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Intoxication symptoms and health conditions of family farmers associated with the use of pesticides: a study conducted in Zona da Mata Mineira, Brazil

Sintomas de intoxicação e condições de saúde de agricultores familiares associadas ao uso de agrotóxicos: um estudo realizado na Zona da Mata Mineira, Brasil

Síntomas de intoxicación y condiciones de salud de agricultores familiares asociados al uso de pesticidas: un estudio realizado en la Zona da Mata Mineira, Brasil

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Abstract
This study aimed to evaluate the association between the use of pesticides, symptoms of intoxication and health conditions of family farmers in the Mata Mineira area, Brazil. This is a cross-sectional study with 48 family farmers from a municipality in the Zona da Mata, Minas Gerais. A semi-structured questionnaire was applied to obtain demographic, socioeconomic information and characterization of the use of pesticides. Blood samples were collected from farmers for biochemical tests and evaluation of markers of exposure to pesticides. It was found that 75% of farmers used pesticides in food production, most of these products being extremely toxic. These farmers showed changes in plasma cholinesterase, erythrocyte cholinesterase and butyrylcholinesterase, markers of exposure to pesticides. There was an association between spraying for more than 4 hours/day and reporting of acute symptoms of intoxication, as well as between the use of pesticides and the presence of chronic non-communicable diseases. Multivariate analysis indicated that non-compliance with the period of re-entry into crops after the use of pesticides remained as an explanatory variable for lung disease. We infer that acute symptoms, as well as chronic non-communicable diseases reported by family farmers, may be associated with the use of pesticides.
Keywords: Agrochemicals; Food production; Occupational health; Human contamination; Cholinesterase.

Resumo
Este estudo teve como objetivo avaliar a associação entre uso de agrotóxicos, sintomas de intoxicação e condições de saúde de agricultores familiares da Mata Mineira, Brasil. Trata-se de um estudo transversal com 48 agricultores familiares de um município da Zona da Mata mineira. Foi aplicado um questionário semiestruturado para obtenção de informações demográficas, socioeconômicas e caracterização do uso de agrotóxicos. Amostras de sangue foram coletadas dos agricultores para exames bioquímicos e avaliação de marcadores de exposição a agrotóxicos. Constatou-se que 75% dos agricultores utilizavam agrotóxicos na produção de alimentos, sendo a maioria desses produtos extremamente tóxicos. Esses agricultores apresentaram alterações na colinesterase plasmática, colinesterase eritrocitária e butirilcolinesterase, marcadores de exposição a agrotóxicos. Houve associação entre pulverização por mais de 4 horas/dia e relato de sintomas agudos de intoxicação, bem como entre uso de agrotóxicos e presença de doenças crônicas não transmissíveis. A análise multivariada indicou que o não cumprimento do período de reingresso nas lavouras após o uso de agrotóxicos permaneceu como variável explicativa para doença pulmonar. Inferimos que sintomas agudos, assim como doenças crônicas não transmissíveis relatadas por agricultores familiares, podem estar associados ao uso de agrotóxicos.
Palavras-chave: Agroquímicos; Produção de alimentos; Saúde ocupacional; Contaminação humana; Colinesterase.

Resumen
Este estudio tuvo como objetivo evaluar la asociación entre el uso de pesticidas, los síntomas de intoxicación y las condiciones de salud de los agricultores familiares en el área de Mata Mineira, Brasil. Se trata de un estudio transversal con 48 agricultores familiares de un municipio de la Zona da Mata, Minas Gerais. Se aplicó el cuestionario semiestructurado para obtener información demográfica, socioeconómica y caracterización del uso de plaguicidas. Se recolectaron muestras de sangre de los agricultores para pruebas bioquímicas y evaluación de marcadores de exposición a pesticidas. Se encontró que el 75% de los agricultores utiliza pesticidas en la producción de alimentos, siendo la mayoría de estos productos extremadamente tóxicos. Estos agricultores mostraron cambios en la colinesterasa plasmática, la colinesterasa eritrocitaria y la butirilcolinesterasa, marcadores de exposición a plaguicidas. Hubo asociación entre aspersiones por más de 4 horas/día y reporte de síntomas agudos de intoxicación, así como entre el uso de pesticidas y la presencia de enfermedades crónicas no transmisibles. El análisis multivariada indicó que el incumplimiento del período de reingreso a los cultivos después del uso de plaguicidas se mantuvo como variable explicativa de la enfermedad pulmonar. Inferimos que los síntomas agudos, así como las enfermedades crónicas no transmisibles reportadas por los agricultores familiares pueden estar asociados al uso de plaguicidas.
Palabras clave: Agroquímicos; Producción de alimentos; Salud ocupacional; Contaminación humana; Colinesterasa.

1. Introduction

Agricultural production can be affected by pests and diseases caused by arthropods, fungi, bacteria and other pathogens, as well as invasive plants. To combat these infestations, many farmers use pesticides such as insecticides, fungicides, bactericides, herbicides, among others. However, these products can bring serious consequences to human health (Jardim & Andrade, 2009; Haggblade, et al., 2017; Sapbamrer & Thammachai, 2020).

The risk of contamination by pesticides through environmental, food and occupational pathways can lead to acute and chronic poisoning (MacFarlane, et al., 2013; Sapbamrer & Thammachai, 2020). Farmers are considered to be the most exposed to these contaminations, because they prepare, transport and apply these products to crops, as well as having frequent contact with spraying and storage sites. Many of them do not respect the interval for re-entry into the crops, called the "safety period" and generally do not use Personal Protective Equipment (PPE) for dilution, application, transport and storage, in addition to not following the safety standards, exposing themselves even more to the risks of contamination by pesticides (Andrade-Rivas & Rothe, 2015).

Biochemical tests to assess the activities of enzymes – plasma and erythrocyte cholinesterases – have been used to diagnose occupational exposure to organophosphate and carbamate pesticides (Brasil, 2006; Ahmadi & Mansourian, 2007; Dhananjayan, et al., 2012). The activities of cholinesterases are due to the actions of two enzymes, erythrocyte cholinesterase indicating chronic exposure and plasma cholinesterase indicating acute exposure (Oliveira-Silva, Meyer & Moreira, 2000). These tests are related to the intensity and duration of exposure to anticholinesterase agents present in these pesticides (Peres, et al., 2005; Câmara, et al., 2012) and are used to detect intoxications by the Protocolo de Atenção à Saúde dos Trabalhadores Expostos a Agrotóxicos no Brasil (Health Care Protocol Of Workers Exposed To Pesticides In Brazil) (Brasil, 2006).

Pesticides themselves are already considered risky, and poisoning by these products can provoke different manifestations. Epidemiological studies have reported that there is an association between occupational exposure to these products, and several types of cancer, hormonal and reproductive damage, liver and kidney, reduction of immune defenses, anemia, headache, insomnia, changes in blood pressure, depression, behavioral disorders, skin diseases, among other health problems, both physical and mental health (Souza, et al., 2011; Fiocruz, 2013; Carneiro, et al., 2015; Kim et al., 2017).

The use of pesticides in agriculture has been justified to meet the growing demand for food, overcome the hunger of the population and increase the income of the farmer by increasing production. With this, conventional agriculture became dependent on pesticides, making Brazil, in 2008, the world's largest consumer of these products (Carneiro, et al., 2015). This model of agriculture can achieve high yields, however, it causes adverse effects on the environment, biodiversity and human health. In addition, there may be a reduction in the natural biological control of pests and diseases by natural enemies and the development of resistance in target organisms, resulting in the need for greater use of pesticides (D'annolfo, et al., 2017; Dainese, et al., 2019).

In addition, the solution to the problem of hunger is not only through increased food production, since access to and use of food depend more on people's financial resources than on increased production (Godfray, et al., 2010). Thus, the justifications for the high use of pesticides have not been confirmed. Concomitantly, this model of agriculture has caused social and economic impact on public health due to occupational exposure to pesticides by rural workers (Ramírez-Santana, et al., 2014; Dang, et al., 2017).

Considering that Brazil is the country that most uses pesticides and has global prominence in agricultural production, studying the impacts of these products on the health of farmers is necessary. This study aimed to evaluate the association between the use of pesticides, symptoms of intoxication and health conditions of family farmers in the Zona da Mata Mineira, Brazil.

2. Methodology

This is a cross-sectional study, conducted with 48 family farmers in a rural sector of a municipality in the Zona da Mata, located in the Southeast region of the state of Minas Gerais, Brazil. With rugged relief, characterized by the predominance of hills, narrow valleys and some mountains, the creation of dairy cattle, pigs and poultry, sugar cane, corn, beans, coffee and vegetables stand out in the Zona da Mata economy, among others.

The selection of farmers was based on research previously conducted by Lopes (2017) in the same rural sector of the respective municipality of Zona da Mata, where the problem of the use of pesticides in food production was raised.

A semi-structured questionnaire was applied with farmers to obtain demographic and socioeconomic information (sex, age, education and income) and to characterize the use of pesticides as described in Table 1.

Table 1. Variables to characterize the use of pesticides by family farmers in the municipality of Zona da Mata, Minas Gerais, Brazil.

Variables	Objective
Application of pesticides by parents	Check if parents who live on another property also used or use pesticides
Family assistance in spraying pesticides	Verify if any family member assists in spraying
Use of Personal Protective Equipment (PPE)	Verify if the use of PPE is correct (Senar, 2015)
Medical diagnosis of intoxication	Obtain information on medical diagnosis of poisoning resulting from the use of pesticides in crops
Type of exposure	Identify the form of exposure to pesticides: dilution of the product, spraying, transportation, etc
Washing of PPE	Verify if the PPE is washed after spraying and who performs this function
Technical guidance	Verify that farmers receive guidance for the use of pesticides by technically trained and qualified professionals
Product leaflet	Verify that farmers read the package leaflet and follow the instructions contained therein
Spraying/day in hours	Verify how many hours a day the farmers are exposed occupationally by spraying pesticides
Re-entry into the crops	Verify that the period for re-entry to the spraying sites is respected by farmers
Destination of packages	Verify the destination of empty pesticide packages
Washing of the sprayer	Verify where the sprayer is washed after completion of spraying: crop, river, house yard, house tank, etc
Class of pesticide used	Identify the target class/function and toxicological classification of the product, active ingredients and application cultures
Quantity of pesticide class used	Quantify the number of farmers using pesticides by class: herbicide, insecticide, acaricide, fungicide
Exposure time in years	Verify how many years farmers using pesticides are occupationally exposed
Presence of acute symptoms after working with pesticide	Verify the occurrence of acute symptoms (Carneiro, et al., 2015)
Presence of Chronic Non-Communicable Diseases (NCDs)	Identify the presence of diseases

Source: Authors.

Blood samples were collected by a health technician from an accredited laboratory. In these samples, evaluations of farmers' exposure to pesticides were performed by measuring the activity levels of plasma and erythrocyte cholinesterases and butyrylcholinesterase, which are markers of exposure to pesticides (Araújo, et al., 2007), adopting as normal values the cut-off points recommended by the pharmaceutical industry that produces the kit. For plasma cholinesterase the value of 5,320 to 12,920 U/L was considered, for erythrocyte cholinesterase 10,229 to 23,761 U/L and for butyrylcholinesterase – women (3930 to 10800 U/L) and men (4620 to 11500 U/L).

Tests were also performed for the analysis of the components of the red and white series of blood, kidney and liver function (complete blood count; creatinine; urea; albumin, total protein; aspartate aminotransferase-TGO; alanine aminotransferase-TGP; alkaline phosphatase-ALP; gamma-glutamyltranspeptidase-GGT). For this, the farmers were fasting for 8 hours. Considering the stages of the research, different sample values were obtained. 48 family farmers answered the questionnaire questions. Regarding the performance of biochemical tests, 41 agreed to perform.

The data were processed in *SPSS*, version 20.0 and the information presented in a descriptive way. The associations were tested by *Fisher's Exact* and *Pearson's Chi-square* tests. The rejection level of the null hypothesis was 0.05. In the multivariate analysis, the multinominal logistic regression model was used with the inclusion of variables related to the use of pesticides with $p<0.20$ and remaining in the final model with $p<0.05$.

The participation of family farmers took place on a voluntary basis, by signing the Informed Consent Form. The project was approved by the Ethics Committee in research with human beings of the Federal University of Viçosa (UFV), *Campus Viçosa*, opinion number 1.861.963.

3. Results

Of the 48 farmers, 79.2% (n = 38) are male. The median age was 60 years old (minimum = 32; maximum = 81); median years of study equal to 4 (minimum = 0; maximum = 13) and calculated monthly *per capita* income of R$624.00 (minimum = R$150.00; maximum = R$2,640.00), based on the minimum wage of R$937.00; value corresponding to the year in which the data were collected.

Regarding schooling, it was found that 10.4% (n = 5) were illiterate and among the literate, 83.7% (n = 36) had 1 to 4 years of study, with 66.6% (n = 24) attended until the 4th Year (Primary School); 11.7% (n = 5) from 5 to 8 years of study (Elementary School); 2.3% (n = 1) 11 years of study (full High School) and 2.3% (n = 1) incomplete higher education.

It was found that 75% (n = 36) of farmers reported the use of pesticides in food production, the majority of which were men – 88.9% (n = 32). Of these, 55.6% (n = 20) used it when the data were collected and 44.4% (n = 16) had already used it in some period of life. The median working time with pesticides was 12 years (minimum = 1; maximum = 51 years). Table 2 shows the characterization of the use of these products.

Table 2. Characterization of the use of pesticides by family farmers (n=36) in the municipality of Zona da Mata, Minas Gerais, Brazil.

Variables	Nº	%
Parents use/used pesticides		
No	23	63,9
Yes	13	36,1
Family assistance in spraying		
No	25	69,4
Yes	11	30,6
Correct use of PPE		
No	31	86,1
Yes	5	13,9
Medical diagnosis of intoxication		
No	34	94,4
Yes	2	5,6
Type of exposure		
Dilution and spraying	35	97,2
Spraying only	1	2,8
Person who washes clothes/PPE		
Wife/daughter	23	63,9
Person himself/herself	12	33,3
It is not washed	1	2,8
Receives technical guidance		
Yes	20	55,6
No	16	44,4
Follows pesticide package leaflet		
No	19	52,8
Yes	17	47,2
Symptoms after spraying		
No	19	52,8
Yes	17	47,2

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Spraying/day for + 4 hours in a row		
Yes	22	61,1
No	14	38,9
Respect for the period of re-entry into the crops		
No	27	75,0
Yes	9	25,0
Destination of packages		
Burning	18	50,0
Returns at pickup location	15	41,7
Other*	3	8,3
Washing of the sprayer		
Field or crop	13	36,1
Backyard	8	22,2
Separate tank	7	19,4
Does not wash it	6	16,7
River	2	5,6
Class of pesticide used**		
Herbicide	29	80,6
Insecticide	15	41,7
Acaricide	7	19,4
Fungicide	6	16,7
Quantity of pesticide class used		
1	11	30,5
2	11	30,5
3	9	25,0
> 3	5	14,0

PPE = Personal Protective Equipment; *The packages are stored on the property; **Values do not close at 100%, as many farmers use more than one class of product. Source: Authors.

Regarding the pesticide to be used, 91.7% (n = 33) of farmers received indication of the product by neighbors and 8.3% (n = 3) by professionals with technical training and qualified by the Conselho Regional de Engenharia e Agronomia (Regional Council of Engineering and Agronomy) (CREA) or Conselho Federal dos Técnicos Agrícolas (Federal Council of Agricultural Technicians) (CFTA), to recommend these products.

Regarding the main crops in which farmers reported spraying pesticides, coffee, corn, beans, tomatoes and sugar cane stand out, with production for sale and/or self-consumption. It was observed that 52.9% (n = 9) of the products used were mostly classified as extremely toxic – packaging with red stripe; 11.8% (n = 2) highly toxic; 29.4% (n = 5) moderately toxic and 5.9% (n = 1) low toxic according to the classification of the Agência Nacional de Vigilância Sanitária (National Health Surveillance Agency) (ANVISA), control body of the Ministry of Health (ANVISA, 2019).

Regarding the products used, 61.0% (n = 22) used 1 or 2 different classes, 25% (n = 9) 3; 2.8% (n = 1) 4; 8.4% (n = 3) 5 and 2.8% (n = 1) 7 classes. The glyphosate herbicide stood out as the most used – 85.0% of family farmers reported using it. Among those who used or have already used pesticides, 47.2% (n = 17) reported having acute symptoms of intoxication on the day of application, being: headache (58.8%; n = 10), dizziness (35.3%; n = 6), nausea (35.3%; n = 6), muscle weakness (23.5%; n = 4), itching of the skin (5.8%; n = 1) and salivation/dry mouth (5.8%; n = 1), and 8.3% (n = 3) already had up to 4 symptoms after spraying.

Considering the exposure to pesticides, there was an association between spraying for more than 4 hours/day and reporting of acute symptoms of intoxication (Table 3). Farmers who used pesticides for more than 4 hours/day presented 2.97 times the prevalence of having some acute symptom compared to those who exercise the activity for less time.

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Table 3. Report of acute symptoms of intoxication by family farmers after spraying pesticides and related factors, in the municipality of Zona da Mata, Minas Gerais, Brazil.

Variables	Reporting of acute symptoms*		p*	RP (IC95%)**
	Yes	No		
	N (%)	N (%)		
Spraying/day for + 4h				
Yes	14 (82,4)	8 (42,2)	**0,015**	**2,97**
No	3 (17,6)	11 (57,8)		**(1,03-8,49)**
Respect for the re-entry period				
Yes	4 (23,6)	5 (26,4)	1,00	1,08
No	13 (76,4)	14 (73,6)		(0,47-2,48)
Correct use of PPE				
Yes	3 (17,7)	2 (10,6)	0,88	0,75
No	14 (82,3)	17 (89,4)		(0,33-1,69)
Use of Herbicide				
Yes	14 (82,3)	15 (79,9)	1,00	1,12
No	3 (17,7)	4 (21,1)		(0,44-2,86)
Use of Insecticide				
Yes	7 (41,2)	8 (42,1)	1,00	0,98
No	10 (58,8)	11 (57,9)		(0,48-1,97)
Use of Fungicide				
Yes	4 (23,5)	2 (10,5)	0,39	1,53
No	13 (76,5)	17 (89,5)		(0,76-3,09)
Use of Acaricide				
Yes	4 (23,5)	3 (15,7)	0,68	1,27
No	13 (76,5)	16 (84,3)		(0,59-2,72)

**Fisher's exact test* (p<*0.005*); * *PR – Prevalence Ratio (CI – 95% Confidence Interval). Symptoms reported: headache, dizziness, nausea, muscle weakness, itchy skin and salivation/dry mouth. Source: Authors.

Among the participants, 81.3% (n = 39) reported the presence of one or more diseases and/or symptoms, as shown in Table 4.

Table 4. Chronic non-communicable diseases self-reported by family farmers, in the municipality of Zona da Mata, Minas Gerais, Brazil.

CNCD*	Nº	%
-High Blood Pressure	20	51,3
-Skin disease (Allergies, Vitiligo)	9	23,1
-Lung Disease (Asthma, Bronchitis)	7	17,9
-Anemia	7	17,9
-Frequent headache	6	15,4
-Diabetes	5	12,8
-Cancer (Bowel, Breast, Prostate)	3	7,7
-Depression	3	7,7
-Kidney Disease (Kidney Stone, Glomerulonephritis)	3	7,7
-Hyperthyroidism	3	7,7
-Cardiovascular Disease (Tachycardia, Myocarditis)	2	5,1
-Hypercholesterolaemia	2	5,1
-Celiac Disease	1	2,6
-Liver Disease (Hepatitis A)	1	2,6
-Bone Disease (Arthrosis)	1	2,6

*All diseases have been reported or considered the use of medications. CNCD = chronic non-communicable diseases. Source: Authors.

Regarding biochemical tests, 56.1% (n = 23) of the 41 family farmers showed changes in the components of the red and white blood series, with 30.4% (n = 7) anemic; elevated values of markers for assessing renal and liver function and

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decreased cholinesterase activity. Among farmers who reported the use of pesticides, there was a reduction in plasma cholinesterase activity (8.3%; n = 3), erythrocyte cholinesterase (2.8%; n = 1) and butyrylcholinesterase (13.9%; n = 5), but these changes were not significant (Table 5).

Table 5 shows the relationship between the total number of farmers and the number of changes, considering the use of pesticides. There was an association between the use of these products and the presence of at least one NCD, and farmers who reported using them had a 5.71 times higher chance of having diseases compared to those who never used them.

Bivariate analysis was performed where the self-reported lung disease was explained by the variables related to the use of pesticides: “compliance with the period of re-entry into the crops” and “follow the package leaflet” ($p<0.20$). After multivariate analysis, non-compliance with the period of re-entry into crops ($p = 0.001$) remained as an explanatory variable for lung disease, regardless of the follow-up of the package leaflet in the application of pesticides. Family farmers who respected the re-entry period had a lower chance of having lung disease (OR= 0.069; CI: 0.011-0.438).

Table 5. Relation of the total number of family farmers according to the number of changes and use of pesticides, in the municipality of Zona da Mata, Minas Gerais, Brazil.

Use of pesticides	**YES**	**NO**	**Number of alterations**	**% of farmers according to number of alterations**	**p**	**OR (CI95%)[2]**
	Reported Diseases[a]					
YES	88,9% (n=32)	11,1% (n=4)	1	50,0	**0,019[1]**	**5,71 (1,21-26,88)**
			2	31,3		
			3	9,4		
			4	3,1		
			5	6,2		
NO	58,3% (n=7)	41,7% (n=5)	1	26,3		
			2	47,4		
			3	10,6		
			5	10,6		
			7	5,3		
	Biochemical alterations[b]					
YES	59,4% (n=19)	40,6% (n=13)	1	42,9	0,650	1,82 (0,41-8,12)
			2	28,6		
			3	14,3		
			4	14,3		
NO	44,4% (n=4)	55,6% (n=5)	1	75,0		
			2	28,6		

[a] = 48; [b] = 41 survey participants.[1] *Pearson's Chi-square*; [2]OR – *Odds Ratio* (CI – 95% Confidence Interval). Source: Authors.

4. Discussion

There was an association between acute symptoms of intoxication and exposure for more than 4 hours/day of spraying. The period of re-entry to the sprayed site, use of PPE and classes of pesticides were not associated with reports of acute symptoms. However, the use of pesticides and the absence of PPE may increase the risks to human health, as these factors add up (Carneiro, et al., 2015).

In the present study, farmers justified the non-use of PPE, mainly because it causes discomfort and is too hot. These justifications have also been found in the literature (Yap & Demayo, 2015; Marcelino et al., 2019; Lini, et al., 2021).

Regarding the pesticides used, these are mostly extremely toxic. The classification is related to the acute toxicity of the product, without identifying possible physiological, biochemical and/or histological changes in the body, resulting from exposure for a longer period (Almeida & Martins, 2008). Regardless of the spraying time or toxicological class, especially when these factors are added together, and the multi-exposure to the different classes of pesticides, the risk of symptoms such as those reported by farmers increases. In addition, belatedly can lead to the emergence of chronic diseases (Almeida & Martins, 2008; Kim et al., 2017).

The risk of exposure to pesticides is also increased by the illiteracy of farmers, lack of guidance and the indication of these products by unqualified people who do not have adequate technical training. This reality has been reported in other studies (Abreu & Alonzo, 2016; Mengistie et al., 2017; Sapbamrer & Thammachai, 2020). Illiteracy implies an increase in risk, since farmers are limited in reading the leaflet that warns about the dangers of contamination. In addition, many farmers are more vulnerable because even if they can read, they may have difficulty interpreting the information. Studies report that low level of education is one of the risk factors associated with the use of pesticides, in addition to the small print and difficult to understand language (Tofolo, et al., 2014; Akter, et al., 2018). It should be noted that literacy, awareness and the recommendation of pesticides by qualified professionals do not eliminate the risks of exposure.

The use of pesticides and the factors already mentioned, which did not show association with reports of acute symptoms, added to the lack of technical guidance and multiple exposure to the different classes of products, many being extremely toxic, can culminate in the emergence of different acute symptoms, such as those reported by the research participants. In the study conducted by Mello e Silva (2013) with coffee growers, reports of acute intoxication symptoms such as vomiting, dizziness, headache and weakness occurred during or after spraying with pesticides were recorded, symptoms reported by family farmers volunteers of the present study. A study conducted with agricultural coffee workers in the Southern Region of Minas Gerais also verified reports of acute symptoms due to occupational exposure, bringing these factors as possible conditioners (Souza, et al., 2011). Acute symptoms related to exposure to pesticides by family farmers were also reported in the study conducted by Ristow, et al., (2020).

Furthermore, the use of these products was associated with the presence of NCDs, with the percentage of reported diseases and higher biochemical changes among farmers who reported the use of pesticides (Table 5). Studies have found an association between exposure to pesticides and kidney problems of unknown etiology (Jayasumana, et al., 2015); stomach cancer (Boccolini, et al., 2014) and oral and neurological diseases (Souza, et al., 2011; Kim et al., 2017). However, this discussion also involves the form of dilution and application of the product; compliance with safety standards that aim to reduce the risks of exposure; toxicological class of the pesticide and number of active ingredients, which can increase the risk and cause different changes in the body, especially in the case of exposure for a longer period; exposure time in years, among other risk factors (Almeida & Martins, 2008).

The conduct of the multivariate analysis showed that compliance with the period of re-entry into the crops, specified in the product package leaflet, may decrease the chance of occurrence of lung disease, but not eliminate it. In the study conducted by Buralli, et al., (2018), occupational exposure to pesticides in the short or long term was associated with the presence of respiratory symptoms and, consequently, impaired lung function. In addition, the authors reported that the burden of morbidity and mortality associated with these diseases affects the public health system with increased financial expenditures.

Changes in plasma and erythrocyte cholinesterase, enzymes found mainly in plasma and nervous system synapses, respectively, were observed. These have been the most used for the evaluation of human exposure to certain classes of pesticides, since they act in the regulation of nerve impulses, being inhibited in the presence of products of the classes of organophosphates and carbamates (Peres, et al., 2005).

It is noteworthy that cholinesterase activity is reduced quantitatively and proportionally with exposure to the pesticide, since these compounds bind to the sterase center of the acetylcholinesterase molecule, reflecting on the regulation of nerve impulses (AChE) (Peres, et al., 2005). Cholinesterases are able to measure acute (plasma cholinesterase) and chronic (erythrocyte cholinesterase) exposure to pesticides, but the results should be considered in conjunction with other evaluations (Araújo, et al., 2007).

In the study by Murakami, et al., (2017), changes in the TGO, TGP, GGT and alkaline phosphatase were observed in fumiculturists exposed to pesticides, suggesting the development of liver and kidney damage due to exposure to pesticides, as observed in the present study. Other studies have found an association between exposure to pesticides, considering occupational exposure and reduced activity of plasma, erythrocyte cholinesterase and butyrylcholinesterase (Linares, et al., 2005; Silva, et al., 2005; Araújo, et al., 2007; Figueiredo et al., 2011; Nerilo, et al., 2014).

A review carried out by Nogueira et al., (2020) showed that family farmers are at greater risk for chronic diseases, biochemical changes and symptoms of acute intoxication.

Data released by Bombardi (2017) reveal that southeast Brazil is the second region with the highest number of poisonings by agricultural pesticides, where the state of Minas Gerais is located, which has the highest number of poisonings. The study also draws attention to the evolution of cases that culminate in death and to the number of intoxication among individuals with lower education.

Preventive measures need to be established, because producers can achieve the goal of higher production and income in the short term with the use of these products, however, in the long term they may have to spend treating diseases arising from exposure to pesticides. The results of the present study draw attention mainly to the use of pesticides associated with acute symptoms and the presence of NCDs, as well as changes in biochemical tests, with the working time in years, of many farmers who spray these products, relevant to the context of the findings.

The low level of education of farmers, the label of pesticides with limitations in the language and size of letters, not respecting the period of re-entry into the crops after the use of pesticides, having recommendations of pesticides by unqualified professionals and the incorrect use of PPEs can increase the risk of exposure to pesticides. Therefore, alternative forms such as agroecological cultivation are recommended, as they aim to deal with pests, diseases and invasive plants without this exposure and risks to human health.

5. Conclusion

This study allows us to infer that acute symptoms such as headache, dizziness, nausea, muscle weakness, itchy skin and salivation/dry mouth, as well as chronic non-communicable diseases with emphasis on hypertension, skin disease, lung and anemia, reported by family farmers, may be related to the use of pesticides.

The exposure added to the different factors presented can aggravate the picture of reports of acute symptoms and biochemical changes, generating more serious impacts on the health of farmers. The biochemical changes verified show that the form of use, the degree of toxicity of the products and the years of exposure, may have culminated in the reported health problems, which lead to other negative impacts on the lives of farmers.

Future research that seeks to assess the relationship between acute symptoms and other forms of exposure, such as environmental and food exposure, is recommended, aiming to broaden the discussion about the impacts of pesticides.

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References

Abreu, P. H. B. & Alonzo, H. G. A. (2016). Family farmer and (un)safe use of pesticides in Lavras, Minas Gerais, Brazil. *Revista Brasileira de Saúde Ocupacional* 41 (6), 1-12.

Ahmadi, A. R. & Mansourian, A. R. (2007). Effects of occupational exposure in pesticide plant on workers serum and erythrocyte cholinesterase activity. *International Journal of Occupational Medicine and Environmental Health* 20 (4), 381-385.

Akter, M. et al (2018). Vegetable farmers' behaviour and knowledge related to pesticide use and related health problems: A case study from Bangladesh. *Journal of Cleaner Production* 200: 122-133.

Almeida, C.G. & Martins, L. H. B. (2008). Liver enzymes as biomarkers and acetyl cholinesterase the effect of pesticides used in cultivation of *Allium sativum*. *Revista Biociências* 14 (2), 117-126.

Andrade-Rivas, F. & Rothe, H. A. (2015). Chemical exposure reduction: Factors impacting on south African herbicide sprayers' personal protective equipment compliance and high risk work practices. *Environmental Research* 142, 34-45.

Anvisa - Agência Nacional de Vigilância Sanitária. *Classificação toxicológica e dados de rotulagem de acordo com a toxicidade aguda*. (2019). http://portal.anvisa.gov.br/documents/10181/2858730/RDC_296_2019_.pdf/ca693bd5-e688-48e0-b072-0ece1dfca268.

Araújo, A. J et al (2007). Multiple exposure to pesticides and impacts on health: a cross-section study of 102 rural workers, Nova Friburgo, Rio de Janeiro State, Brazil. *Ciência & Saúde Coletiva* 12 (1), 115-130.

Boccolini, P. M. M. et al (2014). Stomach cancer mortality among agricultural workers: results from a death certificate-based case-control study. *Cadernos de Saúde Coletiva* 22 (1), 86-92.

Bombardi, L. M. (2017). *Geography of pesticide use in Brazil and restrictions with the European Union*. FFLCH - USP.

Brazil. Ministério da Saúde. Secretaria de Atenção à Saúde. Departamento de Ações Programáticas Estratégicas – Área Técnica de Saúde do Trabalhador. (2006). *Protocolo de Atenção à Saúde dos Trabalhadores Expostos a agrotóxicos*. Brasília: Ministério da Saúde; 2006. http://bvsms.saude.gov.br/bvs/publicacoes/protocolo_atencao_saude_trab_exp_agrotoxicos.pdf.

Buralli, R. J. et al (2018). Respiratory condition of family farmers exposed to pesticides in the State of Rio de Janeiro, Brazil. *International Journal of Environmental Research and Public Health* 15 (6), 1-14.

Câmara, S. A. V. et al (2012). Exposure to agrochemicals: determination of reference values for plasma and erythrocyte cholinesterase. *Brasília Médica* 49 (3), 163-169, 2012.

Carneiro, F. F. et al (2015). *Dossiê ABRASCO: um alerta sobre os impactos dos agrotóxicos na saúde.* Búrigo.

Dainese, M. et al (2019). A global synthesis reveals biodiversity-mediated benefits for crop production. *Science Advances* 5 (10), 1-13.

Dang, H. et al (2017). Risk factors for noncommunicable diseases in Vietnam: a focus on pesticides. *Frontiers in Environmental Science* 5 (58), 1-9.

D'annolfo, R. et al (2017). A review of social and economic performance of agroecology. *International Journal of Agricultural Sustainability* 15 (6), 632-644.

Dhananjayan, V. et al (2012). Assessment of acetylcholinesterase and butyrylcholinesterase activities in blood plasma of agriculture workers. *Indian Journal of Occupational and Environmental Medicine* 16 (3), 127-130.

Figueiredo, G. M.; Trape, A. Z. & Alonzo, H. A. (2011). Multiple pesticide exposure and probable long-term health effects: transversal study in a sample of 370 rural workers of Campinas (SP - Brazil). *Revista Brasileira de Medicina do Trabalho* 9 (1), 1-9.

Fiocruz - Fundação Oswaldo Cruz. (2013). *Em nota conjunta, Fiocruz, Inca e Abrasco alertam para o risco do uso de agrotóxicos.* https://portal.fiocruz.br/noticia/em-nota-conjunta-fiocruz-inca-e-abrasco-alertam-para-o-risco-do-uso-de-agrotoxicos.

Godfray, H. C. J. et al (2010). Food security: the challenge of feeding 9 billion people. *Science* 327 (5967), 812–818.

Haggblade, S. et al (2017). The herbicide revolution in developing countries: Patterns, causes, and implications. *The European Journal of Development Research* 29 (3), 533-559.

Jardim, I. C. S. F. & Andrade, J. A. (2009). Residues of pesticides in food: a global environmental preoccupation - Focussing on apples. *Química Nova* 32 (4), 996-1012.

Jayasumana, C. et al (2015). Drinking well water and occupational exposure to Herbicides is associated with chronic kidney disease, in Padavi-Sripura, Sri Lanka. *Environmental Health* 14 (6), 1-10.

Kim, K. H.; Kabir, E. & Jahan S. A. (2017). Exposure to pesticides and the associated human health effects. *Science of the Total Environment* 575, 525-535.

Linares, C. E. B. (2005). Acethylcholinesterase and Butyrilcholinesterase plasmatic levels in farmers from Frederico Westphalen – RS. *Saúde* 31 (1), 47-51.

Lini, R. S. et al (2021). Exposição ocupacional aos agrotóxicos da classe dos fungicidas em uma população de viticultores. *Research, Society and Development*, 10 (3), 1-12.

Lopes, S. O. (2017). *Nutrition and health actions impact on the incentive to production for self-consumption in the food and nutritional (in)security situation*: increasing the quality of life of family farmers in the Viçosa-MG. MSc. Diss. Universidade Federal de Viçosa, Viçosa.

MAcFarlane, E. et al (2013). Dermal exposure associated with occupational end use of pesticides and the role of protective measures. *Safety and Health at Work* 4 (3), 136-141.

Marcelino, A. F.; Wachtel, C. C. & Ghisi, N. C. (2019). Are Our Farm Workers in Danger? Genetic Damage in Farmers Exposed to Pesticides. *International Journal of Environmental Research and Public Health* 16 (3), 358.

Mello, C. M. & Silva, L. F. (2013). Factors associated with pesticide poisoning: cross-sectional study among coffee plantation workers in southern Minas Gerais. *Epidemiologia & Serviços de Saúde* 22 (4), 609-620.

Mengistie, B. T.; Mol, A. P. J. & Oosterveer, P. (2017). Pesticide use practices among smallholder vegetable farmers in Ethiopian Central Rift Valley. *Environment, Development and Sustainability* 19 (1), 301–324.

Mukami, Y. et al (2017). Chronic pesticide poisoning in the tobacco farming. *Saúde em Debate* 41 (113), 563-576.

Nerilo, S. B. et al (2014). Pesticide use and cholinesterase inhibition in small-scale agricultural workers in southern Brazil. *Brazilian Journal of Pharmaceutical Sciences* 50 (4), 783-791.

Nogueira, F. A. M.; Szwarcwald, C. L & Damacena. G. N. (2020). Exposição a agrotóxicos e agravos à saúde em trabalhadores agrícolas: o que revela a literatura? *Revista Brasileira de Saúde Ocupacional*, 45 (36), 1-23.

Oliveira-Silva, J. J.; Meyer, A. & Moreira, J. C .(2000). Cholinesterase activities determination in frozen blood samples: an improvement to the occupational monitoring in developing countries. *Human and Environmental Toxicology* 19 (1), 173-177.

Peres, F. et al (2005). Challenges in the study of human and environmental contamination by pesticides. *Ciência & Saúde Coletiva* 10, 27-37.

Ramírez-Santana, M. et al (2014). Assessment of health care and economic costs due to episodes of acute pesticide intoxication in workers of rural areas of the Coquimbo region, Chile. *Value in Health Regional* 5, 35-39.

Ristow, L. P. et al. (2020). Fatores relacionados à saúde ocupacional de agricultores expostos a agrotóxicos. *Saúde & Sociedade*, 29 (2), 1-11.

Sapbamrer, R. & Thammachai, A. (2020). Factors affecting use of personal protective equipment and pesticide safety practices: A systematic review. *Environmental Research* 185, 1-23.

Senar - Serviço Nacional de Aprendizagem Rural. (2015). *Gestão de Riscos em Saúde e Segurança no Trabalho Rural. Prevenção de Acidentes com Agrotóxicos - NR31.8*. http://ead.senar.org.br/lms/webroot/uploads/senar/conteudos/149/anexos/RIS2_Modulo05.pdf.

Silva, J. M. et al (2005). Pesticides and work: a dangerous combination for the Brazilian agricultural worker's health. *Ciência & Saúde Coletiva* 10 (4), 891-903.

Souza, A. et al (2011). Multiple pesticide exposure and probable long-term health effects: transversal study in a sample of 370 rural workers of Campinas (SP - Brazil). *Ciência & Saúde Coletiva* 16 (8), 3519-3528.

Tofolo, C. et al (2014). Contributing factors for farm workers' exposure to pesticides in the west of the state of Santa Catarina, Brazil. *Acta Scientiarum Health Sciences* 36 (2), 153-159.

Yap, S. M. S & Demayo, C. G. (2015). Health impacts of pesticide use by rice farmers in themunicipality of Molave, Zamboanga del Sur, Philippines. *Advances Environmental Biology* 9 (27), 134-142.