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Exposure to organophosphate (OP) pesticides and health conditions in agricultural and non-agricultural workers from Maule, Chile

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ABSTRACT
The objective was to evaluate the characteristics of exposure to OP pesticides and health status in Chilean farm workers from the Maule Region. An occupational health questionnaire was administered in 207 agricultural and non-agricultural workers. For the group of agricultural workers, we asked about specific occupational exposure history and symptoms of OP pesticide poisoning. The main health problem of the exposed group was previous OP pesticide poisoning ($p < 0.001$). Fifty-six percent of agricultural workers reported symptoms consistent with acute OP pesticide poisoning. The use of respiratory personal protective equipment and younger age were protective against these symptoms, and number of years of OP pesticide exposure was positively associated with reporting symptoms of poisoning. Of the pesticide applicators 47 % reported using chlorpyrifos. The regulations regarding use and application of pesticides should be strengthened, as should training and intervention with workers to improve the use of personal protective equipment.

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Introduction

The exposure of agricultural workers to pesticides is a public health problem worldwide. The annual incidence of acute intoxication from pesticides is approximately 18 per 100,000 full-time farm workers (Thundiyil et al. 2008). A large body of scientific evidence supports the existence of both acute and chronic effects of exposure to organophosphate (OP) pesticides, the most commonly used in chemicals for agricultural pest control, in agricultural workers (Alavanja et al. 2004; Garry 2004; Kamel & Hoppin 2004; Bradman & Whyatt 2005; Rothlein et al. 2006; Engel et al. 2007; Handal et al. 2007; Eskenazi et al. 2008; Jurewicz & Hanke 2008; Rosas & Eskenazi 2008). Acute poisoning ranges from mild to fatal symptoms (Costa 2006), and manifests as headaches, nausea, respiratory problems, vomiting, bradycardia, miosis, dermatitis, and burns. Neurotoxic effects are associated with chronic exposures,

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especially cognitive, motor and sensory deficiencies, and neurological diseases (Alavanja et al. 2004; Roldán-Tapia et al. 2005; Joshaghani et al. 2007; Muñoz-Quezada et al. 2016). Studies have also found an association between OP pesticide use and emotional disorders, depression and anxiety (Bayrami et al. 2012; Malekirad et al. 2013), breathing difficulties, allergies, endocrine and immunotoxic effects (Costa 2006), cancer (Alavanja et al. 2004; Lee et al. 2004; Bonner et al. 2007), fetal abnormalities (Berkowitz et al. 2004; Eskenazi et al. 2004; Needham 2005; Engel et al. 2007), and neurobehavioral and developmental delays in children of seasonal workers (Eskenazi et al. 2007; Rosas & Eskenazi 2008; Muñoz-Quezada et al. 2013) exposed to OP pesticides.

In Latin America, and specifically in Chile, there are limited data on OP pesticide exposure and health effects of the workers. Many OP pesticides used in Latin America are banned in the United States, Canada, and Europe or their application is strictly regulated and controlled (Muñoz-Quezada et al. 2014). The Maule Region is one of the regions in Chile with the largest rural population and has high rates of OP poisoning (Vallebuona 2006; Muñoz-Quezada et al. 2012). In Chile, more than 38 million kg/L of pesticides are sold per year, and the Maule is the country's second biggest selling region (10,310,633 kg/L). Among insecticides, organophosphates are the best sellers nationally, including the Maule region where they correspond to the best selling pesticides, with over 2 million kg/L (SAG 2012a).

The main objective of this study was to characterize the exposure to OP pesticides and health conditions of agricultural and other workers from the Maule Region. Secondarily, variables related to pesticide poisoning symptoms were evaluated in the group of agricultural workers. This information may be used to guide the control and regulation of OP pesticides in Chile and other parts of Latin America.

Methods

This study is part of a larger project (Muñoz-Quezada et al. 2016), which aims to assess the exposure to OP pesticides in agricultural and other workers in the Maule Region, and to estimate the association with neuropsychological and motor performance of workers. That project was conducted in 2014–2015 and consisted of a cross-sectional analytical study with a random selection of agricultural workers (exposed to OP) and non-agricultural (non-exposed). Although the sample size was estimated from the objective of the aforementioned larger study, it was considered proper for significant analysis of pesticide exposure OP and health conditions, based on other studies that found association between workers' OP exposure and difficulties in their physical health (Bayrami et al. 2012; Malekirad et al. 2013).

For the larger project, we aimed to recruit 136 workers, based on sample size estimation for detection of mean differences of five points in cognitive functioning between exposed and non-exposed workers, as reported by Mackenzie et al. (Mackenzie Ross et al. 2010). The sample size was based on an estimated 56 workers for each group (n = 112), plus 20 % oversampling. Therefore, the results presented below are not based on an estimate of sample size with exposure to pesticides OP and health conditions as variables, but rather considering the sample obtained from the larger study for analysis of other variables that were investigated in agricultural and non-agricultural workers. Finally, a number of 207 workers was obtained, which is considerably higher than the initial estimate of sample size described above. Thus, the results of these 207 workers are those analyzed and discussed in this paper. Support from public and private institutions was requested to generate a sampling frame for each group. The Agricultural Development Institute (INDAP), a government institution that supports agricultural micro-enterprises, was contacted for the identification of agricultural workers. The group of non-agricultural workers was composed of INDAP's non-agricultural workers and other educational and health institutions' workers. Randomly selected workers were administered an informed consent and occupational health questionnaire. The questionnaire was developed based on an examination of exposure to pesticides of the Institute of Public Health of Chile (ISPCH 2004), adding other items to assess exposure characteristics and working conditions of agricultural workers. The Scientific Ethics Committee of the Catholic University of Maule reviewed and approved all contact with human subjects.

The first section of the questionnaire was administered to all subjects and included demographic questions (age, sex, marital status, years of education, health insurance, life partner works in farm, membership in an occupational safety agency); lifestyle questions (alcohol consumption, drug use, smoking, alcoholism); questions about health outcomes (skin allergy, anemia, asthma, cancer, liver damage, depression, diabetes mellitus, epilepsy, arterial hypertension, kidney failure, heart problems, anxiety, previous pesticide poisoning, and hospitalization for pesticide poisoning); questions about work history (previous pesticide exposure); and questions about housing (has greenhouse or crops at home, agricultural land owner, distance from home to agricultural land, use of pesticides at home, use of OP pesticides at home).

The second section was administered only to agricultural workers to assess specific occupational exposure to pesticides (whether work involved direct application of pesticides, use of personal protective equipment [PPE], sanitation facilities at work, training on pesticides and application of the acetylcholinesterase tests), and presence of symptoms associated with recent poisoning by exposure to OP pesticides (headache, abdominal pain, vomiting, insomnia, dizziness, lower limb weakness and cramps, shortness of breath, excessive salivation, blurred vision, mood changes, nausea, diarrhea, night sweats, skin lesions, and fatigue). We considered a subject to have experienced recent (during the last year) OP pesticide poisoning if they had at least two symptoms associated with exposure to OP pesticides. Finally, a third section of 20 questions were asked only of the reporting work experience as a pesticide applicator.

Data analysis was based on descriptive statistics and frequency distributions. Chi-square tests were used to test whether there was a significant association between the socio-demographic, exposure and occupational variables and health outcomes. The farm-worker group was further divided into those that had a history of applying pesticides and those that did not. Multiple logistic regression models were developed to examine the association between occupational exposure to OP pesticides (exposed agricultural worker = 1, non-agricultural worker = 0). Also agricultural workers were distinguished between pesticide applicator (condition = 1) and non-applicator (condition = 0) and reported symptoms of poisoning as the outcome variable (without the condition = 0, with the condition = 1). In this variable, we inquired agricultural workers if in the last pesticide exposure they presented some of the following symptoms: headache, abdominal pain, excessive salivation, blurred vision, vomiting, insomnia, dizziness, legs weakness, shortness of breath, nausea, diarrhea, night sweats, skin lesions, and fatigue. These symptoms are related to OP pesticide poisoning. To incorporate this variable in the models, a new variable was built considering farm workers that present at least two of these symptoms, and other health or chronic conditions. The health conditions consulted were allergies, asthma, anemia, depression, diabetes, hypertension, kidney failure, heart problems, anxiety, congenital malformations in children, OP pesticide poisoning, and pesticide poisoning hospitalization. Non-agricultural workers were used as the reference group only for the dependent variables of health conditions. Multiple logistic regression models were used with each variable of health conditions for both agricultural and non-agricultural workers with adjustment for significant confounders (age, gender, years of pesticide exposure, alcohol intake, cigar smoking, years of education, income, distance of household from agricultural fields, PPE use, use of pesticides at home, frequency of PPE use, sanitation facilities, training on pesticide use, and occupational safety agency tested for acetyl cholinesterase activity) to examine health conditions between applicators and non-applicators. For applicators and non-applicators, symptoms of recent OP pesticide poisoning (presence of at least two symptoms) were analyzed as dependent variable and age, PPE use, frequency of PPE use, sanitation facilities, training on pesticide use and safety agency testing for acetyl cholinesterase activity as covariates. The variables included in the final model were those that were significantly associated with a p-value ≤ 0.10. The software STATA version 12.0 (College Station, TX) was used for analysis.

Results

We successfully recruited 207 workers, 114 agricultural workers (55.1 %), and 93 non-agricultural (44.9 %) workers. The mean age of the study population was 49 years (SD = 12.6, range = 18–75) and

Table 1. Socio-demographic characteristics of non-agricultural and agricultural workers of The Maule region, Chile.

	Non-agricultural workers	Agricultural workers	Total	
	n = 93	*n* = 114	*n* = 207	
	n (%)	*n* (%)	*n* (%)	*p*-value (<0.05)
Gender				
Male	31(30)	74(70)	105(51)	<0001
Female	66(65)	40(35)	102(49)	
Marital status				
Single or widow	37(62)	23(38)	60(29)	
Married or cohabiting partner	56(38)	91(62)	147(71)	0.002
Partner works in agriculture				
No	58(54)	50(46)	108(53)	0.007
Yes	33(35)	62(65)	95(47)	
Years of formal education				
≥12 years	57(61)	36(39)	93(45)	<0.001
<12 years	36(32)	78(68)	114(55)	
Health Insurance				
Private	6(88)	2(12)	8(4)	0.018
Public	75(47)	83(53)	158(79)	
Does not have	9(26)	25(74)	34(17)	
Occupational safety agency				
Member	32(67)	16(33)	48(23)	0.002
Not member	23(43)	30(57)	53(26)	
Does not know	38(36)	68(64)	106(51)	
Location where lives and works				
Talca	52(83)	11(17)	63(30)	<0.001
Curicó	41(28)	103(72)	144(70)	

Note: Frequency, percentage and *p*-value for the difference between the two groups as tested by the chi-square test are shown.

the mean monthly income was $358 USD. Of the agricultural workers, 76 (67 %) reported applying pesticides in their work. The socio-demographic characteristics of participants are described in Table 1. The difference between the two groups was significant for all variables.

Workers did not report situations of drug abuse or alcoholism, although 43 % of workers reported alcohol use (no difference between agricultural vs. non-agricultural workers, $p = 0.617$). With regards to smoking, 25 % of non-agricultural workers identify as smokers, compared to 11 % of agricultural workers ($p = 0.012$). Regarding working history, 31 % of agricultural workers are seasonal workers, 25 % are farmers, 18 % are self-employed in areas non-agricultural, 10 % are assistants or juniors, and the remaining 16 % are distributed amongst diverse other jobs.

In reviewing the health status of workers (Table 2), significant differences were observed between the groups only for previous OP pesticide poisoning ($p < 0.0001$).

A logistic regression model was developed including the dependent variable pesticide poisoning whereas the independent variables were agricultural or non-agricultural worker, income, sex, age, years of study, years of exposure, applicator or non applicator, distance of household from agricultural fields, cigarette smoking, and alcohol consumption. The final model showed an association between pesticide poisoning and agricultural work (OR = 2.9, 95 % CI = 1.2–6.9) and more years of exposure (OR = 1, 95 % CI = 1–1.1).

No significant associations were observed in multivariate models with regard to others health conditions included in Table 2.

Most (98 %) agricultural workers reported previous exposure to pesticides, compared to only half of other workers reporting exposure (Table 3).

When asked about the use of particular pesticides, 105 agricultural workers (92 %) reported using one or more pesticides, including OPs (64 %), herbicides (32 %), pyrethroids (8 %), fungicides (11 %), other pesticides (14 %) or chemicals (copper, fertilizers, hormones, etc.), and unspecified pesticides (8.5 %). At home, 50 % had used pesticides, and 43 % used organophosphates. The most frequently reported pesticide used (17.9 %) at home was Lorsban, which is a trade name of chlorpyrifos considered

Table 2. Health status in non-agricultural ($n = 93$) and agricultural workers ($n = 114$) of the Maule region, Chile (frequency, percentage, and chi-square test).

	Non-agricultural workers	Agricultural workers	Total	
	n = 93	*n* = 114	*n* = 207	
	n (%)	*n* (%)	*n* (%)	*p*-value (<0.05)
Allergies	9(50)	9(50)	18(9)	0.651
Anemia	4(57)	3(43)	7(3)	0.509
Asthma	3(38)	5(62)	8(4)	0.667
Depression	13(57)	10(43)	23(11)	0.236
Diabetes	6(43)	8(57)	14(7)	0.872
Hypertension	18(42)	25(58)	43(21	0.650
Kidney failure	2(33)	4(67)	6(3)	0.562
Heart problems	4(40)	6(60)	10(5)	0.748
Anxiety	21(53)	19(47)	40(19)	0.284
Congenital malformation in children	7(64)	4(36)	11(5)	0.211
Pesticide poisoning	11(22)	40(78)	51(25)	<0.0001
Hospitalization for pesticide poisoning	1(17)	5(83)	6(3)	0.158

Table 3. Occupational exposure and use of pesticides at home in non-agricultural and agricultural workers in the Maule Region, Chile (frequencies, percentages, and chi square test).

	Non agricultural workers	Agricultural workers	Total	
	n = 93	*n* = 114	*n* = 207	
	n (%)	*n* (%)	*n* (%)	*p*-value (<0.05)
Previous pesticide exposure	48(30)	112(70)	160(77)	<0.0001
Greenhouse or orchard at home	33(32)	71(68)	104(51)	<0.0001
Agricultural land owner	31(21)	83(79)	114(57)	<0.0001
Distance from home to farms <500 m (vs. ≥500 m)	46(33)	93(67)	139(70)	<0.0001
Pesticide use at home, orchard or garden	43(30)	99(70)	142(69)	<0.0001
OP use at home, orchard or garden	18(26)	52(74)	70(34)	<0.0001

as moderately hazardous (Thundiyil et al. 2008; CDC 2009; SAG 2012b) and 8.7 % reported use of the highly dangerous OP pesticide methamidophos (trade names MTD 600, Tamaron and Monitor) (Thundiyil et al. 2008; CDC 2009; SAG 2012b). On average, agricultural workers were exposed to pesticides for 21 (±1.6) years, compared to 5 (±0.9) years in other workers ($p < 0.0001$).

The characteristics of both groups and their use of PPE are described in Table 4.

With regard to Table 4, it is important to mention that workers, who reported that occupational safety agency tested for acetyl cholinesterase activity (37 %), were blinded to the results. For this study, it was not possible to access to these values because they are not public data.

No significant differences in cigarette smoking were observed in agricultural workers between applicators and non-applicators ($p = 0.677$). With regard to alcohol consumption, significant differences were observed between applicators and non-applicators ($p = 0.002$), where the latter are those who consume more frequently (67 %). The health status of both groups (non-applicator and applicator) is described in Table 5.

Table 5 shows that the clinical diagnosis of anxiety is more common in agricultural workers that are applicators, with statistically significant differences between both groups (applicator and non-applicator).

A logistic regression model was developed with the dependent variable anxiety and the variables applicator or non-applicator, sex, age, years of education, income, years of exposure, alcohol consumption, cigarette smoking, proximity of household to farm fields, PPE use, sanitation facilities,

Table 4. Socio-demographic characteristics, use of personal protective equipment (PPE) and working conditions of agricultural workers in the Maule Region, Chile.

	Non-applicator	Applicator	Total	
	n = 38	*n* = 76	*n* = 114	
	n (%)	*n* (%)	*n* (%)	*p*-value (0.05)
Gender				
Male	14(19)	60(81)	74(65)	<0.0001
Female	24(60)	16(40)	40(35)	
Age				
49 years or less	16(33)	32(67)	48(42)	0.999
More than 49 years	22(33)	44(67)	66(58)	
Years of education				
Secondary education or higher	16(44)	20(56)	36(32)	0.087
Secondary not finished or lower	22(28)	56(72)	78(68)	
Use PPE body	9(20)	37(80)	46(41)	0.013
Use PPE head	21(34)	40(66)	61(54)	0.791
Use PPE hands	12(27)	33(73)	45(39)	0.223
Use PPE respiratory	10(22)	35(78)	45(39)	0.042
Use PPE eyes	13(28)	34(72)	47(41)	0.282
Use PPE feet	15(22)	54(78)	69(61)	0.001
PPE frequency of use				
Always	13(48)	14(52)	27(24)	0.150
Sometimes	15(31)	33(69)	48(42)	
Never	10(26)	29(74)	39(34)	
Sanitation facilities	23(47)	34(53)	49(43)	0.593
Training on pesticide use from occupational safety agency	8(44)	10(56)	18(16)	0.289
Occupational safety agency tested for acetyl cholinesterase activity	12(29)	30(71)	42(37)	0.410

Note: Applicator indicates subjects who reported applying pesticides OP in their work (frequency, percentage and chi square test).

Table 5. Health status in non-applicator (*n* = 38) and applicator workers (*n* = 76) of the Maule region, Chile (frequency, percentage and chi-square test).

	Non-applicator	Applicator	Total	
	n = 38	*n* = 76	*n* = 114	
	n (%)	*n* (%)	*n* (%)	*p*-value (0.05)
Allergies	3(33)	6(67)	9(8)	1
Anemia	1(33)	2(67)	3(3)	1
Asthma	1(20)	4(80)	5(4)	0.518
Depression	3(30)	7(70)	10(9)	0.815
Diabetes	1(13)	7(88)	8(7)	0.195
Hypertension	11(44)	14(56)	25(22)	0.200
Kidney failure	0(0)	4(100)	4(4)	0.150
Heart problems	1(17)	5(83)	6(5)	0.374
Anxiety	2(11)	17(89)	19(17)	0.021
Congenital malformation in children	2(50)	2(50)	4(4)	0.463
Pesticide poisoning	12(30)	28(70)	40(35)	0.579
Hospitalization for pesticide poisoning	0(0)	5(67)	5(4)	0.106

training on pesticide use from occupational safety agency, and occupational safety agency tested for acetyl cholinesterase activity, showing a positive association between anxiety and work as applicator (OR = 17.1, 95 % CI = 2.6–110.4), female gender (OR = 12.4, 95 % CI = 2.9–53.6) and incomplete secondary education or less (OR = 10.0, 95 % CI = 1.6–61.9).

Fifty-six percent of agricultural workers showed symptoms of recent (during the last year) OP pesticide poisoning. The most common symptoms included headache (46 %), dizziness (19 %), blurred vision (15 %), lower limb cramps (12 %), and shortness of breath (11 %).

Table 6. Association between symptoms of recent organophosphate (OP) pesticide poisoning[1] and independent variables (use of respiratory personal protective equipment (PPE), age, years of OP pesticide exposure, and whether subject reports application of pesticides for work).

Poisoning symptoms[1]	OR	*p*-value (<0.05)	Confidence interval (95 %)	
Use of respiratory PPE[a]	0.338	0.013	0.143	0.797
Age[b]	0.356	0.032	0.138	0.917
Years of OP pesticide exposure[c]	1.030	0.043	1.000	1.060
Applicator status[d]	0.935	0.887	0.373	2.343

[a]1 = Does not use PPE; 0 = Use PPE.
[b]0 = ≤49 years old, 1 = >49 years old.
[c]Continuous variable.
[d]1 = Pesticide applicator; 0 = Non-applicator.
[1]We considered a subject to have poisoning symptoms if they reported at least two symptoms associated with exposure to OP pesticides during the last year (poisoning symptoms: Headache, abdominal pain, excessive salivation, blurred vision, vomiting, insomnia, dizziness, legs weakness, shortness of breath, nausea, diarrhea, night sweats, skin lesions, and fatigue).

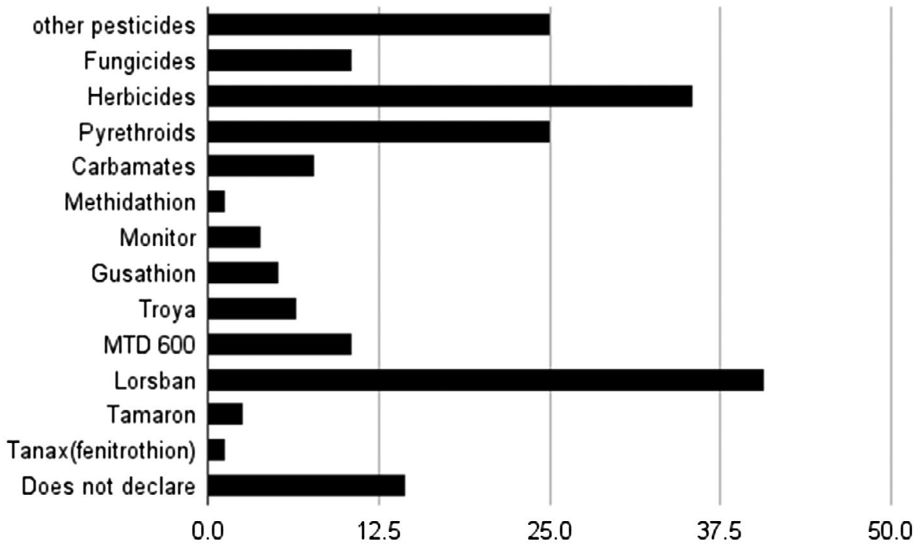

Figure 1. Percentages of pesticide type and organophosphate (OP) pesticides[1] used by applicators (*n* = 76).
[1]OP Pesticides: Methidathion, Monitor (Methamidophos), Gusathion (Azinphos methyl), Troya (Chlorpyrifos), MTD 600 (Methamidophos), Lorsban (Chlorpyrifos), Tamaron (Methamidophos) and Tanax (Feniotrothion).

No statistically significant differences in the symptoms of recent poisoning among pesticide applicators vs. non-applicators were observed. However, the use of respiratory PPE and younger age were protective factors from symptoms of acute pesticide poisoning, while a greater number of years of exposure to pesticides was associated with a higher likelihood of having symptoms of intoxication for OP pesticides (Table 6).

In applicators, the mean number of years applying pesticides was 16 (±1.5). Seventy-nine percent had no pesticide applicator license credentials, 84 % performed the mixing and preparation of pesticides, with 88 % of those doing so in an open area and 48 % of those used PPE while doing so. Eighty-seven percent work as applicator during the agricultural production season. It is observed that in spite of the training that pesticide applicators receive, a significant number of them do not use the PPE, which is associated with symptoms of poisoning.

Of the applicators that knew the trade names of pesticides used in 2014, 72.4 % reported use of OP pesticides. Figure 1 shows the percentage of pesticides type and OP pesticides reported by the subjects as applied during work. Of the reported pesticides used, 17 % reported using the highly dangerous OP methamidophos and 47.4 % reported using chlorpyrifos.

The majority (75 %) of pesticide applicators reported that they know the risks of applying pesticides, although only 50 % reported receiving training on those risks. With respect to best practices, 91 % of applicators used manual backpack sprayers, 50 % used a motorized knapsack; 44 % cleaned their equipment in a specially equipped location, with the other 56 % cleaning their equipment in the yard, orchard or irrigation canals; 70 % stored pesticides in a warehouse, 83 % reported eating food or smoking when applying pesticides, 28 % reported immediately changing work clothes at the end of the application. The average time reported between the end of the application and taking a shower or bath was 52 (±8.6) minutes.

Discussion

The results of this study suggest that agricultural workers from the Maule region, Chile, are exposed to substantial amounts of OP pesticides and a number of other pesticides, many of them without proper protection. Pesticide poisoning is seen primarily in agricultural workers, and almost all agricultural workers reported exposure to pesticides, compared to only half of other workers, with 64 % reporting exposure to OPs.

That most workers in this survey do not belong or are unaware of their membership in job security agencies (Table 1) is an indicator of the vulnerability they experience in the workplace. Another socio-demographic characteristic of agricultural workers indicating vulnerability compared to non-agricultural workers are the number of years of formal education. Most have incomplete secondary education or less. Their exposure to neurotoxins, prevention of health effects, and handling of pesticides may be affected by not being able to understand instructions, not knowing how to read or not having information about the effects of these pesticides in the human body and the environment. The results of our survey suggest that many agricultural workers are not fully trained (only 50 % of the applicators of pesticides) about the health effects of pesticides, do not use PPE, and store pesticides or clean machinery in unsuitable places for such activities.

With respect to the health status of workers, both groups (agricultural and non-agricultural) have similar health indicators except cigarette smoking, which is higher in non-agricultural workers. The lower consumption of cigarettes in agricultural workers may be explained by their lower earnings compared to other workers, and also the greater accessibility to tobacco in urban areas.

Interestingly, non-agricultural workers also reported some cases of pesticide poisoning. This could be explained possibly by previous employment in the agricultural sector, as even non-agricultural workers report a mean of 5 (±0.9) years of exposure to pesticides.

Also, a significant association was observed between anxiety and work as applicator, adjusting for gender and years of study, similar to what was found in other studies (Bayrami et al. 2012; Malekirad et al. 2013). The association with female gender and low educational represents an aspect that increases the risk of developing a mental health problem in applicators. While the proportion of women applicators is lower than men, this study draws attention to the higher levels of anxiety concentrated in women applicators of OP pesticide. The literature refers primarily to the relationship between anxiety and pesticide applicators but considering only a male sample (Malekirad et al. 2013). Therefore, this result constitutes a finding that should be studied in the future. Anxiety disorder develops in OP pesticide applicators (Kamel & Hoppin 2004), but is also more common in women and in people with less education. However, this work shows that the association with anxiety is stronger in women with a lower level of studies compared to women non-applicators with the same level of education. We hypothesize that the very fact of being exposed to OP pesticide could affect executive functions in workers, generating lesser strategies of executive control of their emotions and the resolution of problems, all of which is enhanced by psychosocial elements as gender inequality favoring the development of increased anxiety (Woo & Postolache 2008). Also, women are more proactive than men to declare symptoms of mental health and seeking help (McLean et al. 2011). In this sense, it would be relevant in a subsequent study to control psychosocial and cognitive variables besides gender and level of study of OP pesticide applicators.

Our data suggest that the use of PPE is key to preventing symptoms of poisoning, a situation also observed in other studies with similar populations (Lehtola et al. 2008; Salvatore et al. 2009). Regardless of whether an agricultural worker was classified as an applicator or non-applicator of pesticides, the presence of recent (during the last year) symptoms of OP pesticide poisoning was significantly associated with not wearing respiratory PPE, more years of exposure to pesticides, and older age. This is explained because many non-applicators do not use respiratory PPE during pesticide application by others and they are indirectly exposed. It is also worth mentioning that non-agricultural workers who suffered some kind of poisoning correspond mainly to minors non-frequent poisonings related to exposure at home or indirect exposure. It was considered relevant to investigate this variable because the Maule Region is a predominantly agricultural area in Chile, where environmental exposure to pesticides is expected. Most workers use OP pesticides classified as highly or moderately dangerous (Thundiyil et al. 2008; CDC 2009; SAG 2012b), these pesticides are associated with symptoms such as neurological disorders and cognitive dysfunctions (Alavanja et al. 2004; Costa 2006; Rothlein et al. 2006).

Our results also indicate that the majority of workers receive little training on the effects of pesticides. We suggest that training in safe pesticide handling be carried out amongst all agricultural workers, and respecting the specific cultural context of those workers, as suggested by previous literature (Lehtola et al. 2008; Ospina et al. 2009; Salvatore et al. 2009; Orozco et al. 2011).

Our study was limited by the socio-demographic differences observed between agricultural and non-agricultural workers (gender, years of education, geographic location, and socioeconomic status) that make it difficult to compare between the groups. Also, gender differences were observed among agricultural workers between pesticide applicators and non-applicators. However, these variables were controlled through their inclusion for adjustment of the multivariate regression models developed to examine association between workers' OP pesticide exposure and health conditions. Another limitation was that exposure was determined from an occupational questionnaire and not through bio-markers. In this study, agricultural workers were consulted if the security agency conducted monitoring of the activity of acetylcholinesterase. Workers that declare they have been tested (37 %) did not know the result and it was not possible to have access to them.

While bio-markers are a more accurate indicator of OP exposure, require repeated measurements to determine a baseline (Needham 2005; Muñoz-Quezada et al. 2016), with higher cost for collection and laboratory analysis. Thus, although the application of questionnaires of occupational exposure is not the ideal parameter, it is a useful and less expensive instrument to determine OP pesticide exposure.

The results of this study demonstrate the lack of health and occupational safety of Chilean farm workers, a finding similar to other developing country contexts (Ospina et al. 2009). Whereas Chile recently was incorporated into the group of developed countries by The World Bank (The World Bank 2013), the status of environmental health in the country still lags behind (Pino et al. 2015). With respect to the safety of agricultural workers, there are no clear policies of protection, exposure control, and prevention activities for pesticide handling appropriate to the cultural level and income of rural farmers. Some OP pesticides mentioned by farmers (MTD 600, Tamaron and Monitor, all methamidophos) are classified as highly dangerous (Thundiyil et al. 2008; CDC 2009; SAG 2012b), and are banned in other Latin American countries, USA, Canada, and Europe (Muñoz-Quezada et al. 2014) due to their high level of toxicity and chronic effects associated with cancer and neurological diseases. In addition, in many countries pesticides like chlorpyrifos are highly regulated and cannot be applied or purchased by any individual. In contrast, in Chile the requirements for a certified applicator license is not linked to permission for restricted purchase of and access to these pesticides, and currently anyone can buy them.

We conclude that in Chile development of policies to address the current vulnerability and risk of farm workers is sorely needed. It is also important to more broadly evaluate the hazards associated with pesticide exposure in agricultural settings, as poor regulation and education in the management of these chemicals can also endanger the environment and consequently the general population (Lehtola et al. 2008; CDC 2009; Salvatore et al. 2009; Oliveira Pasiani et al. 2012; SAG 2012a). This could occur, for example, via inadequate practices in cleaning machines or disposing of pesticide residues into irrigation canals, which could subsequently contaminate crops, humans, and animals. Enhanced training and awareness is therefore needed for all those who work in agriculture, not only in pesticide applicators (Salvatore et al. 2009; Oliveira Pasiani et al. 2012).

We also recommend the development of regulations at the legislative level that restrict the use of highly hazardous pesticides, as has already been implemented in developed countries, as well as strict guidelines about the fulfillment of basic requirements for the sale of pesticides, and greater record-keeping requirements, which would enable monitoring of pesticide use nationally.

Statements of authorship

María Teresa Muñoz Quezada, Boris Lucero, Verónica Iglesias, María Pía muñoz, Eduardo Achú, Claudia Cornejo, Carlos Concha, Ana María Brito y Marcos Villalobos, developed the concept and designed this work. María Teresa Muñoz Quezada, Boris Lucero, Claudia Cornejo, Carlos Concha, Ana María Brito y María Pía Muñoz, participated in data collection. All authors participated in the analysis and interpretation of data, drafting the manuscript, critical revision of the text and approval of the final version.

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