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Occupational health and safety in agriculture. A systematic review

Salud y seguridad ocupacional en la agricultura. Revisión sistemática

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Abstract

Introduction: The prevalence of occupational diseases in the agricultural sector is higher than in other industries, since agricultural workers are at higher risk of exposure to different chemicals and pesticides, and are more prone to occupational accidents.
Objective: To conduct a review of recent literature on occupational health and risk in agriculture.
Materials and methods: A literature search was conducted in PubMed, SciencieDirect and Scopus using the following search strategy: type of articles: original research papers; publication language: English; publication period: 2006-2016; search terms: "agricultural health", "agrarian health", "risk factors", "epidemiology", "causality" and "occupational", used in different combinations ("AND" and "OR").
Results: The search yielded 350 articles, of which 102 met the inclusion criteria. Moreover, 5 articles were found in grey literature sources and included in the final analysis. Most research on this topic has been conducted in the United States, which produced 91% (97/107) of the articles included in the review.
Conclusions: Most studies on agricultural health focused primarily on the harmful effects of occupational exposure to agrochemicals and pesticides, and the consequences of occupational accidents. However, since more than 90% of these studies come from USA, a more comprehensive approach to agricultural health is required, since what is reported here may be far from the reality of other regions, especially Latin America.
Keywords: Agricultural Workers' Diseases; Agrochemicals; Occupational Health; Wounds and Injuries (MeSH).

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Resumen

Introducción. En el sector agrícola la prevalencia de enfermedades profesionales es más alta que en otras industrias, ya que los agricultores, debido a las actividades que deben realizar, tienen un mayor riesgo de exposición a diferentes químicos y pesticidas, y son más propensos a sufrir accidentes laborales.
Objetivo. Realizar una revisión de la literatura sobre salud y riesgo ocupacional en el sector agrícola.
Materiales y métodos. Se realizó una búsqueda de la literatura en PubMed, SciencieDirect y Scopus. Se utilizó la siguiente estrategia de búsqueda: tipo de artículos: investigaciones originales; idioma: inglés; periodo de publicación: 2006-2016; términos de búsqueda: "agricultural health", "agrarian health", "risk factors", "epidemiology", "causality" y "occupational", usados en diferentes combinaciones ("AND" y "OR").
Resultados. La búsqueda arrojó 350 artículos, de los cuales 102 cumplieron los criterios de inclusión. Además, se agregaron 5 artículos encontrados en fuentes de literatura gris. El país en el que más se ha investigado sobre este tema es EE. UU., ya que produjo el 91% (97/107) de los artículos incluidos.
Conclusiones. La mayoría de estudios se centró en los efectos de la exposición ocupacional a químicos y pesticidas y las consecuencias de los accidentes laborales; sin embargo, ya que más del 90% de estos proviene de EE. UU., se requiere una discusión más integral sobre la salud en la agricultura, pues lo reportado aquí puede distar mucho de la realidad de otras regiones, especialmente de Latinoamérica.
Palabras clave: Agroquímicos; Enfermedades de los Trabajadores Agrícolas; Heridas y traumatismos; Salud laboral (DeCS).

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Introduction

It is widely believed that many important human diseases originated with the advent of agriculture.[1] Nowadays, there are legislative instruments to regulate health in the agricultural sector, as well as established concepts explaining what both human and animal health entail for such sector. For example, when addressing safety and health in agriculture, the International Labor Organization (ILO) defines agricultural health as the promotion of a safe and healthy environment for human beings that take part in farming activities;[2] in addition, according to the Food and Agriculture Organization of the United Nations (FAO), agricultural health is the primary health of animals, plants, products and by-products obtained from both sources, soil, water, air, and people, and the close relationship between them, which incorporates agro-ecological science principles to promote food security and sovereignty, and popular participation through the formulation, implementation and monitoring of policies, plans and programs for the prevention, control, and eradication of pests and diseases.[3]

Likewise, the National Cancer Institute, the National Institute of Environmental Health Sciences and the Environmental Protection Agency (EPA) of the United States, within the framework of the Agricultural Health Study,[4] have conducted several studies where the main objective was to evaluate agricultural health, understood as the interaction between agricultural exposures and the development of cancer and other diseases in agricultural workers.[4]

In comparison with other industries, agriculture provides a significant amount of jobs worldwide. Nearly 40% (450 million) of workers are in the farming sector and represent more than 40% of total agricultural labor force.[5] In 2016, 40% of the total population of developing countries worked in the agricultural sector or in agriculture-related activities, while in developed and industrialized countries, only 3% of their population did it.[6] However, even in industrialized countries, this sector constitutes a significant portion of the total workforce.

It has been estimated that by 2013 there were about 12 million farms in the 27 European Union member countries, with an average extension of 14.2 hectares, of which, 95% were family farms.[7,8] In the case of Central and North America, in 2010, there were around 4 million farms in Mexico occupying 932 149 million hectares of land, while in USA, there were 2.32 million farms using about 56 667 million hectares;[9] likewise, in Canada, around 64 232 million hectares were used as agricultural land by 205 000 farms in 2011.[10] Regarding Oceania, in 2014 there were 135 000 farms in Australia using around 394 million hectares of land,[11] while in New Zealand, nearly 78 549 farms were found in approximately 555 000 hectares by 2012.[12] Finally, in countries such as Brazil, about 33.81% of the land was used for agricultural purposes, and approximately 21 203 million hectares of land were used for cereal production, according to data reported for 2015.[6]

Similarly, according to the ILO, about 317 million people worldwide suffer from occupational accidents, and 2.34 million die due to occupational accidents and diseases.[2] In Latin America, about 11.1 fatal accidents take place for every 100 000 workers in the industrial sector, while in the agriculture industry and the agricultural services provision services sector, there are about 10.7 and 6.9 fatal accidents for every 100 000 workers.[13] In addition, in some countries, several important economic sectors such as mining, construction, agriculture, and fishery have the highest incidence of occupational accidents. In this regard, according to the Bureau of Labor Statistics, in 2013 the injury rate of agricultural workers exceeded the 40%, being the highest among all industries; also injury rates in crop production and animal production workers were 5.5 and 6.7 for every 100 workers, respectively. In contrast, injury rate in workers from all industries was 3.8/100.[14]

In 2013, 479 occupational deaths were reported within the agricultural industry in USA, that is, a fatality ratio of 22.2/100 000, which is significantly higher than the 3.2/100 000 ratio reported for all occupations in the same country.[15] Somehow, occupational deaths in the agricultural sector in other countries are significantly lower. For example, in Canada and Finland death ratios for 2013 were 11.6/100 000 and 6.5/10 000, respectively.[16,17]

Regarding, non-fatal injuries and diseases, monitoring them is a more challenging task, given the scarcity of data and population based studies. In USA, the non-fatal injury rate in agricultural workers ranged from 5/100 000 to 170/100 000 between 2002 and 2017.[15,18,19] When it comes to occupational diseases in the agricultural sector, these are even more difficult to quantify since they are rarely associated with situations happening at the workplace, and in fact, there is not any reporting mechanism in USA.

According to surveys conducted by the Bureau of Labor Statistics in 2014, occupational disease rate in agricultural workers from USA was 3.1/1 000.[15] However, sensitivity and specificity of these data need to be considered when taking into account such reports, since they greatly depend on the information provided by employers. In said country, most occupational diseases are skin problems (56%), chronic traumas (14%) and respiratory problems (13%). On the other hand, in Finland, an occupational diseases ratio of 6.4/1 000 in this sector has been reported, out of which 40% represent respiratory disorders, 21%, skin problems, and 31%, joint disorders.[20,21]

However, most studies on occupational health and safety in agriculture carried out in recent years have focused on workers inhabiting industrialized countries going through rapid socioeconomic and political changes.[22]

In developing countries, the rapid emergence of industries such as chemical production, car manufacturing, and agriculture has resulted in fewer safety regulations compared to developed countries, which in turn has worsened their existing environmental and occupational problems.[23] In this sense, there is strong evidence that there is a correlation between health condition and socioeconomic status, and that, in general, people's health in low-income countries is affected by several factors, including environmental, cultural, and socioeconomic conditions .[23,24]

Other public health problems affecting these countries include outbreaks of zoonotic diseases and of infections caused, on the one hand, by enteric pathogens due to the consumption of contaminated food, and, on the other, by antimicrobial-resistant organisms acquired in animal production activities.[25] Therefore, in these countries, many of environmental, occupational, and public health problems are affected by the global economy and are too complex to understand, thus their mitigation requires jointly actions by both, actors from several disciplines, and representatives of the different industries.

Since most studies on agricultural health conducted in developing countries focus on small rural communities, further research on this topic in these countries with a broader scope is urgently required. Taking the above into account, the aim of this paper was to conduct a review of recent literature on occupational health and risk in agriculture.

Materials and methods

In April 2016, a systematic review was carried out in the ScienceDirect, Scopus and PubMed databases based on the PRISMA guidelines for conducting systematic reviews,[26] and the methodology proposed by Cardona.[27] Exhaustivity was guaranteed by using non-DeCS (Descriptors of Health Sciences) descriptors as search terms. Also, sensitivity was ensured using descriptors registered in the DeCS or the Medical Subject Headings (MeSH) thesauruses as search terms. The combination of Boolean operators, based on the research question, provided specificity. The "agricultural health "OR" agrarian health" general search path was used alone or combined with the terms "risk factors" OR "epidemiology" OR "causality" OR "Occupational" through the following operators "AND ALL" or "AND". In addition, "2006 to present", "Published 2006 to present" and "published in the last 10 years" publication time filters were used in the searches conducted in ScienceDirect, Scopus, and PubMed, respectively, thus the search included scientific literature published between April 2006 and April 2016.

The specific search combinations used in each database are shown below:

ScienceDirect: TITLE-ABSTR-KEY ("agricultural health" OR "agrarian health") and ALL ("risk factors" OR "epidemiology" OR "causality" OR "Occupational").

PubMed: (("agricultural health" [Title/Abstract] OR "agrarian health" [Title/Abstract]) AND ("risk factors" OR "epidemiology" OR "causality" OR "occupational").

Scopus: TITLE-ABS-KEY ("agricultural health" OR "agrarian health") AND ALL ("risk factors" OR "epidemiology" OR "causality" OR "occupational").

Finally, the citations of the studies retrieved in the searchers, together with their respective abstracts, were imported into the Thomson Reuters EndNote® software manager, 2011 Version, in order to remove duplicate references.

Inclusion and exclusion criteria

Only research articles written in English and published between April 2006 and April 2016 were considered for inclusion. Studies that were finally included for full analysis were required to follow a methodology that allowed the extraction of elements useful in the definition of the concept of agricultural health. Other articles that provided empirical evidence, based on retrospective and prospective findings, regarding agricultural health were also considered. On the other hand, studies in which the units of analysis were in vitro models, cells or those that were conducted only in laboratories were excluded. In order to ensure the reproducibility of the review, two researchers independently conducted the searches and selected the articles to be included for full analysis. Disagreements were solved through consensus.

The following data were extracted from all studies included in the review, and then entered into an information collection form for their analysis: general information (title, name of the journal in which the article was published, year of publication, and country in which the study was conducted); agricultural health topics addressed in the paper (occupational exposure to pesticides or to chemical products, agricultural health and safety, medical training and agricultural health); study type (retrospective, prospective, cohort, qualitative, exploratory, cross-sectional, case- control study), and the organizations involved in the making of each study (academic institutions, public institutions and government agencies).

Results

A total of 350 studies were retrieved after the initial search was carried out (ScienceDirect 23, Scopus 160, and PubMed 167). Once duplicates (n=180) were removed, 43 publications were excluded for full-text reading since, based on the reading of titles and abstracts, it was decided they did not meet the established inclusion criteria and did not provide useful information for the objective of the review. Out of the 127 studies selected for full-text reading, 25 were excluded based on the established exclusion criteria. Finally, 102 articles were included for full analysis. In addition, 5 studies that were published in journals that were not indexed in the databases but met the inclusion criteria were also included. It should be noted that these 5 gray literature studies were retrieved from Google Scholar. The studies screening and selection process is shown in Figure 1.

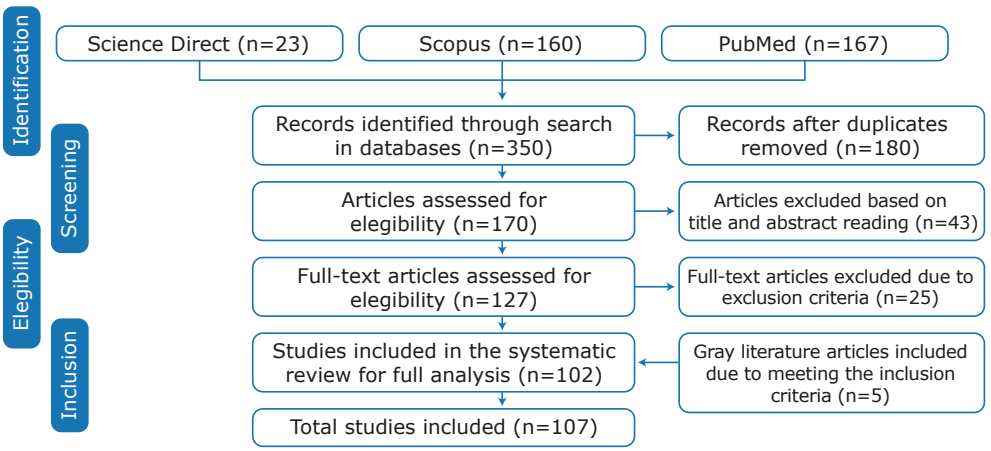

Figure 1. Studies selection flow diagram.[26,27]
Source: Own elaboration.

Despite the 107 studies were conducted in 11 countries, most of them (n=97) were carried out in USA, while the remaining 10 were conducted in the other 10 countries, including France and Canada. Furthermore, in the USA, studies were mainly carried out in the following States: California, Colorado, Iowa, North Carolina, Kentucky, Minnesota, Nebraska, New York, Texas, Washington, and Wisconsin.

Table 1 shows the journals, in a descending order, in which the studies were published; data regarding impact factor, publishing house, year, country and frequency of publication, and field of study of each journal are also shown. The journals in which most studies included were published were the Journal of Agromedicine, Environmental Health Perspective (n=22), and Environmental Health Perspective (n=19).

USA was the most frequent country of publication, followed by the United Kingdom and the Netherlands. Environmental Health Perspective had the highest impact factor for 2015 (8.44), followed by Journal of Cancer (5.531) (Table 1).

Table 1. General data of the journals in which the studies included in the review were published.

Journal name / # of studies published	Impact factor	Publishing house	Field of study	Publication frequency	Publication country
Journal of Agromedicine (n=22)	0.784	The Haworth Medical Press	Agricultural health and security of the rural worker	Quarterly	United States
Environmental Health Perspective (n=19)	8.44	US Department of Health and Human Services	Risk assessment; legal consequences and environmental health of children	Monthly	United States
Occupational and Environmental Medicine (n=8)	3.745	BMJ Publishing Group	Occupational health, risk assessment, and occupational diseases	Monthly	United Kingdom
Journal of Agricultural Safety and Health (n=4)	0.00	American Society of Agricultural Engineers	Health and safety intervention strategies; health policies, laws and regulations; professional development issues; impact and development of agricultural safety	Biweekly	United States
International Journal of Cancer (n=5)	5.531	John Wiley & Sons Inc.	Cancer screening and treatment; environmental associations with cancer	Biweekly	United States
American Journal of Epidemiology (n=6)	5.036	Oxford University Press	Assessment of the impact of pesticides and animal contact on health	Biweekly	United Kingdom
American Journal of Industrial Medicine (n=5)	1.632	John Wiley & Sons Inc.	Occupational diseases; environmental diseases; pesticides; cancer; occupational epidemiology	Monthly	United States
Annals of Epidemiology (n=6)	2.335	Elsevier BV	Risk factors related to agricultural injuries	Monthly	United States
Cancer Causes and Control (n=5)	2.680	Kluwer Academic Publishers	Cancer cases distribution within and among communities; factors associated with cancer risk; preventive and therapeutic interventions	Monthly	Netherlands
Journal of Occupational and Environmental Medicine (n=7)	1.630	Lippincott Williams & Wilkins Ltd	Occupational exposures in agriculture	Monthly	United States
American Journal of Respiratory and Critical Care Medicine (n=2)	1.524	American Thoracic Society (United States)	The journal published an special issue in both adult and pediatric asthma, patient care, and public health in pulmonary diseases, critical illness, and sleep disorders	Biweekly	United States
Annals of Occupational Hygiene (n=4)	1.03	British Occupational Hygiene Society, Oxford University Press (OUP)	Occupational health hazards and risks, especially their recognition, quantification, management, and control	Monthly	United States
The Canadian Journal of Neurological Sciences (n=3)	2.1	Cambridge University Press	Neurology and neurosciences; the journal is the official publication of the five member societies of the Canadian Neurological Sciences Federation	Bimonthly	Canada

Table 1. General data of the journals in which the studies included in the review were published. (continued)

Journal name / # of studies published	Impact factor	Publishing house	Field of study	Publication frequency	Publication country
Cancer Epidemiology Biomarkers & Prevention (n=4)	4.554	American Association for Cancer Research	Research on cancer causes, mechanisms of carcinogenesis prevention and survivorship	Monthly	United States
Chemical and Engineering News (n=3)	1.126	American Chemical Society	Chemistry as a profession and the interactions between chemistry and society in general	Weekly	United States
Emerging Infectious Diseases (n=3)	4.512	National Center for Infectious Diseases	Emerging diseases and public health prevention measures	Monthly	United States
Environment International (n=3)	4.929	Elsevier B.V.	Environmental sciences; public health and health impact assessment, environmental epidemiology; environmental health and risk assessment, environmental chemistry; environmental monitoring and processes, environmental microbiology and toxicology; environmental technology	Monthly	United Kingdom

Source: Own elaboration.

Agricultural health topics addressed in the studies

Agricultural health concepts addressed in the 107 studies, and inferred by us based on their full analysis, are shown in Table 2. Concepts were classified into seven categories.

Table 2. Main concepts of agricultural health inferred from the analysis of the studies included in the systematic review.

Concepts	Institution that mainly addresses the concept	References
Assessment of cancer and other diseases among farmers and their family members in relation to their occupational exposure in agriculture and their lifestyle.	National Cancer Institute	28,29
Aims of agricultural health aims. To reduce the risk of death from livestock-handling-related injuries and to ensure compliance with recommended practices regarding safe livestock-handling and proper facilities, especially when working with aggressive cattle.	Centers for Disease Control and Prevention (CDC)	30,31
Health and safety in farms. To implement better farm machinery safety and hazards control measures such reducing exposure of children to this machinery and making mandatory to wear helmets when riding quad bikes, motorbikes, and horses.	Australian Centre for Agricultural Health and Safety and School of Public Health, University of Sydney	32-35
Occupational health and risks in agriculture. To identify factors associated with work-related injuries in farmers. To provide better information about agricultural health policies and guidelines on good working practices to older farmers, such as policies governing the maximum work hours and the minimum rest hours per week, as well as guidelines about the proper distribution of farming tasks, and information on ergonomic advances and new farm equipment and technology.	Nebraska Department of Health and Human Services, Division of Public Health	36-38
Occupational risks and work-related injuries in farmers due to exposure to chemicals and to the environment.	The University of Iowa, School of Public health	39-41
Agricultural health and safety. To reduce the risk of work-related injuries in farmers through prevention initiatives aimed at achieving a full public health model based on of education interventions, safe farm equipment handling practices, and occupational safety and health regulations.	Canadian Centre for Health and Safety in Agriculture, University of Saskatchewan, Saskatoon, Canada	42,43
Safety and agricultural health. To eliminate occupational hazards by means of on-site inspections of farms, the identification of agricultural health-related concerns through clinical screenings, the implementation n of occupational health and healthcare education interventions aimed at these workers, and the creation of incentives for meeting occupational safety targets in farms.	Department of Occupational and Environmental Health, College of Public Health, University of Iowa	35,42,44

Source: Own elaboration.

Some of the agricultural health topics addressed in the studies reviewed include several occupational factors associated with the development of physical diseases such as age, workforce management, ethnicity, types of products used by workers in farms, work practices, agricultural machinery engineering controls, and the use of personal protection equipment, among others.[28,30,32,39,42,44] It should be noted that workforce varies significantly from one region to another. Also, the number of permanent employees working outside the farms has increased, which means a greater exposure to occupational risks.[45]

Furthermore, in USA, according to the 2014 Census of Agriculture, conducted by the United States Department of Agriculture, the average age of farm workers was 54.3 years, which may increase their susceptibility to the adverse effects of occupational exposure, for example, an increased risk of developing chronic diseases affecting the respiratory and the locomotor systems.[46]

Discussion

Agriculture is one of the most dangerous industries for workers in both, developing and developed countries.[1] In comparison with other industries, occupational accidents, chemical exposure, and fatality rates are higher in farm workers, and resources available for their compensation are scarce.[7,20,24,45]

One of the main challenges of occupational health and safety in agriculture is that a wide variety of working activities are carried out in this sector, which, unlike in other industries, makes it necessary to develop and implement interventions aimed at these many activities. In addition, the monitoring of farm workers' health condition and the reporting systems of work-related injuries are inadequate and non-standardized. For example, according to the ILO, official data on the incidence of occupational accidents and work-related diseases in agricultural workers are inaccurate, notoriously underestimated and insufficient as indicators to measure the effect of occupational health and safety interventions.[2,13]

In recent decades, the interest in agricultural health has increased worldwide, particularly in the field of occupational safety and health. This has led to positive changes in national policies on working practices in the agricultural sector, and the involvement and jointly effort of public agencies, social organizations, occupational health experts, the academy, agriculture companies, unions, and public and private insurance companies.[6,14] Also, both research and prevention actions regarding occupational health and safety in agriculture have increased significantly in the last decade, since more support has been given to this field of study by different academic institutions, private organizations, and government agencies that has resulted in the creation of academic programs aimed at improving agricultural safety and health (ASH), as well as the foundation or involvement of existing institutions in the research of ASH (Tables 3 and 4). However, these initiatives have only been considered in recent years, and so far, most of them have been implemented in developed countries such as USA, Canada, and France.

Table 3. Academic institutions working in agricultural safety and health programs as of 2016.

Institutions	Agricultural safety and health program	Location	Type of Institution
University of Saskatchewan	Public Health and Agricultural Rural Ecosystem (PHARE)	Canada	Public
University of Iowa	ASH Training Program (MS, Ph.D.,and Certificate in ASH)	Iowa City, Iowa, United States	Public
University of Kentucky	Certificate program in ASH (MS or Ph.D.) provided through the NIOSH-funded Education Center	Lexington, Kentucky, United States	Public
North Carolina State University	Online courses on agricultural and environmental safety and health	Raleigh, North Carolina, United States	Public
East Carolina University	Academic program in ASH (certificate)	Greenville, North Carolina, United States	Public
Pennsylvania State University	Hazard Identification and Control in Production Agriculture and Management of Safety and Health Issues in Production Agriculture (Professional program)	Pennsylvania, United States	Public
The Ohio State University	Agricultural health and safety extension program	Columbus, Ohio, United States	Public
Purdue University	Emergency management of agricultural production operations and agricultural safety professional program	West Lafayette, Indiana, United States	Public
University of Illinois	Health and illness prevention and safety and injury prevention professional program	Champaign IL., United States	Public
University of Minnesota	Courses about different zoonoses and occupational safety aimed at young farm workers	Minneapolis and Saint Paul, Minnesota, United States	Public
Australian National Centre for Farmer Health in Cooperation with Deakin University, Hamilton, Australia	Agricultural health and medicine, and Healthy and sustainable agricultural communities professional programs	Hamilton, Australia	Public
Harran University	The Public Health Department of the College of Medicine gives an annual lecture on ASH	Merkez Mahallesi, Turkey	Public

ASH: Agricultural Safety and Health.
Source: Own elaboration.

Table 4. Organizations involved in the research of agricultural safety and health, including the development of training and prevention resources for both agricultural workers and occupational health specialists.

Name of the organization	Institutional objective *	Location/ Country	Type of Institution
International Safety for Agricultural Safety and Health (ISASH)	To promote the development of agricultural safety and health professionals.	United States	NGO
International Commission on Occupational Health (ICOH)	To foster scientific progress, knowledge, and development of occupational health and safety.		NGO
Pesticide Actions Network	To tackle the pesticide problem and to ensure the future of food and farming.		Private
International Social Security Association Section for Agriculture (ISSA)	To set labor standards, develop policies and devise programs promoting decent work for all women and men.		Governmental
Farm Worker Health and Safety Institute	To improve farmworkers' occupational and environmental health and safety conditions by providing them with training around health and safety and environmental justice issues.	United States-Mexico Border and the Caribbean.	Governmental
The National Institute for Occupational Safety and Health(Centers for Agricultural Disease and Injury Research, Education, and Prevention)	To protect the health and safety of agricultural workers and their families. To conduct research, education, and prevention projects to address the nation's pressing agricultural health and safety problems.	United States (California, Colorado, Iowa; Kentucky, Minnesota, Nebraska, New York, Texas, Washington Wisconsin)	Governmental
Vermont Farm Health Task Force	To ensure a healthy and safe workforce in Vermont by working with farmers, medical practitioners, agricultural professionals, public and behavioral health providers and staff from key state and community agencies.	United States	Public
Iowa´s Center for Agricultural Safety and Health (I-CASH)	To enhance the health and safety of Iowa's agricultural community by establishing and coordinating prevention and education programs		Public
National Center for Farmworker Health Inc.	To improve the health status of farmworker families by providing information services, training and technical assistance, and a variety of products to community and migrant health centers nationwide, as well as organizations, universities, researchers, and individuals involved in farmworker health		Private
National Children´s Center for Rural and Agricultural Health and Safety	To enhance the health and safety of all children exposed to hazards associated with agricultural work and rural environments National Child Agricultural Injury Statistics		Governmental
National Education Center Safety (NECAS)	To prevent illnesses, injuries, and deaths among farmers and ranchers, agricultural and horticultural workers, their families and their employees		Public
National Farm Medicine Center	To improve human health and safety associated with rural and agricultural work, life and environments by conducting high quality research, developing and delivering health and safety information, and exploring innovative service models.		Private
National Rural Health Association	To provide leadership on rural health issues through advocacy, communications, education, and research.	European Union	Governmental
AgHealth Australia (Australian Center for Agricultural Health and Safety)	To research on non-intentional fatal and non-fatal incidents occurring on farms across Australia. To provide on-farm health and safety auditing services, since audits start the process of identifying gaps and assist in working towards meeting health and safety requirements.	Australia	Governmental
National Rural Health Alliance Inc.	To improve the health and well-being of the more than 6.7 million people in rural and remote Australia		Governmental
Agricultores Federados Argentinos Sociedad Cooperativa Limitada (Árgentine Farmers Association Limited Cooperative Company)	To work for the benefit of the Farm Families enrolled in the association by promoting the diversification and added value of their farming production, providing them with the necessary tools to both improve their quality of life and allow their active participation in the development processes of their communities.	South America (Argentina)	Private

* This information has been retrieved from the official website of each one of the institutions.
NGO: non-governmental organization.
Source: Own elaboration.

Somehow, the situation in Latin-America is different. According to the ILO, while 59% of the total population in this region are engaged in farming activities, per year there are around 250 million accidents affecting both permanent and temporary workers. National regulations in Latin-American countries concerning safety at work are often too general and vague. In addition, in some of these countries, this situation is worsened due to the exclusion of the agricultural sector and farm workers from workers' compensation insurance systems. Generally, agriculture is classified by these systems in their global statistical estimates as part of other industries such as forestry and fishing, which translates into the underreport of occupational accidents in this sector.[2,13]

Health problems associated with the exposure to agrochemicals

Systemic diseases

Between 29% and 44% of agricultural workers experience skin or respiratory diseases associated with exposure to agrochemicals[47-54] and scarce use of personal protective equipment while handling chemicals.[5,55]

Generally, skin is the organ most affected in workers exposed to these substances.[56] Headaches (90%), skin rashes (85%), eye irritation (43%) and fatigue (23%) have also been reported as symptoms related to the exposure to agrochemicals.[57] Likewise, more than half of workers report experiencing any of these or similar symptoms after prolonged exposure to agrochemicals, and out of these, only half affirm they receive any form of assistance for medical treatment.[29,47,58,59] In addition, respiratory and flu-like symptoms have been associated with the exposure to agrochemicals among agricultural workers from Iowa after the application of insecticides on cattle, as well as skin reactions, mostly over hands and arms.[31,33,37,60-62]

Effects on pregnancy, fertility and fetal development

Based on the studies reviewed, there is an association between the use of thiocarbamates, carbaryl, and pesticides and a higher risk of spontaneous abortion; also preterm birth has been associated with the use of herbicide mixtures or sequential applications.[17,63,64] On the other hand, there was not a consistent or strong pattern of association between being exposed to pesticides and altered pregnancy time.[65-67] However, it has been described that women and men working in agricultural industries and women living in farms have a higher risk of infertility.[68,69] Other birth defects related to the use of agrochemicals include oral and facial clefts[70,71] and congenital anomalies.[65]

Organophosphate poisoning effects on farm workers' health

The serious outcomes regarding organophosphate poisoning in these workers have been well described, including organophosphate induced polyneuropathy (OPIDP), permanent neurological deficits, neuropsychiatric disorders, peripheral neuropathy, poor neuropsychiatric test results, and multiple chemical sensitivity.[72-74]

Mortality rates

Mortality rates due to exposure to agrochemicals in USA have declined markedly each year;[17,38,75-78] hospitalizations and acute intoxications have also decreased since workers have been provided with better training, better technological devices, non-toxic mixtures formulations, and greater regulation and control policies which include the registration of the most toxic agents[34,35,43,79] (Table 5).

Cancer and exposure to agrochemicals

Regarding associations between developing cancer and performing any type of agricultural activity, it has been reported that lip cancer occurs in 29% of agricultural workers.[75,80,81] Also, it has been described that up to 19% farm workers, regardless of their sex, have been diagnosed with multiple myeloma, and that said condition has been associated with their occupational exposure.[82-86] Other types of cancer observed in this population and that have been related to working in agriculture include non-Hodgkin's lymphoma (14%), prostate (14%), skin (7%), melanoma (6%), brain cancer (4%), and soft tissue sarcoma (3%).[87-93]

Additionally, some types of cancer have been associated with specific agricultural exposures, and evidence shows that their occurrence may be higher in certain subgroups of agricultural workers.[94] For example, a greater association between exposure to herbicides such as a phenoxyacetic acid (e.g. 2,4 D) and having non-Hodkin's lymphoma has been described.[82,95] Yet, regarding exposure to Atrazine , the most widely used herbicide in USA, there is no evidence of an increased risk of colon cancer, soft tissue sarcoma, Hodgkin's disease, multiple myeloma, or leukemia[63,95-97] (Tables 5 and 6).

Finally, many types of cancer have been associated with agricultural exposures in both epidemiological and cohort studies, but results by some of these studies have been inconsistent and, thus, there is no consensus on their causality.

Table 5. Agrochemicals associated with cancer.

Active ingredient of the agrochemical/ Agrochemical	Type of cancer associated with exposure	Type of worker	Type of analysis	Reference
2,2-dichloroethenyl dimethylphosphate	Prostate	Farmers and pesticide applicators	Case-control	82,89
Alachlor	Lymphohematopoietic Leukemia	Pesticide applicators	Chemical specific	77
Aldicarb	Colon Lung	Pesticide applicators	Chemical specific	77,98
Atrazine	Thyroid	Corn farms workers	Longitudinal molecular epidemiology study	97
Butylate	Prostate	Farmers and other pesticide users	Case-control	75
Captan	None observed	Pesticide applicators	Chemical specific	84
Carbaryl	Melanoma Multiple Myeloma	Private applicators (farmers)	Chemical case-control	95
Chlordane	Rectum	Pesticide applicators	Cohort	98
Chlorpyrifos	Lung Brain Rectal	Pesticide applicators	Case-control Chemical specific	77,84
Metribuzin	Lymphohematopoietic Rectal	Licensed pesticide applicators and their spouses	Chemical specific	64
S-etil dipropil tiocarbamato (EPTC)	Colon Leukemia	Licensed pesticide applicators and their spouses	Cohort	94
Fonofos	Prostate Prostate Leukemia	Farmers and pesticide applicators	Case-control Chemical specific	75,95
Glyphosate	Multiple myeloma	Pesticide applicators	Control cases	83
Imazethapyr	Bladder	Pesticide applicators	Chemical specific	80
Malathion	No associations observed	Pesticide applicators	Chemical specific	29
Methylbromide	Prostate	Pesticide applicators	Control cases	75
Trifluralin	Colon	Pesticide applicators	Chemical specific	92

Source: own elaboration.

Table 6. Agrochemicals associated with non-cancerous diseases.

Active ingredient of the agrochemical/Agrochemical	Non-cancerous diseases	Type of worker	Type of study	Reference
Organophosphate	Skin rashes Eye irritation Fatigue	Farmers	Chemical specific	57
Pesticides	Respiratory and flu-like symptoms	Farmers	Case-control	60
High pesticide exposure events (HPEE)	Asthma and neurologic diseases	Farmers	Case-control	28
Chlorpyrifos thiocarbamates, carbaryl	Altered pregnancy time Infertility	Farmers	Chemical specific	65,66,68
Chlordane Chlorpyrifos	Congenital malformations	Farmers	Case-control	65
Malathion	Polyneuropathy Permanent neurological deficit Neuropsychiatric disorders Peripheral neuropathy Poor results in neuropsychiatric tests Multiple chemical sensitivity	Farmers	Case-control	73-74
Pesticides	Myocardial infarction Monoclonal gammopathy	Male pesticide applicators	Case-control	76,78,85

Source: own elaboration.

Farmers and agricultural workers are subject to multiple hazardous exposures to pesticides, fertilizers, paint fumes, solvents, welding fumes, dust, pathogens, and endotoxins.[63,69,98,99] In general, most agricultural health studies have been conducted on permanent workers and, to a much lesser extent, on their partners. However, little research has been done regarding temporary agricultural workers, who may be subject to prolonged occupational exposures. Furthermore, these studies have generally focused on crop production workers, who are exposed to different pesticides (depending on the crops) only a few times per year.[98] Somehow, it should be noted that the results obtained in this review may greatly depend on the heterogeneity of the studies, the type of study, the geographical area and the period in which they were conducted, and the limitations of each study regarding the assessment of agricultural exposures.

Other conditions associated with agricultural exposures

Different physiological conditions, injuries or mechanical traumas, and infections caused by microorganisms have been associated to some extent with agricultural work. For example, it has been reported that more than 50% of agricultural workers experience hearing loss.[100] Also, the adoption of forced postures, the performance of repetitive movements and the manual handling of heavy loads have been associated with musculoskeletal disorders such as chronic back pain and low back pain, being more frequent in older men than in women (50% and 10%, respectively), and even with spontaneous miscarriages. [101]

Furthermore, agricultural equipment operators are exposed to whole-body and hand-arm vibrations that cause them several health problems and health conditions, including tendinitis, tenosynovitis, carpal tunnel syndrome, degenerative changes of the spine, low back pain, herniated discs, and peripheral, vascular, gastrointestinal and vestibular nerves injuries. Likewise, excessive physical effort and fatigue as a result of using traditional farming tools and methods may increase the risk of occupational accidents.[101]

On the other hand, agricultural work-related respiratory disorders include occupational asthma, allergic rhinitis, chronic bronchitis, extrinsic allergic alveolitis (or hypersensitivity pneumonitis), which are mainly associated with working in closed areas such as nurseries and silos where workers are exposed to high concentrations of allergen dust, fumes, pollen, dust mites, and grain dust.[40,102] According to some studies, chronic bronchitis is more prevalent in farmers compared to the general population. In this regard, it has been reported that most farmers with this disease have a history of exposure to grain dust or work in confined pig farms. Chronic bronchitis has also been described in farmers who grow cereals, especially during harvest time.[40,103,104]

Among infections caused by microorganisms as a result of working in agricultural activities, it has been described that both latent tuberculosis infection and tuberculosis disease (caused by the *Mycobacterium tuberculosis* bacterium) cases are increasing in the migrant workforce, mainly in Mexico and Central America, and that most of cases occur in the Mexico-United States border area.[105,106] In addition, prevalence rates are significantly higher in communities living in said area. In that regard, Garfein *et al.*[107] report the need to improve the diagnosis and the monitoring of TB cases, as well as to promote the successful completion of TB treatments in order to reduce the occurrence of multidrug-resistant TB cases.

According to the evidence found here, studies on agricultural health and safety address topics such as cancer screening, autoimmune, respiratory, neurological and reproductive diseases, allergic disorders, work-related

injuries, and overall mortality rates and their association with a wide range of agricultural exposures. Most of these studies have been conducted in northern and southern mid-latitudes, mainly in USA, possibly because this country is one of the largest consumers of insecticides and agrochemicals in the world.[6] In addition, 47% of the rural population in USA is engaged in some type of agricultural activity, and the US Government has acknowledged both, life and health sciences, as important factors for the Nation's economic growth, as well as the importance of increasing the quality of treatment provided to people who experience agricultural work-related injuries.[22]

Limitations

Due to their design, in a systematic review fewer studies may be included compared to a narrative review. Also, systematic reviews are observational and retrospective studies that are susceptible to biases.

Conclusions

In agricultural workers, exposure to pesticides and other agrochemicals is one of the main occupational hazards, which can lead to intoxication and death, and, in some cases, to occupational cancers and reproductive disorders. Likewise, poor compliance with safety and health regulations in this sector worsens this situation.

The absence of registers regarding infections and infectious diseases affecting both humans and animals has been so far addressed independently by several disciplines, but not in a holistic way, which may be leading to the underreport of occupational diseases in agricultural workers.

The existing studies on agricultural health have been conducted mainly in developed countries, particularly in USA, and most of them focus on the harmful effects resulting from occupational exposure to the handling of farm machinery, and on work-related traumas. However, an adequate approach to agricultural health requires further discussion and a wider scope, since what is reported by said studies may be far from the reality of other regions, especially Latin America, where workers' agricultural health may be conditioned by several factors including weather, fauna, population density, living conditions, level of schooling, professional background, technological development, and health care services quality.

Even if systematics reviews have some limitations, results obtained here show that it is a useful tool for the identification of predominant research topics within a certain field of study. Further research should focus on studying agricultural health in other regions of the world and in the different production systems.

It is worth noting that in Latin America, most agricultural research is carried out by government and federal government agencies, which makes it difficult to access information regarding agricultural health in these countries.

Conflicts of interest

None stated by the authors.

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