/mortality and cancer research drawing larger samples from regional surveillance databases.

Among the 45 reviewed papers, studies recruited fewer women participants than men. Seven papers included less than 15% of women in their sample and most papers (n = 24, 53%) included between 15% and 40% of women in their sample. Fourteen studies recruited more than 40% women to their studies [McCurdy et al., 2003; Holmberg et al., 2004; Carlson et al., 2005; Faria et al., 2005; Lee et al., 2005; Eckerman et al., 2007; Trang et al., 2007; Cha et al., 2009; Marcum et al., 2011; Moisan et al., 2011; Behrens et al., 2012; Humann et al., 2012; Liu et al., 2012; Peraza et al., 2012]. The low number of women in some studies was sometimes with good justification. For example, 11 studies reliant on the use of hospitalization records and death certificates included between 4% and 37% women in their sample, representing the only available records for extraction.

Ten studies relied on one variable to measure occupational exposure, while 26 studies report on 2 to 4 variables and the 9 remaining studies assessed five or more. Studies assessed exposure in a variety of places: at the home, in the workplace, and using aggregate-level geographic data. In total, 12 studies (27%) analyzed data on tasks, while the remaining did not collect or analyze this data. A number of studies (n = 4) identified risk factors for health outcomes using estimated exposure at the aggregate level based on a geographically limited area. The studies employing this method utilized area-level pesticide-use information to determine the relationship between exposure and cancer or Parkinson's [Mills et al., 2005; Dodge et al., 2007; Lee et al., 2008; Moisan et al., 2011].

There is no uniform approach to capturing work task or exposure information, yielding a diverse taxonomy of classifications used in the papers under review. The most frequent means of assessing occupational exposure were by job title, with a number of studies (n = 11) relying primarily on this indicator to assess occupational risk for health outcomes [Tuchsen and Jensen, 2000; Lee et al., 2002; Holmberg et al., 2004; Lembke et al., 2004; Mills et al., 2005; Parikh et al., 2005; Dodge et al., 2007; Alterman et al., 2008; Bretveld et al., 2008; Cha et al., 2009; Moisan et al., 2011]. Crop type was also used as a surrogate measure of potential occupational exposures. Studies of chronic illnesses were the most frequent to rely on this approach, estimating regional pesticide use by the types of crops grown in an area and its hectarage [Mills et al., 2005; Dodge et al., 2007; Moisan et al., 2011]. A number of studies (n = 11, 24%) attempted to quantify incident rates based on exposure-time estimates, 3 of which studied pesticide-related illnesses [Bell et al., 2006; Calvert et al., 2008; Kasner et al., 2012] and another 3 that studied injuries among farmworkers [McCurdy et al., 2003; Stallones and Beseler, 2003; Marcum et al., 2011].

Sex/Gender Differences in Outcomes

The 45 reviewed studies reported differences in terms of exposure and outcomes between men and women

TABLE II. Summary of Articles Identified in the Systematic Literature Review of the Occupational Health Literature on Farmworkers that (2000–2012)

Studies		Study design & sampling		Exposure assessment			Data analysis	Health outcome
Author/ Year/ Country	Outcomes	Study design/ Data sources	Sample/% Women	Occupational exposure indicators	Task assessment	Exposure duration or frequency	Gender treatment	findings by gender
Injuries and mortalities								
Lee et al./ 2002/US	Fatalities	Cross-sectional/ Death certificates	267,479 farm fatalities/4% women	Job title	No	No	Gender stratification	Men: livestock farmers had higher mortality rate for cancer of pancreas, prostate, brain, non-Hodgkin's lymphoma, multiple myeloma, and Parkinson's. Men: crop farmers had higher mortality from cancer of lip, skin, multiple myeloma and chronic lymphoid leukemia.
Locker et al./ 2002/Canada	Injuries from farm machines	Cross-sectional/ Hospital records	2,333 cases/11% women	Machine type; mechanism of injury; agricultural season	No	No	Gender stratification	Ratio of men to women injuries was highest in winter. Injuries from falls among women were higher than men. Injuries from PTO (power take-off) mechanisms and harvest equipment were 10 times higher in men than in women. Older men reported more injuries; younger women also reported more injuries.
Alexe et al./ 2003/Greece	All cause injury	Cross-sectional/ Hospital records/ Questionnaires	4,326 injuries/31% women	Mechanism of injury; time of injury during the day	No	No	Gender as covariate	Older women had high injuries from falls on same level occurring during winter.
McCurdy et al./ 2003/US	All cause injury	Cohort/ Questionnaire	1,201 farm workers/51% women	Work tasks (i.e. hoeing, sorting, picking, tying, packing); crop type; employment type; payment type; years of work; weekly work hours	Yes (no gender differentiation)	Yes, full-time equivalent	Gender stratification	Men at higher risk of injury than women; worked at younger age, more hours/wk.; mostly involved in machine and irrigation tasks. Women working piece-rate payment at higher risk than women paid hourly (RR = 4.9); 60% lower risk if indirectly employed vs. directly; more indirectly hired; performed hoeing and produce selection tasks.

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Stallones & Beseler/ 2003/US	All cause injury	Cross-sectional/ Questionnaire	754 farm workers/ 40% women	Work tasks (farmstead material handling, crop production, farm maintenance, animal handling, transport); hours worked; farming season	Yes (with gender differentiation)	Yes, full-time equivalent	Gender stratification	Injury rates were similar for men and women. Men: high injury rate in farm-maintenance activities. Women: very high injury rate while doing other farm work; worked more hours on other farm work; men worked more hours on all other tasks.
Virtanen et al./ 2003/Finland	All cause injury	Cohort/Population consensus-Registry	69,629 farmers/ 35% women 11,657 compensated injuries	Farm type; farm tasks; cause/ event of injury	Yes (no gender differentiation)	No	Gender as covariate	Men had higher injury rates than women (OR = 1.74l 95%CI = 1.66-1.83). Women: more likely to have animal-related injuries. Men: More injuries with objects.
Dimich-Ward et al./ 2004/Canada	All cause injury/fatality	Cross-sectional/ Death certificates; Hospital records	716 fatalities/9% women 8,263 injury cases/ 17% women	Cause of injury/ fatality: machinery, non-machinery	No	No	Gender stratification	Men: 11 times more agriculture-related fatalities. Highest fatal injuries for men were roll-overs (32%) and for women were being run-over (45%); 50% of men fatalities among owners/ operators, highest women-fatalities were children of owners /operators (30%). Higher fatality rates among older men than older women; more fracture injuries among women older than

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Simpson et al./ 2004/Canada	All cause injury/stress	Cross-sectional/ Questionnaire	361 farm cases/ 22% women	Employment history; work tasks—cultivating, harvesting, harrowing or disking, and heavy lifting	Yes (with gender differentiation)	No	Gender stratification	Men: age standardized rates of injury was 13.3/100/year; 18% of men; more likely to use mechanical equipment at time of injury Women: age standardized rates of injury, 3.8/100/year; 11% of women reported stressful lives; reporting stress and no off-farm employment led to more injuries than all other categories. The risk for farm injury increased with levels of stress for women (OR = 2.73) and men (OR = 1.61).
Carlson et al./ 2005/US	Tractor-related injuries	Cohort/ Questionnaire	16,537 farmers/ 48% women	Source of injury; mechanism of injury; activity at time of injury; hours worked per week	No	No	Gender as covariate	Injury rate was higher among men (16.2 injury events per 1,000 persons per year) than among women (2.5). Men at higher risk of tractor injury (OR = 5.3; CI = 2.9, 9.9).
Pickett et al./ 2008/Canada	Head Trauma injury	Cross-sectional/ Hospital records	1,245 cases/26% women	Cause of injury-animal-/machine-related, fall, struck	No	No	Gender stratification	Men are over twice as likely injured (18.6 event rate) compared to women (7.3 event rate). Women ages 10-19: animals led to most head injury. Men older than 60: machinery led to most head injury.
Rautiainen et al./ 2009/Finland	All cause injury	Cross-sectional/ Registry-Insurance records	93,550 farmers/ 37% women	Farm type; presence of animals; employment status; work activity during incident; cause of injury	No	No	Gender as covariate	Men at higher risk of injury.

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Hendricks & Hendricks/2010/US	All cause injury	Cross-sectional/ Questionnaire	79,809 farm youth cases/37% women	Source of injury (i.e. All-terrain vehicle, crop, livestock)	No	No	Gender stratification	Trend in injury rates declined for men but increased for women.
Marcum et al./ 2011/US	All cause injury	Cohort/ Questionnaire	670 farmers in 2002, 536 in 2003, 477 in 2004, 454 in 2005/49% women	Farm tasks; time doing farm work past week	No	Time doing farm work past week	Gender as covariate	Men reported 80% of injuries and had four times the odds of injury (EOR = 3.94) as women. Most common reported farmwork injury was cuts for men and chemical reactions for women.
Van den Broucke & Colémont/ 2011/Belgium	All cause injury	Cross-sectional/ Questionnaire	510 participants/ 20% female	Machine use; animal handling; fall prevention behavior; pesticide use; farm characteristics	Yes (no gender differentiation)	No	Gender as covariate	3.6% of women and 6.8% of men reported injuries; 10.8% of women and 15.9% of men reported disease; women behaved safer than men with animal handling and fall prevention.
Lee et al./ 2012/ South Korea	All cause injury/ fatality	Cohort/Census & worker compensation data	219 fatalities/8% women	Cause of injury/ fatality	No	No	Gender stratification	Men (18/1,000 persons-years) were more likely to be injured than women (13/1,000 persons-years); Men also had higher mortality rates (38/ 100,000 persons-year) than women (9/100,000 person-years). Men: most common cause of deaths from machinery use (35.6%); 85 and older highest injury incidence. Women: most common cause of deaths from transport (23.5%); most common cause of injuries from falls (45.4%). Women between 60 and 64 had highest

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Cancers								injury incidence.
Lee et al./ 2005/US	Glioma-Brain Tumor	Case-control/ Questionnaire	251 farmer cases/ 45% women 498 controls/ 43% women	Type of herbicide/ pesticide used; years of farm work; size of farm	No	No	Gender stratification	Associations between farm work and glioma found for men (OR = 3.9). More brain cancer among men farmers reporting use of insecticides (OR = 1.8), nitrosatable pesticides (OR = 1.9), or organophosphate (OR = 2.0).
Mills et al./ 2005/US								Lymphohematopoietic cancers
Case-control/ Cancer registry; pesticide databank	131 cases/28% women 655 controls/28% women	Estimated pesticide exposure by crop employment for cases and controls; crop type; geographic location	No	No	Gender stratification	Women: work in vegetables had increased risk for leukemia (OR = 4.01). Women: working with chemicals had higher risk (Malathion OR = 4.91; Mancozeb OR = 4.78; Chorothalonil OR = 4.78; Trifluralin OR = 4.51).		
Dodge et al./ 2007/US	All Cancer Mortality	Cohort/Cancer registry	1,186 Hispanic farm cases/31% women178,718 Hispanic controls/51% women	Job title; regional farming exposure	No	No	Gender stratification	Cancer diagnosis mean age 65 for men, 54 for women. Cancer-specific survival worse in farmer men than non-farmer men; no difference observed for women.

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Lee et al./2008/ South Korea	All Cancer Mortality	Ecological study/ Death certificates; census data	62,403 cancer mortality/36% women	Regional farming exposure cumulatively estimated by many variables (i.e. number of farm households, farm size, crop type)	No	No	Gender stratification	Greater farm exposure in men led to higher cancer mortality of esophagus, stomach, brain and leukemia, while in women led to higher cancer mortality of esophagus and stomach.
Ruder et al./ 2009/US	Glioma-Brain Tumor	Case-control/ Questionnaire	481 farm cases/ 39% women 753 controls/ 42% women	Work tasks (pesticide/ fertilizer use, equipment use, farm maintenance); frequency task performed; PPE use; chemical use; crop types, hectarage, & years grown; work tools	Yes (with gender differentiation)	No	Gender stratification	Women: greater risk of glioma on farms where milo grown (OR = 4.19) compared to men(OR = 2.15). Men: lower risk of glioma on farms growing corn, rye or soy beans. Pesticide applicators never washing face and hands immediately after applying had increased risk of glioma (women OR = 10.5; men OR = 2.71).
Behrens et al./ 2012/Europe (9 countries)	Uveal melanoma	Case-control/ Questionnaire - Pathology reports	293 cases /44% women 3,198 controls/34% women 34% women	Crop type; farm tasks; pesticide mixing and/or application; PPE use; duration of pesticide exposure	No	No	Gender as covariate	No increased risk of uveal melanoma in men or women for pesticide exposure and occupational activities in farming.

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TABLE II. (*Continued.*)

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Pesticide poisoning								
Bell et al./2006/US	High pesticide exposure event (HPEE)	Case-control/ questionnaire	369 pesticide applicators, spouses/17% women 738 controls/17% women	Work tasks, frequency engaged in pesticide application, type of pesticide, type of pesticide delivery method (i.e. vehicle, backpack, sprayer)	Yes (with gender differentiation)	Yes, cases analyzed for frequency of pesticide application	Gender stratification	Women applying pesticides over 6 days/year more likely to experience pesticide exposure event compared to 5 days/year (OR = 1.7); women wearing gloves and not storing pesticides at home less likely to experience pesticide exposure event. Men: increased application days per year, not removing work boots when entering home, and not wearing PPE increased the risk for a pesticide exposure event.
Calvert et al./ 2008/US	Acute pesticide poisoning	Cohort/Pesticide poisoning database	3,271 farm worker cases/32% women 2,423 farm owner cases/29% women	Type of exposure to pesticide (i.e. drift, contact with treated surface); crop type; pesticide handling; use of PPE	Yes (with gender differentiation)	Yes, poisoning rates calculated based on estimated hours (full-time equivalent)	Gender stratification	Incidence rate of pesticide poisoning was twice as high for women farmers (141.8 per 100,000 FTE) than men farmers (74.7 per 100,000 FTE). Women handled pesticides less than. Women less likely to use PPE (27%) than men (40%).
Kachaiyaphum et al./2010/ Thailand	Abnormal serum cholinesterase (SChE) levels	Cross-sectional/ Questionnaire/ Blood samples	350 farmers/38% women	Type of work; duration of pesticide exposure; frequency pesticide use; cholinesterase level; PPE use; practices during and after spraying	No	No	Gender as covariate	Men more likely to develop abnormal serum cholinesterase levels than women (adjusted OR = 5.80)

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TABLE II. (*Continued.*)

Studies		Study design & sampling		Exposure assessment			Data analysis	Health outcome
Author/ Year/ Country	**Outcomes**	**Study design/ Data sources**	**Sample/% Women**	**Occupational exposure indicators**	**Task assessment**	**Exposure duration or frequency**	**Gender treatment**	**findings by gender**
Zhang et al./ 2011/China	Acute pesticide poisoning	Cross-sectional/ Questionnaire	910 applicators/ 39% women	Crop types, application methods; application time; PPE use	No	No	Gender as covariate	Higher proportion of women reported acute pesticide poisoning than men (13.1% vs. 6.1%, $p < 0.001$). Acute pesticide poisoning was 70% more likely to occur among women than men (AOR = 1.70, 95% CI:0.99–2.91).
Kasner et al./2012/US	Acute pesticide poisoning	Cohort/Pesticide poisoning database	2,534 cases of acute pesticide/ illness and injury; 30% women	Pesticide exposure type (i.e. drift, contact with treated surface); crop type; pesticide handling; use of PPE	Yes (with gender differentiation)	Yes, poisoning rates calculated based on estimated hours (full-time equivalent)	Gender stratification	Incidence rate for women farmers nearly twice that of men (OR = 2.2); more women reported exposure due to off-target drift (80%) than men (65%), fungicides (39%) compared to 30%), and inorganic compounds (30% to 20%). More women had respiratory (42%) gastrointestinal (50%) and neurological problems (63%) compared to men (30%, 35%, and 50% respectively). Men reported greater exposure to cholinesterase inhibitors (36% compared to 30%). Exposed women more likely to work in small fruit crop production (46%) than men (21%). Exposed men more likely to work in tree fruit crop production (36%) than women (10%). Women: higher incidence rates among all age groups except youngest (15-17) and oldest (55-64); more likely to report illness or reaction when exposed.

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TABLE II. (*Continued.*)

Studies		Study design & sampling		Exposure assessment			Data analysis	Health outcome
Author/ Year/ Country	**Outcomes**	**Study design/ Data sources**	**Sample/% Women**	**Occupational exposure indicators**	**Task assessment**	**Exposure duration or frequency**	**Gender treatment**	**findings by gender**
Other health outcomes								
Tuchsen & Jensen/2000/ Denmark	Parkinson's disease	Cohort/Registry	949 Parkinson's cases/36% women	Job title	No	No	Gender stratification	Increased risk of Parkinson's disease among men self-employed farmers.
Hwang et al./2001/US	Hearing loss	Cross-sectional/ Questionnaire	1622 farmers/38% women	Use of noisy farm equipment; duration of use; average hours worked per day; work status on farm; farm type	No	Life-time exposure to noisy farm equipment (hours)	Gender as covariate	Men are at higher risk of hearing loss than women (R = 2.53; 95% CI = 1.98 – 3.23). Men had higher exposure to noisy farm equipment than women.
Kimbell-Dunn/ 2001/New Zealand	Respiratory symptoms	Cross-sectional/ Questionnaire	1,706 farmers/24% women	Work exposures; chemical exposures; farm type	Yes (no gender differentiation)	No	Gender as covariate	Women had higher incidence of Dyspnea (OR = 1.7, 95% CI = 1.3 – 2.3) and lower incidence of chronic bronchitis (OR = 0.7, 95% CI = 1.5 – 1.03) than men.
Park et al./2001/US	Dermatitis	Cross-sectional/ Questionnaire	638 farmers & spouses/40% women	Work tasks (i.e. pesticide application; animal work) and specific exposure agents (i.e. pesticides, cleaning items, detergents, food products); PPE use; health/ safety training	Yes (with gender differentiation)	No	Gender stratification	9.6% of men and 14.4% of women reported dermatitis. Rates of exposure to causal agents were lower among women. Men: history of allergy associated with higher risk. Women: higher education and exposure to petroleum products related to higher risk.

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TABLE II. (*Continued.*)

Studies		Study design & sampling		Exposure assessment			Data analysis	Health outcome
Author/ Year/ Country	**Outcomes**	**Study design/ Data sources**	**Sample/% Women**	**Occupational exposure indicators**	**Task assessment**	**Exposure duration or frequency**	**Gender treatment**	**findings by gender**
Melbostad & Eduard/2001/Norway	Respiratory and eye irritation	Cross-sectional/ Questionnaire; personal exposure assessment	8,482 farmers/ 34% women 106 farmers tested/ 19% women	Work tasks (i.e. farm handling, animal, manuring); ppm measures for tasks; number of years worked; weekly work hours	Yes (with gender differentiation)	No	Gender stratification	Prevalence of work-related irritation symptoms was 71% in men farmers compared to 56% in women farmers.
Holmberg et al./ 2004/Sweden	Osteoarthritis	Case-control/ Questionnaire	778 cases/57% women 695 controls/58% women	Job title; years of farm work	No	No	Gender stratification	Women who worked for 11-30 years in farming had an increased risk of osteoarthritis (OR = 2.1). Working on the farm and being overweight produced an increased risk of developing osteoarthritis in men (OR = 3.1) and women (OR = 4.4).
Lembke et al./ 2004/Sweden	Respiratory health	Case-control/ questionnaire	1,134 farmer cases/11% women 1,843 controls/51% women	Job title	No	No	Gender stratification	Prevalence of respiratory symptoms where generally higher among farmers compared to controls: 14% wheezing in women farmers compared to 12% in controls; high prevalence of asthma was found among young women farmers. 8% work-related wheeze in men farmers compared to 2% in controls; prevalence of asthma in men farmers increased by age. Men farmers had a higher prevalence of work-related wheeze than controls (OR=1.74).

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TABLE II. (*Continued.*)

Studies		Study design & sampling		Exposure assessment			Data analysis	Health outcome
Author/ Year/ Country	**Outcomes**	**Study design/ Data sources**	**Sample/% Women**	**Occupational exposure indicators**	**Task assessment**	**Exposure duration or frequency**	**Gender treatment**	**findings by gender**
Faria et al./ 2005/Brazil	Asthma and chronic respiratory disease	Cross-sectional/ Questionnaire	1,379 farmers/ 45% women	Crop type; machine type; frequency and type of pesticide exposure	No	Days per month of chemical exposure	Gender as covariate	Women had higher incidence of asthma OR = 1.51; 95% CI:1.07-2.14) and chronic respiratory disease (OR = 1.34; 95% CI 1.00-1.81).
Parikh et al./ 2005/India	Green tobacco sickness; reproductive health	Case-control/ Questionnaire; Medical examination	685 cases/33% women 655 controls/40% women	Job title	No	No	Gender stratification	Prevalence of green tobacco sickness was higher among women (55.7%) than men (42.66%). 98% of women are non-smokers suggesting women had mainly occupational exposure to tobacco.
Eckerman et al./ 2007/Brazil	Neurological health	Cross-sectional/ Questionnaire; neurobehavioral test battery (BARS)	38 rural youth/ 53% women 28 urban youth/ 36% women	Pesticide exposure index: work tasks (i.e. pesticide handling); work hours per day/ week; years of farm work	No	No	Gender stratification	Average exposure was higher for women (55.6) than men (25.4) among rural (agricultural) groups.
Trang et al./ 2007/Vietnam	Skin ailments	Case-control/ Questionnaire	636 farmers/66% women	Type of farm work; sources of irrigation; contact with wastewater; use of personal protective measures	No	Person time at risk	Gender as covariate	Incidence of skin ailment was higher among women than men (RR = 2.02, 95% CI 1.46—2.49, adjusting for age).
Alterman et al./ 2008/US	Acute and chronic health conditions	Cross-sectional/ Questionnaire	7137 farm operators/7% women	Job title; years of farm work; years of non-farm work	No	No	Gender stratification	Women reported more respiratory and musculoskeletal problems, fewer hearing problems.

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TABLE II. (*Continued.*)

Studies		Study design & sampling		Exposure assessment			Data analysis	Health outcome
Author/ Year/ Country	**Outcomes**	**Study design/ Data sources**	**Sample/% Women**	**Occupational exposure indicators**	**Task assessment**	**Exposure duration or frequency**	**Gender treatment**	**findings by gender**
Bretveld et al./ 2008/Holland	Reproductive health	Cross-sectional/ Questionnaire	1,058 farmer couples/10% women farmers/1,408 control group	Job title	No	No	Gender stratification	Among primigravidous couples, when women were farmworkers, there was a twofold increased risk of prolonged TTP (time-to-pregnancy) and a three-fold increased risk of abortion than couples with men as farmworker.
Cha et al./2009/ South Korea	Osteoarthritis; intervertebral disorders	Cross-sectional/ Hospital records	7,085 farmers/48% women 79,147 other workers/ 53% women	Job title	No	No	Gender stratification	Women farmers reported higher prevalence of chronic disease and greater number of doctor visits and hospitalization than other occupations. Men farmers had lower prevalence of hypertension and diabetes than other occupations.
Martins-Filho et al./ 2011/Brazil	Actinic cheilitis	Cross sectional/ Questionnaire; Clinical examination	240 famers/10% women	Cumulative exposure time (years); daily exposure time (hours)	No	Cumulative exposure time (years); daily exposure time (hours)	No	Exposure time to solar radiation was higher among men than women. Incidence of Actinic cheilitis higher in men (Crude PR = 2.72, 95% CI = 1.52 – 4.90).
Moisan et al./ 2011/France	Parkinson's disease	Cross-sectional/ Registry	1,659 cases/50% women	Job title; regional farming data (crops grown and farm density)	No	No	Gender stratification	Prevalence of Parkinson's disease was higher in men than women (OR = 1.52), especially among men working on farms specialized in fruits or permanent crops.
Humann et al./ 2012/US	Hearing loss	Cohort/ Questionnaire/ Clinical screening tests/ Audiometry	1568 participants/ 56% women	Lifetime exposure engaged in 11 agricultural or rural activities	Yes (with gender differentiation)	Lifetime exposure	Gender stratification	Men spent significantly more years than women in 11 agricultural tasks; hearing loss greater among men farmers than men non farmers and among women farmers than women non farmers; women spent fewer years performing farm tasks than men, faced less exposure.

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TABLE II. *(Continued)*

Studies		Study design & sampling		Exposure assessment			Data analysis	Health outcome
Author/ Year/ Country	Outcomes	Study design/ Data sources	Sample/% Women	Occupational exposure indicators	Task assessment	Exposure duration or frequency	Gender treatment	findings by gender
Liu X et al./ 2012/China	Back pain	Cross-sectional/ Questionnaire; population-based survey/ Registry	2,045 farmers/ 48% women	Agricultural activities	No	No	No	Back pain was reported by 40.7% of women and 36.3% of men ($P = 0.041$). Women more likely to have back pain than men (OR 1.22; 95% CI: 1.09–1.36).
Peraza et al./ 2012/El Salvador	Kidney disease	Cross-sectional/ Questionnaire; Blood samples	383 farmers/48% women 664 non-farmers/ 61% women	Crop type; farm altitude	No	No	Gender stratification	Kidney function decreased most on sugarcane farms or cotton plantations (compared to corn-farmers) with men (OR = 3.1) and women (OR = 2.3). Kidney function reduced for both men and women as years of work in agriculture increased.

in agricultural work. The outcomes under study included 15 (33%) on injuries and mortality, 6 (13%) on cancers or tumors, 5 (11%) assessing acute pesticide poisoning, 4 (9%) on other chronic illnesses (kidney disease, osteoporosis), 4 (9%) on respiratory illnesses, 3 (7%) on neurological health, 3 (7%) on skin disorders, 2 (4%) on hearing loss, and additional studies on reproductive health, back pain, and green tobacco sickness, respectively.

Cancer

Studies focusing on cancer (n = 6) as their primary health outcome [Lee et al., 2005, 2008; Mills et al., 2005; Dodge et al., 2007; Ruder et al., 2009; Behrens et al., 2012] generally found men and women reporting differential cancer outcomes, especially as some cancers are sex/gender specific (i.e. prostate for men, uterine and cervical for women). Across the studies, men were more diagnosed with elevated rates of lung, esophageal, stomach, brain, bone and glioma cancers, while women had increased risk of cancers of the esophagus and stomach. Farmworker men were found to have higher rates of prostate cancer compared to a general population, while women reported more uterine, cervical, and breast cancer than the general population. Dodge et al. reported that the age of cancer diagnosis was higher for men than for women [Dodge et al., 2007].

All studies showed sex/gender differences between exposure and cancer diagnosis. In their research of rural South Korea, Lee and colleagues found that as regional farm exposure (i.e. number of farm households, farm size, crop type) increased, men showed higher cancer mortality of the esophagus, stomach, brain and leukemia, while women had elevated cancer mortality for esophageal and stomach cancers [Lee et al., 2008]. Differences were also noted on the tasks involved for men and women. Lee et al. [2005] noted an increase in risk of brain cancer among men while using pesticides. Mills et al. [2005] speculate that the higher risk of leukemia among women farmworkers working with chemicals may be due to involvement in cutting and harvesting of crops, putting them into direct contact with pesticide-sprayed crops [Mills et al., 2005]. Many chemicals used in these settings are also documented as endocrine disruptors, which can affect women differently than men [Mills et al., 2005].

Injuries and Mortality

Differences in injury rates for men and women varied in the reviewed papers (n = 15), with the majority of studies reporting higher incidence of injuries among men farmers. This difference was attributed to the tasks assigned to men and women, but also the higher number of men and their greater number of hours worked in agriculture in the study populations. In these studies, men are more likely to use

machinery and tractors [Locker et al., 2002; McCurdy et al., 2003; Stallones and Beseler, 2003; Virtanen et al., 2003; Dimich-Ward et al., 2004; Simpson et al., 2004; Carlson et al., 2005; Hendricks and Hendricks, 2010; Lee et al., 2012], while women more often worked with farm animals [Alexe et al., 2003; Virtanen et al., 2003; Pickett et al., 2008; Hendricks and Hendricks, 2010] and engaged in hoeing [McCurdy et al., 2003] or worked with chemicals [Marcum et al., 2011]. Each task was related to its own unique injury profile.

One study found that injury risk increased with levels of stress for women much more than men because women release epinephrine with stress, which could increase risk of injury [Simpson et al., 2004]. The two other injury studies assessing exposure duration and frequency [McCurdy et al., 2003; Stallones and Beseler, 2003] found higher frequencies of men injury reports but equivalent injury rates when accounting for exposure time. Age was also closely related to injury: older men reported higher injury rates than older women [Locker et al., 2002; Dimich-Ward et al., 2004; Pickett et al., 2008], likely because men continue to work in hazardous tasks even after retirement age [Pickett et al., 2008] and the onset of age-related physiological changes [Dimich-Ward et al., 2004]. Men were also more likely to engage in more hazardous tasks [Rautiainen et al., 2009; Van den Broucke and Colemont, 2011] such as working with tractors [Carlson et al., 2005], while women practiced greater safety than men while handling animals and in fall prevention [Van den Broucke and Colemont, 2011].

Pesticide Poisoning

Studies on pesticide poisoning (n = 5) also attributed sex/gender variation in their results. Two studies found that the incidence of a pesticide exposure event were lower for women than men [Bell et al., 2006; Kachaiyaphum et al., 2010]. Bell and colleagues report that among men, increased application days per year, not removing work boots while entering home, and not wearing personal protective equipment increased the risk of an exposure event and its related health symptoms [Bell et al., 2006]. Two other studies found the opposite relation, where women farmworkers had higher incidence of pesticide exposure than men [Zhang et al., 2011; Kasner et al., 2012]. Zhang and colleagues [2011] showed that a higher proportion of women reported acute pesticide poisoning; while Kasner et al. [2012] report that women had higher incidence with exposure to fungicides and inorganic compounds, though men were more frequently exposed to cholinesterase inhibitors [Kasner et al., 2012]. The difference in exposure patterns were attributed to men and women working on different crops, as well as each having biologically different responses to pesticides [Zhang et al., 2011; Kasner et al., 2012]. Another revelatory finding by Calvert et al. [2008] was that though women were predominant as processing/packing plant workers, men had higher incident rates of acute pesticide poisoning in these settings; paradoxically, incidence rates were higher among women farmers in agricultural settings where they work much less frequently and are significantly less likely to be pesticide handlers than men [Calvert et al., 2008].

Other Health Outcomes

Other reviewed studies included research on skin ailments [Park et al., 2001; Trang et al., 2007], green tobacco sickness [Parikh et al., 2005], reproductive health [Parikh et al., 2005; Bretveld et al., 2008], respiratory illnesses [Kimbell-Dunn et al., 2001; Melbostad and Eduard, 2001; Lembke et al., 2004; Faria et al., 2005], kidney disease [Peraza et al., 2012], osteoarthritis [Holmberg et al., 2004; Cha et al., 2009], actinic cheilitis [Martins-Filho et al., 2011], hearing loss [Hwang et al., 2001; Humann et al., 2012], Parkinson's disease [Tuchsen and Jensen, 2000; Moisan et al., 2011], back pain [Liu et al., 2012] and neurobehavioral performance [Eckerman et al., 2007]. All studies indicated noticeable sex/gender differences for the studied health outcomes and attributed such differences to several factors including, agriculture tasks on the farm, years of working in agriculture work, workloads, history (or hereditary) of illness, and lifestyles (such as smoking and weight), sociocultural and behavioral explanations, and biological differences.

DISCUSSION

This review found that farm work remains hazardous for both men and women in unique ways, and that the relationship between exposure and outcome is shaped by sex/gender. The following discussion analyzes the findings of this study, identifying shortfalls in gender-sensitive analyses and possible areas of improvement within this field.

Sex/Gender Differences in Outcomes

The reviewed studies found substantial differences between men and women in health outcomes relating to farm work, although researchers must be cautious in generalizing across contexts. Inconsistencies were common: some studies identified higher injury rates among men farmworkers, while the reverse was found elsewhere. Studies of pesticide-related symptoms also reported opposing data on rates for men and women. These reported inconsistencies highlight the complex context-specific conditions that give rise to health outcomes among farmworkers, as well as the

strengths and weaknesses of different methodologies utilized to collect and categorize outcomes data (issues that will be addressed below).

One consistency across numerous studies was a relationship between age and sex/gender. Men were found to engage in farm tasks much more frequently in their youth as well as into old age. This led to higher frequencies of injuries and mortalities in both age groups. Older men, in particular, had the highest fatality rates, explained as a potential by-product of their continued work in hazardous physical environment despite age-related physiological changes. Yet it is likely that these outcomes would appear much different in farming contexts where women were much more likely to engage in work later into life, such as in poorer communities. More broadly, studies hypothesized physiological, biological, and social explanations to explain differences in health outcomes; yet most did not analyze occupational risk factors and social determinants that would help establish evidence to support these claims.

Sample, Design, and exposure Assessment

The vast majority of reviewed studies marginalized sex/gender at an early point in their research, primarily by not recruiting enough women participants to analyze gender. In most studies, men represented the majority of those sampled, reflecting the proportion of men in the formal agricultural workforce or among those in the relevant exposure category. However, in epidemiological studies that establish risk associations, representativeness is less important than securing adequate sample sizes to garner statistically significant results.

Further, for research to assess exposure/outcome rates using equivalent exposure duration and frequency measures, oversampling women may not be enough; rather studies might also consider collecting equivalent exposure frequencies and durations for each sex/gender group. If women participants largely work or engage in specific exposure-related tasks for fewer hours than men participants, researchers may have to include more women than men to collect equivalent exposure data.

Large longitudinal studies are one approach to increase catchment of women participants, yet there was a notable dearth of these studies in the review, likely because farm workforces are seasonal and migrant. While long-term prospective studies prove difficult to implement in such contexts, shorter-term studies with larger catchment areas may be possible and would be valuable in understanding acute health concerns like pesticide poisonings, injuries, and musculoskeletal complaints. Alternately, many farming communities in developing countries have more stationary labor forces and could be a valuable location to engage in occupational health research, addressing both issues of equity and scientific rigor in research.

Another trend was for large studies on injury, mortality, and chronic illness to gather data from hospital records and death certificates, an approach with known limitations. For example, mortality studies run a potential risk of excluding farmer "spouses" from their samples, as many who do engage in farm work may not be identified as farmers on their death certificates, substantially deflating the number of women cases identified through surveillance programs. Concerns over selection bias when relying on hospital records are also well warranted. Bell et al. [2006] found that only 15% of farmers reporting pesticide poisoning symptoms sought medical attention; while another California study reported only 22% of workers had health insurance [McCurdy et al., 2003]. In contexts where health care is not guaranteed to low-income and/or undocumented workers, this is a fundamental methodological concern that was not problematized by studies using this methodology.

Echoed in our findings, one of the important methodological concerns in this literature is that a majority of studies on farmworker populations continue to pool men and women together for analysis, effectively silencing findings of any gender differences in outcomes or exposures. A second methodological concern which requires reflection is the analysis of sex/gender as a covariate. As Messing and colleagues [2009] suggest, this approach has its limitations. Their study of population wide data on musculoskeletal disorders in Canada analyzed the same dataset with and without sex/gender stratification, finding a greater range and stronger associations between occupational exposures, individual characteristics and musculoskeletal health in the stratified analysis.

Another area of emphasis that must be addressed in future studies is how best to assess exposure in ways that capture gender differences. The use of job title or crop type to classify employees may also minimize the diversity of risks facing workers within the same job or working the same crops. This danger becomes more pronounced when equating women 'farmers' or 'spouses' with men 'farmers' or 'spouses' working similar crops. The type of tasks and frequency and intensity of exposure within these occupational categories are diverse when comparing some women to other women and men to other men, and different still when comparing men and women.

Task differentiation has proven a valuable indicator to identify health risk factors. McCurdy and peers' injury study highlighted manual harvesting and machine operation as major sources of injury in California's agriculture industry [McCurdy et al., 2003], while several other articles found machinery as a leading cause of injury or death, especially among men [Locker et al., 2002; Pickett et al., 2008; Lee et al., 2012]. Papers have often speculated that these observations are a result of task differentiation and exposure-

time at work and home, yet few studies evaluated task and exposure-time by sex/gender. In particular, the lack of exposure-time or frequency measures in this literature severely limits the ability of researchers to identify outcome rates in relation to occupational exposure for men and women.

There is also a need to account for physiological differences between men and women (i.e. anthropometric measures such as height and weight, body fat percentages and hormonal, chemical and organ differences). For instance, Mergler [2012] found neurotoxic exposure research has largely ignored the influence of sex/gender on exposure to pesticides despite the variables' evident impacts. The sociological literature also foregrounds this interaction between physiology, tasks, tools and health. Tools of the farm trade have often been conceived as masculine objects and may therefore be designed with men's physiology in mind [Brandth, 2002, 2006]. Women using hand or machine tools not designed for their anatomical dimensions may face additional negative health consequences, especially injury or musculoskeletal problems. Future injury studies may attempt to incorporate indicators on tool 'awkwardness', 'discomfort', or other factors reflecting the ease of use of tools ranging from pesticide application devices and hand tools to large farm equipment between men and women.

There is a pressing need to research the use of hand tools such as hoes, shovels and sheers, as studies of agricultural workers using rudimentary equipment are underrepresented in the epidemiological literature. This reality has clear ethical dimensions, as most of the world's farmers and especially women farmers in disadvantaged communities work using these tools [ILO, 2004, 2007; USDOL, 2005]. These settings where the vast majority of farmer work-related injuries and deaths take place, the lack of research among these populations silences the global inequities they bear the brunt of.

Women and "Other" Occupational issUes on the Farm

Research on farmworker health has struggled to assess the occupational risks affecting women farmworkers. In fact, numerous studies in the review found it difficult to categorize the exposures associated with women's health outcomes. Both Stallones and Beseler [2003] injury study and Simpson et al. [2004] found that women were injured at much higher per-hour rates than men while completing tasks categorized as "other." This "other" grouped various work activities that did not fall into frequently performed tasks on the farm. Bell et al. [2006] found that while most high pesticide exposure events for men occurred during pesticide application, applicator spouses reported "other" activities, such as walking by a freshly treated field, at fault as commonly as the application of pesticides. Calvert and colleagues [2008] found a similar gray area in reporting to health surveillance systems: women were less likely to be identified by traditional surveillance organizations–government agencies, workers' compensation and poison control centers. These observations convey a certain invisibility of women farmworkers to the primary methods of epidemiological study [London et al., 2002].

The role of women as homemakers is another issue that remains inadequately conceptualized, although housework activities expose women to risk factors that often aggravate workplace exposures [Messing et al., 2003; Habib et al., 2010]. While several studies touched on this issue, the vast majority did not include indicators that accounted for women's other occupation and its effect on farming-related health outcomes. Many studies asked participants about 'off-farm employment' without considering women's household responsibilities as a source of risk. Off-farm employment was often protective against many health outcomes for women, which could very well reflect poorer health outcomes for women engaged in farming activities compounded by increased homemaking responsibilities. Moreover, many of these women live on or near farms, which may compound exposures to farm chemicals and other risk factors.

The designation of 'farmer spouse' also presents a particularly tricky methodological challenge for researchers, as one US study identified 40% of farm 'homemakers' that frequently engaged in farm work tasks [Reed et al., 1999]. Studies including farmer spouses in their samples without assessing their engagement in farm work may confound occupational risk factors experienced by spouses who engage in farm work with spouses who do not.

Identifying farming activities that women engage in is important to a literature often tangentially exploring the experiences of the wives of farmers. This issue has been touched upon by Stallones and Beseler [2003] who attribute different injury reports between women and men to women's perceived role on the farm; women may downplay their work risks, as they view their role on the farm as minor, emphasizing instead their position as homemakers. Another study identified housework and the use of detergents and exposure to other irritants as likely risk factors for increased rates of dermatitis for women compared to men [Park et al., 2001]. These studies' hypotheses—that women's role as homemakers is instrumental in determining the prevalence, risk and understanding of injury and illness—highlight the need for research to deeply examine the relationship between farm work, housework and other non-occupational exposures.

CONCLUSIONS AND POLICY RECOMMENDATIONS

The literature suggests important health differences between men and women farmworkers; yet this body of

research does not adequately incorporate sex/gender analysis into its design and analytical approaches. A positive sign is that an increasing number of studies now assess occupational health outcomes using sex/gender-stratified analysis, although the vast majority do not. Even when research stratifies by sex/gender, it is rarely considered or used as a justification for study design, suggesting that understanding sex/gender differences is not a primary concern of disciplinary research.

The emerging framework of intersectionality research may offer a vehicle to improve understandings of sex/gender in occupational health research. Intersectionality research applied within the agricultural context would attempt to elucidate the intersection of class, gender, race, ethnicity, physiology, task, exposure to hazards, and other variables that impact health outcomes. Intersectional research lends itself more to qualitative methodologies and can be difficult to apply in quantitative research [Shields, 2008]. Notwithstanding, the quantitative papers we reviewed did not mention intersectionality as a possible research framework. Future studies might consider this approach as a means of eliciting data that produces more holistic understandings of the interactions of farm work and health outcomes.

Encouraging sex/gender-sensitive approaches in occupational health research of farmworkers requires funding agencies and academic publishing institutions to be proactive beyond current efforts. Funding agencies can place calls for proposals focusing on these issues, especially for research in traditional agriculture industries in developing countries. Specifically, international agencies and large foundations funding health research must lead in promoting sex/gender-based research in less-mechanized agriculture industries, as this is likely an area where great sex/gender disparities in health outcomes exist.

Scientific journals can contribute by calling for special issues and manuscripts focusing on this approach in studies of agricultural workers. Along these lines, the Gender and Work Technical Committee of the International Ergonomics Association, chaired by the lead author of this paper, has called upon journal editorial boards to consider incentivizing authors to adopt sex/gender-sensitive approaches in their research.

Research on farmer health has strides to take before understanding the role sex/gender plays in shaping health outcomes for this population. Utilizing sex/gender-sensitive methodologies, study designs and analyses will advance knowledge and help tailor future interventions and policies that meet the health needs of this diverse workforce. This issue is more than an academic argument over methodological merit: the subjects of this research are 50% of the worlds' workforce [ILO, 2009] —mostly low-income people living in developing economies, 40% women and 60% men farmworkers [FAO, 2011a], who stand to benefit from progresses made.

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