ORIGINAL ARTICLE

Neurobehavioural symptoms and acute pesticide poisoning: a cross-sectional study among male pesticide applicators selected from three commercial farming systems in Ethiopia

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ABSTRACT

Objective To estimate prevalence of acute pesticide poisoning (APP) and its association with neurobehavioural symptoms in Ethiopian pesticide applicators.

Methods We performed a cross-sectional survey among 256 pesticide applicators from small-scale irrigated farms, a large-scale open farm and large-scale greenhouses. APP was ascertained using a modified WHO case definition, and neurobehavioural symptoms were collected with a standardised questionnaire (Q16). Exposure to pesticides was estimated using detailed exposure algorithms specifically developed for Ethiopian farms. Multiple logistic regression models were used to estimate risk of APP and its association with neurobehavioural symptoms.

Results Overall APP prevalence was 16%. Working as an applicator in greenhouses was strongly associated with APP (OR 3.00, 95% CI 1.38 to 6.54). Estimated annual pesticide exposure was also associated with APP (OR 1.14, 95% CI 1.00 to 1.20). Longer duration of employment appeared to be negatively associated with APP. Having had an APP was strongly associated with reporting more neurobehavioural symptoms (OR 2.15, 95% CI 1.01 to 4.58) independent of cumulative pesticide exposure. Cumulative exposure to pesticides appeared to be associated with neurobehavioural symptoms among applicators without and with APP.

Conclusions We showed a substantial prevalence of APP that differed between farming systems and was strongly associated with neurobehavioural symptoms. Intensity of exposure was also clearly associated with these symptoms. Reduction and control of occupational exposure to pesticides is urgently needed in Ethiopia.

Key messages

What is already known about this subject?

- ► Commercial agriculture in Ethiopia has recently intensified dramatically, and studies have reported unsafe use of pesticides which could result in occupational health risks.

What are the new findings?

- ► This is the first study investigating an association between neurobehavioural symptoms and acute pesticide poisoning (APP) cases among pesticide applicators in commercial agriculture in Ethiopia. The prevalence of severe forms of APP was considerable (16%) among male applicators with on average 4 years of pesticide application-related farm duties.
- ► Having experienced an APP episode was associated with reporting more neurobehavioural symptoms. Longer duration of employment appeared to be negatively associated with having had an APP. This could either be due to replacement of affected applicators or more experienced applicators having a smaller chance of being acutely poisoned during their work.

How might this impact on policy or clinical practice in the foreseeable future?

- ► There is an urgent need to reduce occupational pesticide exposure through strengthening of post pesticide registration activities including sustainable capacity building of well-trained farmers and farmworkers and establishing an active occupational health surveillance system for (commercial) farming systems in Ethiopia.

INTRODUCTION

Pesticides are used for preventing and controlling pest in households, in vector control and agriculture. Adverse health effects as a result of pesticide exposure are more common in less developed countries because of weak regulation, low hazard awareness of users, inadequate use of personal protective equipment, lack of proper care during application and (continuing) use of more hazardous pesticides.[1] Intentional and unintentional pesticide poisoning have been acknowledged as a serious problem in many agricultural communities of low and middle-income countries.[2] Even though low and middle-income countries use only 20% of the world's agrochemicals, they have 99% of deaths from acute pesticide poisoning (APP) cases.[3] In high-income countries, APPs have largely been controlled and the main focus of attention is now on possible health effects arising from exposure to low levels of pesticides over a long time period. However, in many low and middle-income countries the problems associated with occupationally related APP are still significant.[4–6]

Studies in different parts of the world have indicated as a consequence of (chronic) exposure to pesticides and of APP a higher prevalence of neurological symptoms and changes in neurobehavioural performance,[7] a higher risk developing neurological and neuropsychiatric effects,[8 9] an increase in number of people with depression and committing suicide,[9 10] lower performance on neurobehavioural tests,[10–12] changes in mood and affection,[13 14] and risk of depressive symptoms.[15]

In Ethiopia due to recent intensification in agriculture, new farming systems such as large-scale greenhouses (LSGH) and small-scale irrigated farms (SSIF) have emerged which has led to a significant increase in pesticide use intensity (6–13 fold).[16] Additionally, unsafe use of pesticides has also been reported.[17 18] In Ethiopia, there is no poisoning centre or an integrated reporting system of occupational accidents and diseases hampering the estimation of the number (prevalence) of APP cases. Hospital-based studies on intentional poisoning in Ethiopia have identified organophosphate pesticide as the main means of self-poisoning.[19 20]

To our knowledge, there is a lack of insight in APP prevalence, estimates of neurobehavioural effects of occupational exposure to pesticides and their interactions among pesticide applicators from commercial farming systems in Ethiopia. Therefore, our main objective was to study the associations between exposure to pesticides, prevalence of APP and reported neurobehavioural symptoms among pesticide applicators selected from three commercial farming systems in Ethiopia.

METHODS

Study area and population

The study was conducted in the Central Eastern part of Ethiopia where abundant hydrological resources exist from the Rift valley Lakes and Awash River. Farms in the area produce commercial crops on which use of agrochemicals including pesticides is high due to production of different kinds of horticultural crops: roses and cuttings in LSGH; vegetable, fruit and cotton in large-scale open farm (LSOF); and mainly vegetables such as onions and tomatoes in SSIF. The three farming systems co-exist in this horticultural production belt in a similar ecological zone.

The selection of applicators differed between the farming systems because of the uneven distribution of number of applicators per farm. Generally, in SSIF there is usually only one applicator per farm, while in LSGH and in the LSOF there are many specialised applicators undertaking their application work every day in different sections of the farms. We aimed to include all applicators from each randomly selected farm within each of the three farming systems. Recruitment of pesticide applicators in the SSIF was done by randomly selecting five primary farmers' cooperatives from a list obtained from Meki–Batu vegetables and fruit growers' cooperatives union, which operates in the study area. Each farm of the selected cooperative members was visited and pesticides applicators present at each of the farms were invited to participate. In the LSOF (Upper Awash Agro-Industry Enterprise), all pesticide applicators present during the survey were invited to participate in the study. Two LSGH were randomly selected from two clusters of farms in the study area (Zeway cluster with five farms and and Koka cluster with four farms). All applicators working in the two LSGH were invited to participate in the study.

Applicators were defined as farmers or farmworkers who were directly involved in pesticide application-related activities (ie, pesticide mixers/loaders, pesticide sprayers and application supervisors). We were not able to include female applicators because pesticide application is usually performed by men and we did not encounter female applicators in our survey.

In total, we surveyed 256 pesticide applicators. In general, there was a high participation rate (96%). Only 8 of 179 invited applicators from SSIF (which are scattered privately owned farms covering a large area) refused to participate because of time constraints at the time of the interview. In the other farming systems, almost all of the selected farmworkers were more than willing to participate in the study (only 1 out of 60 in the two LSGH and 2 out of 28 in case of the LSOF did not appear at the time of the interview). Most of the pesticide applications were performed either late in the afternoon or early in the morning. Interviews were arranged at pertinent and convenient times of these workers. To ascertain maximal participation in the study, meetings were held with the relevant authorities, that is, spraying supervisors, farm owners, farmers' cooperative leaders and human resource managers.

Data collection

A pretested closed and open-ended structured questionnaire was administered to collect information on (1) sociodemographic information, (2) pesticide exposure factors (eg, frequency and duration of application, close/openness of a farm, use of personal protection devices and hygienic measures), (3) APP factors after Thundiyil *et al*[2](ie, ever poisoning, acute symptoms during the poisoning episode, frequency of poisoning, pesticide causing the poisoning, away from work due to poisoning, attaining treatment after poisoning, hospital admittance after poisoning) and (4) neurobehavioural symptoms as assessed using the standardised Q16 method.[21]

The questionnaire was translated in to Amharic, the national language of Ethiopia, and back translated to English to check consistency and piloted on 32 farmworkers in order to standardise the data collection process.

The questionnaire was administered by two data collectors who were trained to be consistent in administration of the questionnaires and the interpretation of responses. Study subjects were selected and invited to participate if they had been working on the farm for at least during the past 12 months. Participation was on a voluntary basis, and written consent was obtained from all the participants after explanation of the objectives of the study. The data collection was done before spraying activities, that is, early in the morning (eg, small-scale farmers) or late in the afternoon (eg, greenhouse or open farmworkers) after consultation with the farm owners or managers.

Neurobehavioural symptoms

In order to assess neurobehavioural effects, a standardised questionnaire (Q16) was administered. The Q16 was developed and validated in Sweden and was designed to record chronic neurobehavioural symptoms from populations exposed to neurotoxins.[21] The Q16 has been used previously in low and middle-income countries.[22–24] In the Q16, the following current symptoms are queried: abnormally tiring, palpitations without exertion, painful tingling, irritation without any particular reason, problem with concentration, short memory, perspire without any particular reason, problem with buttoning and unbuttoning, short memory as told by others and feeling of chest tightness. The median value of the distribution of the sum of 'yes' responses to Q16 questions per individual (≥4 symptoms) was used to create a dichotomised Q16 score.

Acute pesticide poisoning

In order to assess occupational APP scenarios, a modified form of the proposed WHO tool for of possible pesticide poisoning was used.[2] According to the classification tool, a possible APP case requires to meet criteria in each of the categories: exposure, health effects and causality. That is, a plausible description of pesticide exposure, two or more subjective symptoms reported by the study subject and a temporal relationship between exposure and the reported symptoms (ie, symptoms occurring within 48 hours of exposure). In the pretest of the questionnaire, we noted frequent reporting of symptoms which might not be necessarily due to APP (eg, nausea, general weakness and headache) but could be related to endemic infectious diseases in the study area (eg, malaria and typhoid). Therefore, we added additional criteria to the proposed WHO APP case definition matrix in order to increase its specificity and focus on the more certain and severe APP cases. Also, a study in Nepal underlined that non-specific self-reported acute pesticide symptoms seem to be a poor proxy for APP as those symptoms will occur among farmers in low and middle-income countries regardless of pesticide exposure or poisoning.[25] Therefore, those having at least three symptoms were further asked about whether they had a pre-existing disease condition at the time of the reported APP symptoms and were additionally asked if they had (temporally) discontinued their work and/or fainted while applying pesticides. Consequently, only symptomatic pesticide applicators who discontinued their application work and/or fainted without any known previous (before pesticide application) disease condition or symptoms were considered to be cases of APP and were further asked about APP-related factors (eg, frequency of poisoning and which pesticide caused the APP) during the main field survey. Cases of APP were assessed for the period since an applicator started pesticide application work.

Exposure assessment

The semiquantitative exposure assessment was based on an exposure algorithm adapted from the Agricultural Health Study[26] that was modified based on contemporary occupational pesticide exposure settings in different farming systems in Ethiopia. The algorithm for estimating pesticide exposure included exposure-modifying variables that reflected:

1. Intensity of exposure (eg, application methods, pesticide use intensity, closed or open farming)
2. Exposure protection (ie, use of personal protection devices and hygienic measures)
3. Exposure frequency and duration (ie, application frequency per year and years working as an applicator).

Based on the algorithm, we estimated daily exposure, annual exposure (product of daily exposure estimate and frequency of application per year) and cumulative exposure (product of annual exposure estimate and number of years working as an applicator) as described previously.[27]

Data analysis

The collected data were entered using Epi Data V.3 (Epi Data Association, Odense Denmark) and analysed using Stata/SE V.12.00 (Stata). Descriptive statistics included frequency and percentiles for categorical variables. Arithmetic mean and SD for continuous variables were used in order to compare the distribution of pesticide poisoning among the three farming systems. Student's t-test and χ^2 test were used to statistically test differences between continuous and categorical variables, respectively. Multivariate (logistic) regression models were used to investigate associations between farming system, exposure intensity metrics and APP. Potential confounders like Khat chewing and duration of employment showed statistically significant associations ($P<0.05$) in univariate (logistic) regression models with APP and were therefore included in the final multivariate model. In order to investigate the association between past APP, cumulative exposure to pesticides and reporting neurobehavioural symptoms, a priori selected potential confounding factors, which are known or suspected to affect reporting of neurobehavioural symptoms (ie, age, educational level, cigarette smoking, Khat chewing and alcohol consumption) were included in the final multivariate logistic regression model.

Table 1 Descriptive characteristics of studied applicators by acute pesticide poisoning (APP) status

	APP (n=41)		Non-APP (n=215)		
Study variables	**N**	**%**	**N**	**%**	**P value**
Educational level					
No formal education	–	–	5	2	0.531
Grade 1–6	21	51	92	43	
Grade 7–8	14	34	66	30	
Grade 9–12	6	15	51	24	
Diploma(12+2)	–	–	1	1	
Marital status					
Married	23	56	116	54	0.875
Divorced	–	–	2	1	
Widowed	–	–	1	1	
Single	18	44	96	44	
Ever alcohol use	26	63	145	67	0.618
Ever smoking	7	17.1	20	9.3	0.139
Ever khat*use	12	29.3	35	16.3	0.049
	Mean	**SD**	**Mean**	**SD**	
Age (years)	26.6	6.1	27.4	5.8	0.413
Monthly income(birr)	1090.5	489.3	1483.2	674.8	0.001
Duration of employment (years)	3.1	1.6	4.5	2.5	0.001
Daily exposure (EU)†	16.9	10.6	16.6	9.9	0.862
Annual exposure (EU)	2973.6	2929.6	1663.9	2264.9	0.001
Cumulative exposure (EU years)	8451.1	8347.1	5934.5	8697.8	0.089
Neurobehavioural symptoms (Q16 score)	5.3	1.9	4.1	1.9	0.001
	N	**%**	**N**	**%**	
Neurobehavioural symptoms (Q16 score≥4)	26	63.4	94	43.7	0.021

*Khat is an evergreen shrub of eastern Africa and Arabia; its leaves have narcotic properties.
†Exposure units, estimates of occupational pesticide exposure using algorithms as described in Negatu *et al* [27].

RESULTS

Selected study variables of the surveyed population are shown in table 1. A statistical significant ($P<0.05$) higher proportion of Khat chewers (29%) were reported in the APP subpopulation. APP cases were slightly younger than applicators without APP (26.6 vs 27.4 years), and they appeared to be employed for a significantly shorter duration (3.1 vs 4.5 years). APP cases also had a significantly lower income per month (1090 (€45) vs 1480 Birr (€61)). Applicators with APP scored a significantly higher average neurobehavioural symptom score than applicators without APP (5.3 vs 4.1), and they also had a

Table 2 Distribution of acute pesticide poisoning (APP) and related covariables across three farming systems among 256 applicators

			Farming systems					
			Small-scale irrigated farms (n=171)		Large-scale open farms (n = 26)		Large-scale greenhouses (n= 59)	
Study variables	N	%	N	%	N	%	N	%
Prevalence of APP	41	16	17	10	5	19	19	32
Frequency of poisoning								
One time	29	71	17	100	4	80	8	42
Two times	9	22	–	–	1	20	8	42
Three times	3	7	–	–	–	–	3	16
Away from work due to poisoning	26	63	10	59	2	40	14	74
Receiving treatment after poisoning	24	59	5	29	3	60	16	84
Hospital admission after poisoning	11	28	2	12	2	40	7	37
Pesticide cause of the poisoning								
Do not remember/know	17	42	3	18	–	–	14	74
Spiroxamine	3	7	–	–	–	–	3	16
Malatine	1	2	1	6	–	–	–	–
Endosulfan	5	12	3	18	2	40	–	–
Profenofos	9	22	8	46	1	20	–	–
BN3*	2	5	–	–	–	–	2	10
Chlorpyrifos	2	5	1	6	1	20	–	–
Lambda-cyhalthrin	2	5	1	6	1	20	–	–

*Biological control agent bitoxibaccilin (*Bacillus thuringiensis* subsp. *thuringiensis*).

higher percentage of individuals reporting a neurobehavioural score≥4 (63.4% vs 43.7%).

An overall occupational APP prevalence of 16% was reported (table 2). APP prevalence was highest in LSGH (32%) and lowest in SSIF (10%). APP cases with multiple poisonings represented (29%) the total number of cases who reported APP, and the majority of them were reported in LSGH (92%). The highest proportion of cases receiving treatment after an APP episode was reported in LSGH (67%). More than half of the poisoned applicators remembered the name of the pesticide that caused their APP (58%), but in LSGH the majority of the poisoned applicators (74%) did not remember or know the name of the involved pesticide (table 2). Most reported pesticides causing APP were insecticides and for a smaller proportion fungicides. Fifty per cent of the reported pesticides causing the APP were organophosphates (predominantly Profenofos, since 2015 a banned pesticide in the EU) followed by organochlorines (in particular Endosulfan, banned in the EU since 2005 and Morpholine, banned in the EU for application in fruit coating since 2008).

Using SSIF as a reference group, a statistically significant increased OR for APP (OR 3.00, 95% CI 1.38 to 6.54) was reported among applicators employed in LSGH. Also a statistically significant increased OR for APP (OR 1.14, 95% CI 1.00 to 1.29) was reported for estimated annual pesticide exposure (per 1000 exposure units). In both multivariate logistic regression models, Khat chewing was significantly positively associated with APP (OR 2.51 and 2.62) while duration of employment was significantly negatively associated with APP (OR 0.76 and 0.75 per additional year of employment) (table 3).

Multiple logistic regression analysis showed that past APP was significantly associated with reporting an increased number of neurobehavioural symptoms (OR 2.15, 95% CI 1.01 to 4.58) even when adjusting for cumulative exposure to pesticides (table 4). Past multiple poisonings (APPs) appeared to be an even stronger risk factor for an increased number of reported neurobehavioural symptoms, although the association did not reach formal statistical significance (OR 3.46, 95% CI 0.69 to 17.41).

Additionally, cumulative exposure by itself appeared to be positively associated with reporting increased numbers of neurobehavioural symptoms among both applicators with and without APP, but only reached statistical significance among the

Table 3 Risk factors for acute pesticide poisoning (APP) among pesticide applicators

		Crude OR of poisoning (n=41)		Adjusted OR of poisoning(n=41)	
Model	Variable	OR	95% CI	OR	95% CI
Model 1	Small-scale irrigated farms(n=171)	1		1	
	Large-scale open farms (n=26)	2.16	0.72 to 6.46	1.18	0.36 to 3.83
	Large-scale greenhouses (n=59)	4.30	2.05 to 9.03	3.00	1.38 to 6.54
				2.51	1.09 to 5.78 (Khat chewing)
				0.76	0.61 to 0.93 (duration of employment in years)
Model 2	Annual exposure (per 1000 exposure units)(n=256)	1.20	1.06 to 1.33	1.14	1.00 to 1.29
				2.62	1.15 to 5.97 (Khat chewing)
				0.75	0.62 to 0.92 (duration of employment in years)

Table 4 APP as a risk factor for reporting neurobehavioural symptoms (Q16 score≥4)

Variable	Crude OR of Q16≥4(n=120)		Adjusted OR Q16≥4(n=120)	
	OR	95% CI	OR	95% CI
Past APP(n=41)	2.23	1.12 to 4.45	2.15	1.01 to 4.58
			1.08	1.02 to 1.13 (age)
			0.94	0.67 to 1.30 (educational level)
			0.96	0.37 to 2.48 (cigarette smoking)
			1.22	0.58 to 2.56 (Khat chewing)
			1.21	0.67 to 2.22 (alcohol drinking)
			1.09	1.04 to 1.41 (cumulative pesticide exposure per 1000 EU years)
Past APP (≥ 2 times)(n = 12)	6.44	1.38 to 30.08	3.46	0.69 to 17.41
			1.07	1.02 to 1.13 (age)
			0.92	0.66 to 1.28 (educational level)
			0.92	0.36 to 2.39 (cigarette smoking)
			1.26	0.61 to 2.64 (Khat chewing)
			1.15	0.63 to 2.08 (alcohol drinking)
			1.08	1.04 to 1.13 (cumulative pesticide exposure per 1000 EU years)

APP, acute pesticide poisoning; EU, exposure units.

Table 5 Cumulative exposure to pesticides as a risk factor for reporting neurobehavioural symptoms (Q16 score≥4) among applicators with and without an APP

Group	Variable	Q16≥4 (n=120) OR 95% CI
Applicators without APP (n = 215)	Cumulative pesticide exposure per 1000 EU years	1.08 (1.03 to 1.13)
	Age	1.06 (1.00 to 1.11)
	Educational level	0.88 (0.62 to 1.25)
	Cigarette smoking	0.89 (0.31 to 2.54)
	Khat chewing	1.31 (0.57 to 2.98)
	Alcohol drinking	0.93 (0.49 to 1.77)
Applicators with APP (n = 41)	Cumulative pesticide exposure per 1000 EU years	1.15 (0.95 to 1.38)
	Age	1.58 (1.10 to 2.26)
	Educational level	1.41 (0.26 to 7.59)
	Cigarette smoking	0.27 (0.01 to 8.92)
	Khat chewing	1.14 (0.08 to 16.7)
	Alcohol drinking	3.04 (0.33 to 28.0)

APP, acute pesticide poisoning; EU, exposure units.

non-poisoned applicators (OR 1.15, 95% CI 0.95 to 1.38 and OR 1.08, 95% CI 1.03 to 1.14, respectively) (table 5).

DISCUSSION

The proposed WHO APP case definition is likely to overestimate APP cases in low and middle-income countries like Ethiopia, where many infectious diseases are endemic and therefore symptoms such as headache, nausea and general weakness not necessarily related to APP are being often reported. Therefore, we used a modified form of the proposed WHO case definition which is more specific to severe cases of APP according to the WHO case definition (ie, any cases including symptoms of paralysis or syncope).[2]

Our study reported similar APP prevalence (16%) when compared with those reported in studies in low and middle-income countries in Asia (11.9% to 19.4% among pesticide users)[28] despite differences in APP case definitions (ie, 'ever suffering from APP' as reported in the Asian studies vs the adapted APP case definition that has resulted in reporting of more serious cases of APP). Another study using the (non-modified) WHO classification tool reported an APP prevalence of 6.1% among Chinese pesticide applicators in small-scale agriculture,[5] which is slightly lower for the prevalence among applicators in SSIF in our study (10%). A Tanzanian study using self-reported poisoning to define APP among small-scale farmers reported a very high prevalence of APP cases (93%),[29] which is far higher than the 10% in our study in SSIF using our modified WHO case definition. However, the figures became comparable when we applied the non-modified WHO case definition for the SSIF (88%) (data not shown).

Our study indicated a higher prevalence (32%), a higher rate of multiple APPs and an increased risk of having experienced an APP in the LSGH than in the two other farming systems. Another study in Ethiopia using the (non-modified) WHO case definition also demonstrated a high prevalence of APP within 12 months among (greenhouse) flower farmworkers (56%),[30] but for reasons explained above they might have overestimated the number of APP cases.

The decrease of APP risk with years of application might indicate a 'healthy worker effect'. Applicators experiencing an APP might leave their work or be no longer capable of performing their work in an appropriate way. This selection process might have resulted in more senior applicators reporting less APP. Making the population, we studied one of 'surviving' applicators and might therefore have resulted in underestimated rates of APP. An alternative explanation might be that more experienced workers may have less accidents of APP. Only a longitudinal study will be able to shed light on this finding.

Our study showed that past APP is significantly associated with reporting a higher number of neurobehavioural symptoms independent of level of pesticide exposure. Cumulative pesticide exposure as such also contributed to reporting an increased number of neurobehavioural symptoms, but it reached only statistical significance among the applicators without an APP.

Other studies in low and middle-income countries have also shown that pesticide poisoning might have a long-term sequel of neurotoxic effects. Farmworkers in Costa Rica who were treated for APP performed worse on tests of cognitive and psychomotor function than non-poisoned workers.[31] In Sri Lanka, occupationally exposed subjects who had suffered from organophosphate poisoning showed elevated symptom prevalence,[23] and a study in South Africa showed a strong association between past poisoning with pesticides and neurological symptoms in South African farmers (OR 4.08, 95% CI 1.48 to 1 1.22).[32]

Our study has several strengths. First, we used a standardised questionnaire (ie, Q-16 and the proposed WHO APP case definition), we pretested the questionnaire and we had a survey with a relatively high response rate. Second, as some symptoms of pesticides poisoning are similar to symptoms resulting from other infectious diseases (which are endemic in the study area) we modified the proposed WHO case definition to identify only the more severe cases of APP. Third, we estimated for the first time the extent of neurobehavioural symptoms and its association with pesticide poisoning in commercial farming systems in Ethiopia.

Our study also has some limitations. First, a questionnaire-based cross-sectional study design is often the only feasible study design for estimating the prevalence of disease symptoms in low and middle-income countries like Ethiopia where objective measurement of exposure or outcome is costly; therefore, we cannot exclude some degree of (over)reporting bias due to the self-reported nature of the surveyed symptoms and on the other hand might have suffered from a 'healthy worker effect' leading to an under-reporting of APP.[33] In order to reduce responder' bias we had questions on health outcomes preceded those on exposure-related questions.

Second, again due to the cross-sectional study design, it was not possible to infer that APP is a causal risk factor for increased reporting of neurobehavioural symptoms. Third, we excluded re-entry farmworkers (which are mostly female) due to difficulty in investigating APP cases among indirectly exposed subjects since these female farmworkers are not directly involved in pesticide application and therefore causality and exposure, which are part of the WHO acute poisoning case definition matrix, are much harder to assess. Fourth, our data collectors could not be blinded to exposure status or farming system given they had to interview the farmers and farmworkers in the field. However, we tried to minimise observer bias by selecting capable data collectors and train them and by using a pretested standardised questionnaire. Finally, our exposure estimates were not pesticide specific and given clearly differences in mechanism of action, toxic manifestation and potency for causing adverse health effects we might have missed associations between specific pesticides and APP and or neurobehavioural symptoms as reported in the Q16.

CONCLUSIONS

This study is the first study reporting on prevalence of occupational APP and its association with neurobehavioural symptoms among pesticide applicators from three commercial farming systems in Ethiopia. The results indicate a considerable overall prevalence of severe APP (16%) which was highest among applicators from LSGH (where almost one third of the surveyed pesticide applicators had been severely acutely poisoned within on average 3 years of pesticide application). Also our findings indicate that both cumulative exposure and having experienced an APP in the past are associated with increased reporting of neurobehavioural symptoms. It is not unthinkable that similar figures hold for other low and middle-income countries where commercial small-scale and large-scale commercial farming of fruits, vegetables and horticultural products take place, but local agricultural and farming system differences might result in higher or lower risks of APP and neurobehavioural symptoms. The underlying reasons for these pesticide-related occupational health risks to occur in Ethiopian commercial farms are mainly lack of knowledge on how to handle pesticides safely, a weak postregistration surveillance system that keeps an eye on pesticides being handled and managed in accordance with the registration requirements, and an almost total absence of occupational safety and health expertise with appropriate practical knowledge on safe use of pesticides in the surveyed farms.

Training farmers and farmworkers on how to use pesticides safely and provision of appropriate personal protection equipment in each of the farming systems is a necessity. The postregistration surveillance system should be strengthened so that it can inspect and study the actual use of pesticides under field conditions and if necessary can take appropriate regulatory measures. It is clear that these actions are needed in order to prevent severe APP and neurobehavioural symptoms among farmers and farmworkers applying pesticides in low and middle-income countries.

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