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Effectiveness of Interventions to Reduce Pesticide Exposure in Agriculture

Fabrizio Giannandrea[1] --- Domenica Fioredistella Iezzi[2]

[1]University of Rome "La Sapienza", P.le Aldo Moro, 5 00185 Rome, Italy
[2]"Tor Vergata" University, Unit **of** Social Statistics, Via Columbia, Rome, Italy

Abstract

The harmful effects of acute pesticide poisoning have been well documented as an established hazard of agricultural work, while the evidence of the association between chronic pesticide exposure and health consequences, continues to emerge. Despite many pesticides have been banned or restricted in several developed countries, exposures to these toxic agents are still occurring in most of the developing world. The objective of this review is to determine the effectiveness of educational interventions designed to reduce exposure to pesticides in order to prevent health effects in agricultural workers. Intervention approaches to prevent pesticide exposure in agriculture vary vastly from country to country probably depending on the level of development achieved. Although many of the papers on educational safety interventions reported some positive results, the availability of randomized controlled trials for this topic is limited and several interventions exclusively measured changes in attitudes or knowledge of participants, with scarce efforts to determine if there was a consistent reduction in pesticide exposure.
We conclude that although educational interventions show some efficacy at raising participants' awareness of pesticide risks, studies using better quality educational approaches are needed.

Keyword: Pesticide exposure, Educational interventions, Preventive measures, Agricultural workers.

1. Introduction

The harmful effects of acute pesticide poisoning have been well documented as an established hazard of agricultural work, while the evidence of the association between chronic pesticide exposure and health consequences, continues to emerge. Despite many pesticides have been banned or restricted in several developed countries, exposures to these toxic agents are still occurring in most of the developing world [1, 2].

In the last decades concern has been raised about the long-tem effects of pesticides on human health [3, 4]. In addition to acute poisonings, there is a wide range of diseases that have been suggested to be related to chronic exposure to pesticide, including cancer, neurobehavioural disorders, impaired immunity, endocrine problems and reproductive disorders [3, 5]. Pesticides may be categorized according to their function (e.g. insecticides, herbicides, fungicides), or their chemical structures (e.g., organochlorines, organophosphates, carbamates, phenoxy acids) [3, 4]. The main routes of absorption of pesticides into the body are dermal, oral, and inhalation. Skin exposure route largely prevails for workers in agriculture.

However, relatively little is known about the awareness and health beliefs of workers who are exposed to pesticides and how to develop preventive interventions that effectively reduce the long-term effects of these hazardous substances.

An increasing number of studies conducted in the last two decades among agricultural workers found that reducing exposure to pesticides is possible not only through environmental control measures but especially by emphasizing and encouraging the use of personal protective equipment (PPE) and education and training of workers in correct preventive behaviours. Arcury, et al. [6] studied how safety information affects the perceived pesticide safety risk and control among farmworkers and how perceived risk and control affects farmworkers knowledge and safety behaviour [6]. They found that receiving information about pesticide safety (e.g. warning signs) reduced perceived risk and increased control.

Cross-sectional studies on the degree of adherence to correct safety behaviours by agricultural workers show that safety precautions are often scarce [7]. McCauley, et al. [8], studying 166 agricultural workers in Oregon (USA), found that only 18% used some type of protective clothing, while 75% went home with their work clothes, with 33% changing these clothes > 30 min after arriving home [8]. In a group of 383 female farm workers in Washington State, Thompson, et al. [9] reported that 46% did not remove their boots before entering their home after work, and 45% did not remove their work clothes within 1 h of returning home [9].

Even less attention has been paid to the safety behaviours of vulnerable working populations such as pregnant women, who might have a higher risk than the rest of the population for adverse pregnancy outcomes and reduction in fertility [5].

In the study of Goldman, et al. [10] in California, a substantial proportion of pregnant women living in farm households were not adopting pesticide safety behaviours [10].

A study from Italy found that pregnant greenhouse workers performing the most dangerous jobs often did so without using PPE [11]. Even the use of gloves was absent in 50% of pregnant greenhouse workers who during their pregnancy prepared and mixed pesticides, and among 38% of those who applied pesticides directly.

Intervention approaches to prevent pesticide exposure in agricultural workers vary vastly from country to country probably depending on the level of development achieved. Studies on practices indicate that unsafe use of pesticides is common in developing countries. Insufficient legislation combined to illiteracy, poverty and unfavourable weather conditions result in higher health risks from occupational exposure [12]. In the more industrialized countries, pesticide safety practices often depends on workers’ perceived susceptibility, educational level and safety training, rather than on legal regulations or economic conditions [7]. Educational campaigns such as those undertaken in the USA in the 1990s have shown that pesticide safety practices can improve by appropriate educational interventions [13, 14].

The objective of this review is to determine the effectiveness of educational interventions designed to reduce exposure to pesticides in order to prevent health effects in agricultural workers.

2. Methods

2.1. Search Strategy

Relevant studies from peer-reviewed journals, technical and government reports, and unpublished reports were retrieved using a systematic approach. The search had no language restrictions through the following electronic databases: Cochrane Central Register of Controlled Trials, Cochrane Injuries Group’s specialised register, MEDLINE (1990 to present), EMBASE (1990 to present), ISI Web of Knowledge, Agricola, Agris using combination of the following search terms: “pesticide exposure”, "pesticides", "carbamates", "pyrethrins", “herbicide”, ”biocides”, “organophosphate”, “fungicide”, “fumigant”, “intervention”, “trial”, “randomized controlled trial”, “controlled clinical trial”, “control”, “educational program”, “training”, “work”, “occupation”, “prevention”, “protect”, “safety”, “safety behavior”, “personal protective equipment”, “glove”, “mask”, “boots”, "agriculture", "gardening", "crops, Agricultural", "agricultural Workers' diseases", “farming”, "crop production", “horticulture”, “greenhouse”, “gardener”, "farm worker", “farmworker”, "agricultural worker", "fruit grower", “orchardist”, “grower”, “cultivator”, “planter”.

2.2. Study Population

We evaluated studies that addressed pesticide exposure or poisoning of subjects of all ages and both genders. Subjects could be agricultural workers of all ages and both genders, all persons that are professionally involved in agricultural activities associated with pesticides (i.e. mixers, loaders, sprayers; general farm workers).

2.3. Types of Intervention

Educational interventions applied to reduce pesticide exposure were included. Such interventions may apply to the national, regional, organizational, community or individual level. Example interventions considered included conducting worker education and training programs aimed at demonstrating the proper use of personal protective equipment (PPE), enhancing safety behaviours such as hand washing after pesticide application and frequent changes of work clothes, increasing the knowledge and awareness of pesticide-associated health risks, improvement of pesticide application and mixing methods, passing new pesticide laws and regulations, and using incentive interventions. Behaviour changes will be evaluated both by self-reported questionnaires and structured questionnaire administered by trained interviewers.

2.4. Inclusion Criteria

This review includes all randomized controlled interventions (RCI), pretest/post-test interventions (PPI), controlled pretest/post-test interventions (cPPI), and time series designs (TSD) irrespective of language of publication. Studies that examined the effectiveness of an educational intervention targeted at agricultural working populations were selected. Studies with educationl programs targeted at non-working populations (eg., families, children and householdes) were excluded by the present analysis. Studies were included according to the terminology previously adopted in studies evaluating the effectiveness of an educational program or a policy intervention in which X stands for the intervention that is being evaluated (e.g., training campains, introduction of PPE, graphic warning labels through pesticide legislation), and “O” stands for an observation (e.g., enhanced adherence to pesticide safety behaviours, improved KAP score for safe pesticide handling) [2] (Tab.1). For randomized controlled interventions, there should be mentioned that participants are randomly (R) assigned to the intervention and control group (Tab. 1).

For PPI, comparison of outcomes from study participants before and after an intervention is introduced (Tab.1). cPPI is a follow-up study of participants who have received an intervention and those who have not, measuring the outcome variable both at baseline and after the intervention period, comparing either final values if the groups are comparable at baseline, or change scores (Tab. 1). TSD resemble the pretest/post-test designs, with the exception that there are multiple measurements before and/or after the intervention.

2.5. Types of Outcomes

The primary outcomes of interest were grouped into the following categories:

1) effectiveness of an educational program promoting PPE use (e.g. gloves, breathing mask and boots, eye protection) and proper safety behaviours (e.g. frequent changes and washing of work clothes and other personal hygiene).

2) knowledge acquisition and awareness (through pre-and post-tests administered in participants), knowledge attitude and practice (KAP) questionnaires or structured tests evaluating acquisition among workers of negative health effects of pesticides will be assessed.

3. Results

A total of 29 studies were identified that described an educational intervention for the prevention of pesticide risks; 8 of these met our inclusion criteria [15-22]. The remainder were excluded because did not include a specific education intervention to reduce pesticide exposure (n=7), or were mainly targeted to farmworkers' families (n = 9), or were previous systematic reviews (n=2). The characteristics of the included studies are shown in Table 1. All were pre-intervention and post-intervention studies, with the exception of two studies that were randomized trials using concurrent controls [21, 22]. Control groups were often only defined as individuals in which exposure was measured in the absence of the intervention; and the number of study subjects generally were quite small. Two studies used non-randomized pre-intervention and postintervention design but also had concurrent controls [15-22]. Five studies were conducted in the United States [15, 16, 21, 22]; the remainder were conducted in Colombia [18], India [19], and Thailand [20]. The duration of each intervention was highly variable, ranging from a 60 min course to sustained interventions lasting up to 6 months.

3.1. Pretest/Post-Test Studies

Most of the evaluations of educational programs utilized a pretest/post-test design to examine changes in self-reported behaviours, attitudes or knowledge, or some combination of the three. Only the PPI study conducted by Vela Acosta, et al. [15] had concurrent controls [15]. This study was a 60 min pesticide program providing training about sources of pesticides and pesticide absorption and toxicity among 152 migrant farmworkers in Colorado [15]. The intervention trial group (n=77) demonstrated significantly better posttest scores than the control group (n=75) with improvements in farmworkers' pesticide safety knowledge ($p<0.001$) and increased perceptions of pesticide-related risks ($p<0.001$)[15]. One pretest/post-test study examined an intervention using Spanish one-act plays to increase Washington farmworkers' (n=185) knowledge about pesticide safety and other heath issues. The intervention was found to be effective in increasing farmworkers' knowledge about pesticides ($p<0.01$) [17]. Similar significant increase in knowledge were found among intervention studies conducted in Colombia, India, and Thailand [18-20].

3.2. Randomized Controlled Interventions

Only two of the educational interventions analyzed have a randomized controlled design, finding that educational interventions had significant effects on the use of PPE, in particular gloves, during the most recent application. In particular, Salvatore, et al. [21] conducted a cluster-randomized controlled trial among 130 farmworkers from Monterey County CA, with a significant improvement found in the use of gloves (OR: 5.0; 95 % CI 1.7-14.8), and wearing clean work clothes (OR: 3.4; CI 1.2-9.0) after the intervention [21]. Similarly, the randomized control trial conducted by Perry and Layde [22] among approximately 100 randomly assigned Winsconsin dairy farmers observed a significant change after the educational sessions in the use of gloves (OR: 1.23 ; 95 % CI 1.13-1.34) and any other gear (OR: 1.53; 95 % CI 1.05-2.11), and a significant reduction in the total number of pesticides used (OR: 2.04; 95 % CI 1.52-2.75) [17].

3.3. Effectiveness of Knowledge Acquisition and Awareness

Several studies addressed the effectiveness of knowledge acquisition and awareness using knowledge attitude and practice (KAP) questionnaires or structured tests evaluating acquisition among workers of negative health effects of pesticides. The use of KAP questionnaires was common in developing countries with perhaps limited resources to undertake more refined quality interventions. A participative strategy-based occupational health and labour risk educational intervention was conducted among 659 potato farmers from the Boyacá department of Colombia [18]. This study evaluated the impact of educational intervention concerning knowledge, attitudes and practices (KAP) aimed at changing behaviour in pesticide use, finding significant changes in KAP ($p < 0.001$) [17]. A further educational intervention using a KAP questionnaire was provided by Sam, et al. [19] among 74 pesticide handlers from Karnataka state, South India in order to evaluate the effectiveness of educational interventions [19]. The average baseline KAP score improved after education significantly at first follow-up ($P < 0.001$) [20]. Finally, a training pesticide program conducted over a six-month period by Janhong, et al. [20] found that the average baseline KAP score improved after education significantly at first follow-up ($P < 0.001$) [19].

3.4. Effectiveness of Educational Programs Promoting Proper Safety Behaviours

Four studies included in the review examined the effectiveness of an educational program promoting the use of some form of personal protective equipment (e.g. gloves, breathing mask and boots, eye protection) and proper safety behaviours (e.g. frequent changes and washing of work clothes and other personal hygiene) [15, 16, 21, 22].

All the studies reported some positive changes in outcomes following the interventions with significant improvement in the use of gloves observed in three studies [16, 21, 22]. Two of the four studies utilized a RCI methodology to examine changes in self-reported behaviours [21, 22]. The remainder non-randomised trial studies used a pre-post test methodology with concurrent controls [15, 16]. In particular, the intervention trial conducted by Vela Acosta, et al. [15] demonstrated also improvements in readiness to change for washing hand in the field (OR: 3.84; 95 % CI 1.3 - 10.9) and for separating clothes before washing them (OR: 1.3; 95 % CI 1.0 - 1.5) [15]. Salvatore, et al. [21] found a similar significant improvement in washing hands before going home (OR: 3.5; 95 % CI 1.2-10.0) after the intervention [21]. All the educational interventions promoting proper safety behaviours were conducted in US countries which provided comprehensive occupational health services.

4. Conclusions

Our review shows that a variety of educational approaches have been studied for the prevention of pesticide-related risks. We found that the systematic application of educational interventions can promote pesticide safety. However, it is difficult to determine which particular educational intervention is the most effective because the studies used a variety of strategies, many in combination with other approaches to prevent pesticide risks. We found that studies of educational interventions conducted in lesser developed countries, with perhaps fewer resources to implement more technological advances in pesticide control, also found similar considerable benefit, as did studies that were undertaken in more industrialized countries.

Although most of the interventions addressed and emphasized the need for proper use of PPE, unfortunately compliance with PPE use remains inadequate [15-22].

The availability of RCI is limited for the present topic. This maybe is due to the fact that the interventions designed to reduce pesticide exposure are often different from the experimental interventions in other work settings and require greater availability of financial resources. The two RCIs showed that the intervention had significant effects on use of PPE, in particular gloves, during the most recent application [21, 22]. Proper adherence to PPE is particularly important as skin exposure route largely prevails for workers in agriculture and previous studies have reported negative health outcomes (eg. haematological and other diseases) deriving from prolonged hand contact of toxicants or the misuse of gloves in several workplaces [23-25].

The findings of these studies suggest that it is possible to have at least a short-term effect on pesticide application practices and pesticide safety behavior by increasing safety knowledge, intentions, and health risk perceptions. Although many of the papers on educational safety interventions reported some positive results, they were very heterogeneous, and we were unable to determine which type of educational intervention has the best potential to reduce pesticide risks. Several interventions were good at raising participants' awareness of pesticide risks and exclusively measured changes in attitudes or knowledge, or intended behavior change with scarce efforts to determine if there was a consistent reduction in pesticide exposure.

In conclusion, we find that although educational interventions show efficacy at raising awareness of pesticide risks, studies using better quality educational approaches under carefully controlled conditions are needed. We recommend the use of randomized trials to study educational interventions. For nonrandomized interventions, we suggest the use of a time-series design with multiple observations before and after intervention and use of a parallel control group.

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Table 1. Effectiveness of Interventions to Reduce Pesticide Exposures. Characteristics and results of the included studies (O_n = observation at time n; R = randomization; N = without randomization; X = intervention; RCI = randomized controlled intervention; PPI = pretest/post-test intervention; PPI = controlled pretest/post-test intervention; TSD = time series design)

Reference	Design	Methodology	Intervention	Participants	Outcome(s)	Results	Notes
Salvatore et al., 2009	RCI	R O_1 X O_2 R O_3 X O_4	Four-weekly field-based educational sessions to increase awareness of pesticide exposures, promote safe behaviour at work and after work	130 farmworkers employed at 2 Monterey County CA, strawberry farms	Improvement farmworkers' behaviours at work and after work to reduce occupational and take-home pesticide exposures	Significant improvement in the use of gloves (OR: 5.0; 95 % CI 1.7-14.8), wearing clean work clothes (OR: 3.4; CI 1.2-9.0) and washing hands before going home (OR: 3.5; 95 % CI 1.2-10.0)	Absence of improvement in some hand-washing behaviors
Ospina et al., 2009	PPI	N O_1 X O_2	A participative strategy-based occupational health and labour risk educational intervention	659 potato farmers from the Boyacá department of Colombia	Impact of educational intervention concerning knowledge, attitudes and practices (KAP) aimed at changing behaviour in pesticide use	Significant changes in KAP (p < 0.001)	Educational interventions in vulnerable, low scholastic level populations require ongoing accompaniment and support for achieving significant changes in health practice
Sam et al., 2008	TSD	N O_1 X O_2 O_3	Education was provided using a structured individualized training program	74 pesticide handlers from Karnataka state, South India	Effectiveness of educational interventions using a Knowledge attitude and practice (KAP) questionnaire	The average baseline KAP score improved after education significantly at first follow-up (P < 0.001)	A significant decrease (P < 0.001) was also seen in the knowledge from the first to the second KAP assessment, which may be attributed to a decrease in retention of knowledge due to the time gap between the follow-ups
Vela Acosta et al., 2005	cPPI	N O_1 X O_2 N O_3 X O_4	A 60 min pesticide program provided training about sources of pesticides and pesticide absorption and toxicity. A pretest was administered to all participants prior to the pesticide program. Within 2 weeks of the pretest the experimental group received the pesticide program, and approximately 1 week later a posttest was administered to all articipants.	152 migrant farmworkers in Colorado assigned to either the experimental (n=77) or the control group (n=75)	Pesticide knoledge, safety risk perception, and safety-behavior outcomes	Increase in farmworkers' pesticide knowledge (p=0.0001), safety risk perception (p=0.0001), and readiness to change for washing hand in the field (OR: 3.84; 95 % CI 1.3 - 10.9) and for separating clothes before washing them (OR: 1.3; 95 % CI 1.0 - 1.5)	The majority of study population does not believe that they can influence their own health through their own actions, but that their health is in the hands of doctors and others, and it was for this population that the training seemed to be least effective.
Janhong et al., 2005	PPI	N O_1 X O_2	A training pesticide program conducted over a six-month period	33 voluntary farmers from Rachaburi Province, Thailand	Effectiveness of educational interventions using a Knowledge attitude and practice (KAP) questionnaire	The average baseline KAP score improved after education significantly at first follow-up (P < 0.001)	Small field tests involving few workers
Elkind et al., 2002	PPI	N O_1 X O_2	An Intervention using Spanish one-act play	185 Washington farmworkers'	Pesticide knowledge, safety and other heath issues	Increase in farmworkers' knowledge about pesticides (p<0.01) .	Self-selected and self-reporting sample with indirect measures of attitude and behavior
Perry et al., 2000	RCI	R O_1 X O_2 R O_3 X O_4	Three-hour educational sessions with approximately 100 randomly assigned participants	400 Winsconsin dairy farmers certified to apply pesticides to field crops	A change in use of required protective equipment use during application and self-reported dermal exposure	Significant change in the use of gloves (OR: 1.23 ; 95 % CI 1.13-1.34) and any other gear (OR: 1.53; 95 % CI 1.05-2.11), significant reduction in the total number of pesticides used (OR: 2.04; 95 % CI 1.52-2.75)	No significant impact on acheiving full PPE copliance; no reduction in the amount of self-reported dermal pesticide exposure during the most recent application reported by applicators.
Mandel et al., 2000	cPPI	N O_1 X O_2 N O_3 X O_4	Mailed pesticide information to farm households, educational programs on pesticides for county physicians, elementary school training modules on the safe use of pesicides	508 Minnesota farm pesticide users (186 in the intervention counties and 322 in the control counties)	A change in use of gloves and other protective clothing while handling pesticides. Modest improvement in use of gloves and other protective clothing while handling pesticides. Use of gloves relative change ratio 1.2 (CI 0.9-1.7) for those <75% time pre-intervention use & 1.0 (Ci%0.9-1.1) those >75% of time pre-intervention use.	Modest improvement in use of gloves and other protective clothing while handling pesticides	It appears that a preventive educational approach at a community level migth have a modest impact in how farmers protect themselves when using pesticides