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Research Engagement Changes Attitudes and Behaviours towards Agrichemical Safety in Australian Farmers

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Abstract: There is limited research that evaluates the effect of farmer involvement in agrichemical exposure surveillance on their attitudes and behaviour towards pesticide handling and use of personal protective equipment. This limited follow-up study aimed to (i) evaluate attitudes/behaviours towards the use of personal protective equipment (PPE) among farmers who participated in the In-Field Personalised Cholinesterase Assessment Project (PCAP) (2016/17); and (ii) qualitatively assess the effect of monthly presentation of acetylcholinesterase (AChE) testing results on farmer agrichemical safety practices and behaviours prior to, and following participation in PCAP. This study surveyed 42 farming men and women, asking questions about agrichemical usage and hygiene practices. The majority of surveyed farmers' self-apply agrichemicals on their farm (97.6%), with 81% reporting that involvement in PCAP research changed the way they handled Organophosphates (OPs)—a widely used insecticide in agriculture. By enabling people to think critically about their exposure, there was a 66% increase in frequency of respirator usage post-PCAP. Following this, participants were invited to take part in one-on-one interviews to further discuss their involvement in PCAP. Many responses were positive, with participants stating they were more aware and cautious of their own practices. This study determined that research participation and point-of-care testing and education can result in effective engagement of farmers and farm workers, increase health literacy and change farming practice—highlighting the importance of an interactive, participatory model in order to bring about change, to reduce possible pesticide exposures.

Keywords: cholinesterase; farmers; organophosphates; attitude; agriculture; health literacy; safety; research translation

1. Introduction

Pesticides are any substance or mixture intended for repelling, killing or controlling pests. These pests may include vectors of human or animal disease, or unwanted species of plants or animals [1]. Examples of pesticides include herbicides to kill plants and weeds, fungicides to kill fungi and moulds, rodenticides to kill mice and rats, and insecticides to kill insects [2]. Fertilisers and plant and animal protection products are used to support the productivity of agricultural systems, and their application rates have increased over the past decades [3]. However, unsafe use of pesticides poses risks to people involved in farming activities, and for those consuming agricultural produce [4]. A chemicals' potential to cause harm is determined by a number of factors, including the level of chemical toxicity, and the duration and frequency of exposure.

Agricultural workers are exposed to pesticides: through direct contact with treated crops or soil; during sowing and seeding; whilst spraying for insects, weeds or desiccation; during application for animal husbandry purposes; and, as the result of misadventure by spills, splashes, drift or inadequate protection. Pesticide poisoning has been identified as an important occupational health problem in farmers and farm workers globally. An estimated 200,000 people die from acute pesticide poisoning per annum—most commonly in developing countries [5], and such poisoning is often associated with individuals taking their own lives [6].

In periods of particularly intense labour requirements, there is a tendency towards high-risk behaviour, especially when farmers are under increased pressure or stress [7]. It is well recognised globally that farming is a dangerous and unpredictable occupation [8] and that the longer the person has worked in agriculture, the more resistant to change they become [9]. Farming populations have been identified and often describe themselves as a physically tough and stoic. These characteristics are thought to have stemmed from isolation associated with rural and remote settlements, and according to Hull et al. have resulted in farmers having a high tolerance to risk, and a greater need for control and self-reliance [10].

One of the most commonly used classes of pesticides are organophosphates (OPs). They are used: in livestock production to control lice or internal parasites; in fruit, vegetable and crop production to control insect infestation; and, in public health to control head lice. Organophosphates are predominately absorbed through dermal exposure and inhalation. They act by inhibiting the neurotransmitter acetylcholinesterase (AChE) [11]. Organophosphates attack the nervous system through the irreversible inhibition of AChE in nervous tissue, resulting in an accumulation of AChE in the synaptic cleft. This leads to hyperstimulation at the synaptic cleft, resulting in disrupted neurotransmission, and in severe cases eventual death [12].

Symptoms of OP toxicity include: meiosis; small, pinprick pupils; blurry vision; headache; nausea; and muscle weakness [12]. Immediate symptoms may occur within several minutes or hours after exposure. Diagnosis of OP exposure can be made by determining levels of cholinesterase (ChE) enzymes—plasma cholinesterase (PChE)—in the blood, as the inhibitory action on AChE is associated with inhibition of these enzymes. These enzymes can be detected using the Ellman method [13].

While the acute effects of OP exposure are well documented [14,15], knowledge is growing about chronic exposure and asymptomatic monitoring—both in Australia and internationally [16]. A number of international studies have reported associations with neurological symptoms such as memory loss, impaired fine motor skills, and Parkinson's disease [17–19]. Exposure to OPs may occur years before onset of neurological symptoms. This is of importance to agricultural workers who may be regularly exposed to low levels of OPs over a long period. At low, asymptomatic exposure, farmers are unaware of any long-term risk, and their behaviour when using pesticides may increase this risk. Western Victoria has been a centre of sheep production in Australia since European settlement, with many farmers being exposed to OPs through routine sheep dipping for lice control, drenching for internal parasite control, and jetting for blow fly control. Additionally, practices such as mixing contaminated clothing with household laundry and storing pesticides in the home may put other household members at risk of low-level, long-term exposure.

Australian farmers have increased their understanding of pesticide use and handling over the last two decades with the introduction of compulsory chemical user training [20]. However, recent research suggests that many farmers and agricultural workers do not meet the recommended standards for handling and application of pesticides and use of PPE [21]. A study commissioned in 2015 by the Rural Industries Research and Development Corporation (RIRDC) reported barriers to using PPE—as reported by farmers—include discomfort and lack of availability for everyday use, as well as difficulty in changing entrenched behaviour, particularly when perceived exposures are low [22].

Although AChE surveillance is available in Australia, it has traditionally been an expensive process, requiring venous blood samples across time to establish a therapeutic baseline as well as access to pathology laboratories—impractical in most Australian farming communities. Furthermore, it is unknown whether monitoring ChE and establishing individual baselines is effective in increasing knowledge and changing the perception of risk. Current evidence suggests that education is effective in increasing knowledge and PPE usage [12].

In-Field Personalised Cholinesterase Assessment Project (PCAP) project, is a research study which measured ChE activity and pesticide use in a South West Victorian agricultural community. It involved monitoring agricultural workers' exposure to OPs over a 12-month period, and further validating the use of clinical point-of-care sampling to determine the level of OP exposure (Unpublished). Participants in this study were able to see their own AChE test results monthly, to determine their level of OP exposure and consider their possible exposure pathway and other agrichemicals that are in use. This paper reports on two major aims, (i) the follow-up evaluation of pre- and post-usage of PPE following user involvement in PCAP, and (ii) explores changes in farmer agrichemical safety practices and behaviours with a view to reducing agrichemical exposure.

2. Materials and Methods

2.1. Study Design

This was a follow-up study, building on existing baseline data from PCAP (April 2016–March 2017) to assess change over time. The original research (PCAP) was a prospective cohort study, where farmers (n = 64) where recruited in different locations within western Victoria, Australia. Participants AChE and PChE) were measured at a number of time points (monthly) over a full season (12 months) of agricultural production (e.g., cropping, livestock, mixed agriculture). Monthly assessment and monitoring of farmers and agricultural workers was required as participants continued to use agrichemicals through seasonal crop and livestock production cycles. This was necessary to identify if farmers and/or agricultural workers were experiencing accumulative and repeated chronic, low-level exposures during the year. General health checks and chemical usage questionnaires were conducted at the beginning and conclusion of the study period Table 1).

Table 1. Sequence of intended outcomes from the In-Field Personalised Cholinesterase Assessment Project (PCAP).

Participation in PCAP	Behaviour Changes	Point of Care: Measurement of AChE and PChE and Baseline Health and Lifestyle Assessment (HLA)	Changes in Behaviour and Practices	Benefits of These Changes
	Self-report	Measured at 10 time points over 12 months.	Projected changes	Estimated benefits
	Pre-clinic • Health demographics • Methods of application • Handling of chemicals • Type of tractor • PPE usage • Disposal and storage of PPE • Safer farming work practices • Health follow-up checks **Monthly** • Pesticide use (monthly)	**Pre and Post** • Obesity-related indicators: ○ Waist circumference ○ Body mass index ○ Waist-hip ratio ○ Percentage of fat in body mass • Blood sugar level • Blood pressure ○ Systolic ○ Diastolic • Cholesterol levels • Pulse rate • General health **Monthly** • Red Blood Cell Cholinesterase (AChE) • Plasma Cholinesterase (PChE)	• Increased health literacy • Understanding of pesticide (OP) mode of action • Increased use of PPE when using OP • Increased routine use of PPE when using agrichemicals • Reduced pesticide usage (when not needed) **In addition, there are likely to be reductions in** • **Chronic low-level pesticide exposure** • **Risk of cancer, neurodegenerative disease** • **Use of schedule 7 anticholinesterase pesticides**	• Downstream cost savings • Long-term changes occupational safety practices • Cultural shift in risky work behaviours • Reduced occupational injury and illness • Increased Quality Adjusted Life Years

Follow-up evaluation was conducted from April–October 2017. Participants completed a survey at two time points: (1) prior to their involvement in PCAP, and (2) within 12 months following completion of their participation in PCAP. The survey looked at participant's pre- and post-study agrichemical knowledge, chemical usage and handling, and behaviours. Participants who completed both these surveys were invited to take part in a one-on-one interview.

2.2. Participants

Participants involved were either farmers or agricultural workers, and recruited through their involvement in PCAP. The inclusion criteria required participants to be over 18 years of age, English speaking, and without a diagnosis of a neurodegenerative disease. The inclusion and exclusion criteria is further discussed in the study protocol by Cotton et al. [23].

2.3. Sample

A power analysis indicated that from the possible 64 original PCAP participants, a sample size of 45 participants would be sufficient (power $[1 - \beta] = 95\%$; $\alpha = 0.05$, $z = 1.96$).

2.4. Ethics

Participants were provided with a Plain Language Statement and written consent was obtained. Ethics was granted by the Deakin University Research Ethics Committee (HEAG_H_2017 dated 14 May 2017).

2.5. Data Collection

Eligible PCAP participants were contacted through email or text message. They were given a copy of the Plain Language Statement and Consent Form to sign and return, either through post or email. Responses were collected over April–October 2017. Those who did not respond after one month were sent a reminder via text message and/or email to complete the survey. Another reminder was sent out a month later through email, and those who had not replied were contacted via telephone. A flow chart of the recruitment process is illustrated in Figure 1.

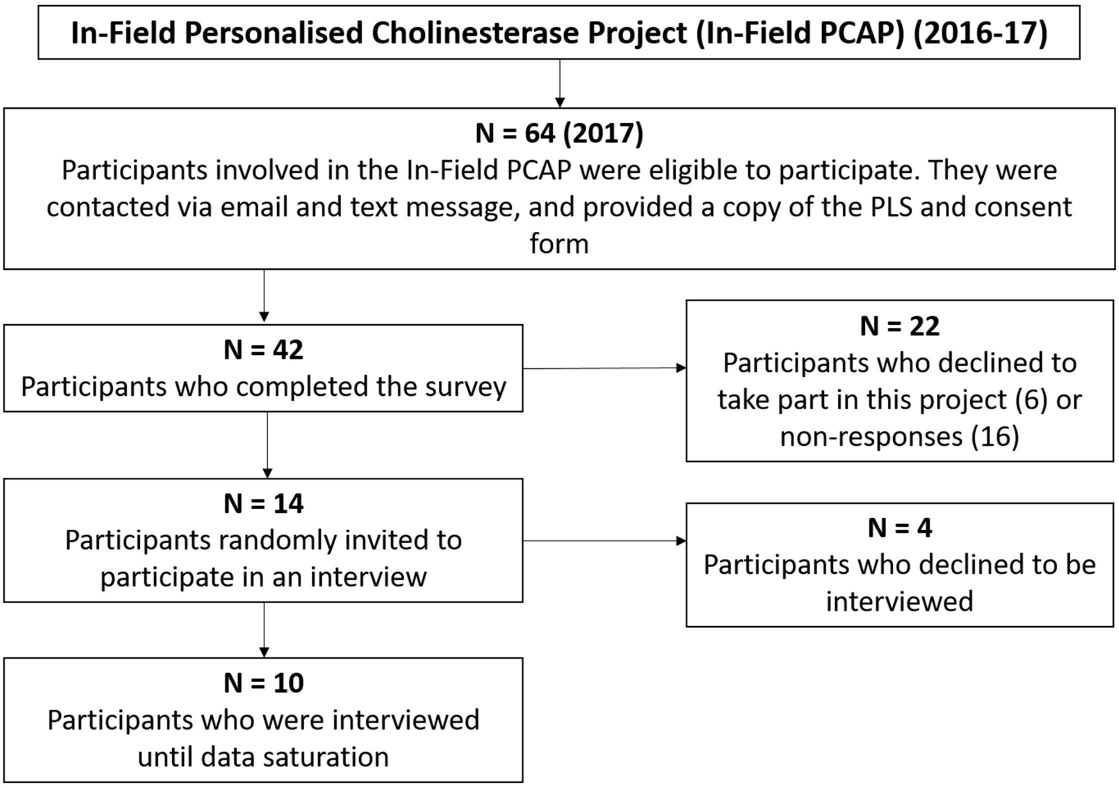

Figure 1. Flow chart of study recruitment.

2.6. Survey

The survey contained 29 questions about agrichemical knowledge, chemical usage and handling, PPE usage, hygiene practices, and behaviours following participant involvement in PCAP (Appendix A). Seventeen of these 29 questions were repeated from the baseline pre-PCAP questionnaire. The remaining 12 questions were new, aimed at identifying potential changes to agrichemical usage and changes in practices to minimise exposure as a result of participation in PCAP. Question types used were closed-ended, including demographic questions, multiple choice questions and Likert Scale (5-point) [24]. The survey was piloted with four independent individuals and questions were modified accordingly. Data was collected using the online survey platform SurveyMonkey, obtained with a license from Western District Health Service (WDHS).

2.7. Interview

As illustrated in Figure 1, participants who completed the survey were randomly invited to a semi-structured interview, conducted either face-to-face or over the telephone. These interviews went for approximately 30 min to 1 h. A copy of the interview schedule can be found in Appendix B. In total, 14 participants were invited to participate in an interview. However, interviews were conducted until data saturation was reached (n = 10). Therefore, there were no additional participants interviewed. Topics discussed include personal health, farmer attitudes towards agrichemicals and PPE, barriers to practice change, and risk perception when using pesticides.

2.8. Data Analyses

Existing, stored data that was used as part of this project included the baseline pre-clinic questionnaire previously completed by PCAP participants [25]. Individual responses from this questionnaire were identifiable; however, only those involved in this follow-up study had their data extracted. Participant records remained non-identifiable throughout the remainder of the project.

Quantitative data was examined for normality using a Kolmogorv–Smirmov test and frequencies. Following descriptive analysis, data were also analysed by Spearman's rank-order test, and Wilcoxon signed-rank test. Association between variables was assessed using chi-squared tests and statistical significance was considered at the value $p < 0.05$.

Data was cleaned in Microsoft Excel and analysed using SPSS (IBM Corp. Released 2012 IBM SPSS Statistics for Mac. Version 25.0 Armonk, NY, USA). Hard copy data was stored in a locked, secure room at the National Centre for Farmer Health (NCFH). Data is presented in the results section as mean ± SD and p. Qualitative data were transcribed ad verbatim by the research team and were analysed using NVivo.

3. Results

3.1. Quantitative Results

3.1.1. Demographics

In total, 42 of 64 (65%) previous research participants took part in this study, with a mean age of 48.8 years (± 12.5). Sample size was predominately male (n = 40). Participants came from a variety of farming backgrounds, including cropping (n = 26) and sheep/wool production (n = 11) (Table 2). Most participants completed further education beyond high school (n = 25).

Table 2. Participant demographics and health behaviours (n = 42).

Variables	Participants, n (%)
Total participants	42
Age (years)	
Mean (± SD)	48.8 (± 12.5)
Age groups	
25–44 years	17 (40.4)
45–64 years	20 (47.6)
65+ years	5 (12)
Gender	
Male	40 (95.2)
Female	2 (4.8)
Education	
Did not finish Year 12	10 (24)
Year 12 or High School equivalent	6 (14.4)
Certificate I–IV	10 (24)
Diploma or Associate Degree	7 (15.6)
Bachelors or Honours	9 (22)
Masters or PhD	0 (0)
Farming Type	
Primary Farming Type	
Beef Cattle	4 (9.5)
Sheep Farming	11 (26.2)
Broad-acre Cropping	26 (61.9)
Dairy Cattle	1 (2.4)
Pig Farming	
Secondary Farming Type	
Beef Cattle	7 (16.6)
Sheep Farming	22.5 (52.4)
Broad-acre Cropping	3 (7.1)
Dairy Farming	0 (0)
Pig Farming	1 (2.3)
Nil	8.5 (20.2)

Of the cohort, 97.6% (n = 41) personally applied agrichemicals on their farm. The majority of participants (81%, n = 34) either agreed or strongly agreed that their participation in PCAP had been personally beneficial. Only one participant disagreed with this statement, and 16.7% (n = 7) neither agreed nor disagreed. Additionally, 90.5% (n = 39) of participants believed that their participation in the study positively changed the way they handled OPs, or changed their agrichemical usage practices.

The most common methods of agrichemical application both pre- and post-PCAP were by boom spray, handgun, seed treatment, and backpack sprayer (Figure 2).

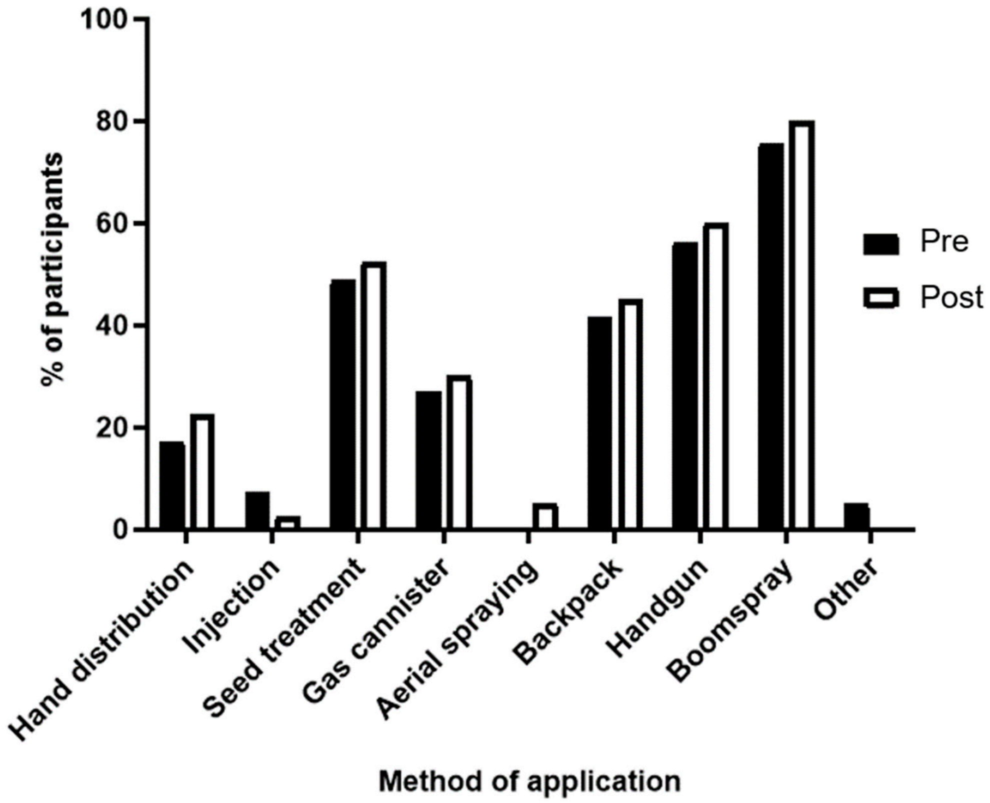

Figure 2. Pre- and post-methods of pesticide application used on farm to apply agrichemicals, following the PCAP research study. N = 41.

The most common agrichemicals used and reported as self-applied by participants were herbicides (85.4%)—including glyphosate (commonly referred to as Roundup™) and 2,4-DP (dichlorprop)—and insecticides (71.4%), such as dimethoate (organophosphate) and imidicloprid—a neonicotinoid commonly used in seed treatments.

3.1.2. Use of Personal Protective Equipment (PPE)

Responses relating to PPE usage pre- and post-PCAP were compared to see change over time (Figure 3). Variables measured included use of overalls/coveralls, a respirator, safety glasses, gloves and safety boots. Increases in PPE usage were seen across all categories, with participants moving from 'never use' to 'sometimes use', or from 'sometimes use' to 'always use'. The biggest increase was seen in respirator usage, with the percentage of participants in the 'always use' category increasing from 16.6% to 68.3% post-PCAP ($Z = -4.504$, $p < 0.001$). Other significant changes in PPE usage included the use of overalls/coveralls, with users in the 'never' category decreasing from 19.2% to 11.7% and safety boots with the number of respondents who 'never' use safety boots decreasing by 20% ($p < 0.05$). There were additional trends that suggest an increase in the use of eye protection, although there was no statistical significance.

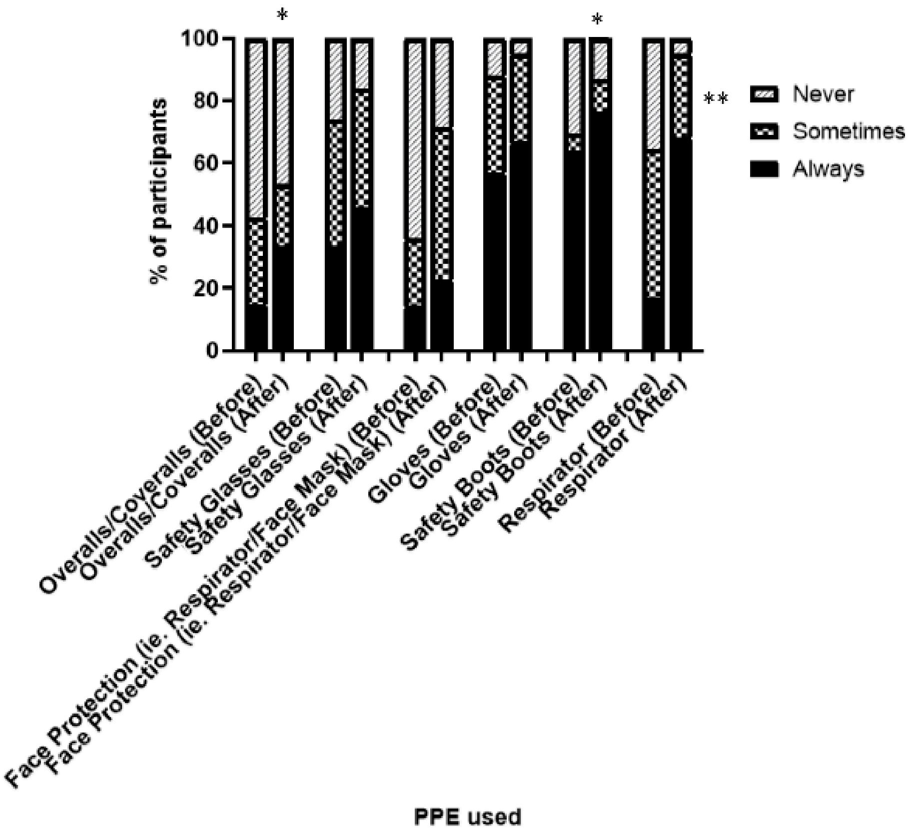

Figure 3. Percentage of participants using PPE pre- and post-PCAP. N = 42. * Significant at $p < 0.05$, ** Significant at $p < 0.01$ using Wilcoxon signed-rank test.

A Spearman's correlation was applied to determine the relationship between participant age and use of PPE (Table 3). There was a modest inverse correlation between age and respirator use post-PCAP ($r_s(42) = -0.390$, $p < 0.010$) indicating as age increased, respirator use decreased. Additionally, there was a positive correlation between use of safety glasses and age ($r_s(37) = 0.420$, $p = 0.010$), implying that as age increased, so did use of safety glasses. A positive trend was also observed between glove use and age ($r_s(39) = 0.386$, $p = 0.015$).

Table 3. Spearman's rank-order correlation (r_s) between Age and use of Personal Protective equipment (PPE).

Measure	Number of Participants	Correlation Coefficient - Age	p
Respirator	42	−0.390	0.0010
Safety Glasses	37	0.430	0.010
Gloves	39	0.386	0.015

Significant correlations were also found between wearing certain items of PPE (Table 4). A positive correlation was found between frequency of gloves worn and frequency of safety glasses worn ($r_s(36) = 0.443$, $p < 0.05$); frequency of safety boots worn and frequency of safety glasses worn ($r_s(36) = 0.409$, $p < 0.05$); frequency of safety boots and frequency of gloves worn ($r_s(37) = 0.475$, $p < 0.05$); frequency of overalls and frequency of safety glasses worn ($r_s(28) = 0.423$, $p < 0.05$), frequency of overalls and frequency of safety boots ($r_s(30) = 0.443$, $p < 0.05$) (Table 4). These correlations indicate that as the use of specific items of PPE, in particular, gloves, safety boots, or safety glasses increases, so does the use of additional PPE. This implies that positive behaviour change could have a snowball effect.

Table 4. Spearman's rank-order correlation (r_s) frequency between simultaneous use of PPE.

	Measure	Gloves	Safety Glasses	Safety Boots	Overalls
1.	**Gloves**	—	$r_s(36) = 0.443$ ($p < 0.05$)	$r_s(37) = 0.475$ ($p < 0.05$)	
2.	**Safety Glasses**	$r_s(36) = 0.443$ ($p < 0.05$)	—	$r_s(36) = 0.409$ ($p < 0.05$)	$r_s(30) = 0.423$ ($p < 0.05$)
3.	**Safety Boots**	$r_s(37) = 0.475$ ($p < 0.05$)	$r_s(36) = 0.409$ ($p < 0.05$)	—	$r_s(28) = 0.443$ ($p < 0.05$)
4.	**Overalls**		$r_s(30) = 0.423$ ($p < 0.05$)	$r_s(28) = 0.443$ ($p < 0.05$)	—

Information was collected from participants regarding the type of PPE worn when handling agrichemical, namely loading, mixing and applying agrichemicals. Results are illustrated in Figure 4.

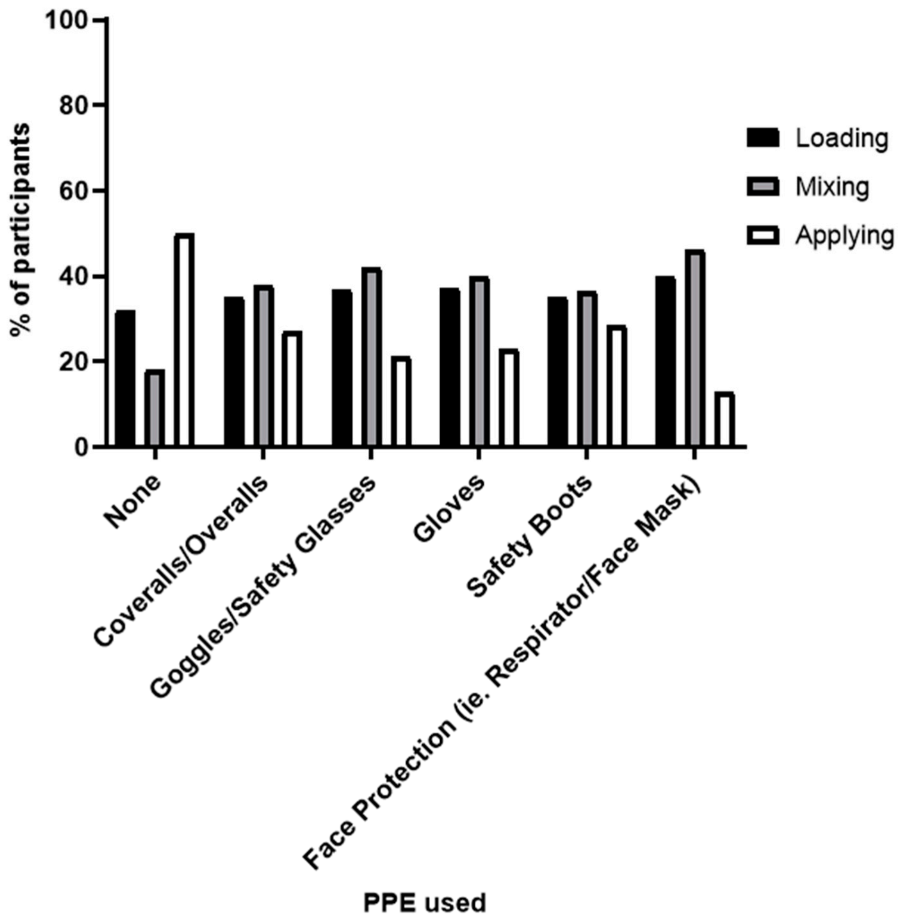

Figure 4. Frequency of PPE usage depending on agrichemical-related task performed—loading, mixing, and applying. N = 42.

3.2. Qualitative Results

This section will focus on one key theme identified during qualitative analysis: 'Participation in PCAP'. This theme contains a combination of positive, negative and neutral experiences, as well as understanding participants gained over the duration of the study, and whether they had implemented any changes into their routine. Many responses towards the study were positive, with participants commenting on how both visualising their ChE test results and participating in the study had changed their handling of OPs. Participants were more aware and cautious of their own safety practices. One participant noted that they were more acutely aware of this when their monthly AChE results fluctuated after they had used OPs. They also said that they had started to look carefully at labels to see if a chemical was an OP.

Participants also stated that their involvement had changed the way they handle agrichemicals in general. Some examples of these are included below:

> *"It was interesting to see how much chemical I was exposed to, and how my levels might peak and trough in relation to use of agrichemicals".* —John * (*name changed)

Others discussed how beneficial PCAP testing was.

> *"There was initial skepticism when it first began, but when I started to see a correlation, my option changed. Visualising personal results was key in helping to change attitudes toward agrichemicals"*. —(James*, Farmer)

Receiving an AChE measurement each month and gaining an understanding of why this may be happening prompted some people to conduct their own research into agrichemicals they regularly use, as well as use of different types of PPE. Some participants went to purchase new PPE following a few weeks of agrichemical testing and found that this correlated with trends in their AChE results. Others found that they *"learnt a lot of practical knowledge about equipment, in particular, respirators"*.—(Andrew *, Farmer)

> '*I think the take home is that you can't be safe enough. . . . you've just got to think it out and think what the consequences are of everything you do. Now having said that, I wish I knew that forty of fifty years ago*'. —(Lou, Farmer)

Participants responded in different ways following their involvement in PCAP. It is evident that this study enabled participants to have a greater awareness of their current behaviours and attitudes towards agrichemicals, allowing them to re-evaluate their safety practices.

4. Discussion

This work builds a greater understanding of the significance of research and research translation to potentiate the engagement of agricultural workers in their health, wellbeing and safety.

4.1. Principal Findings

Boom sprays were the most common method of agrichemical application by the sample group (Figure 2). This was expected, as over half of the participating farmers identified broad-acre cropping as their primary enterprise. A boom spray is attached to a tractor with or without an enclosed cabin. Those with cabins may use a carbon filter to prevent chemical sprays, organic dust, gas and other pollutants from entering the cabin. Aside from boom sprayers, most participants self-applied agrichemicals using a handgun and/or backpack spray (Figure 2). Manufacturers recommend that PPE, in particular, eye protection, be worn at all times whilst spraying, yet participants reported minimal PPE is worn whilst applying agrichemicals (Figure 4). There was a higher percentage of participants wearing PPE when mixing agrichemicals than any other task, indicating that farmers may correctly view this task as having a higher risk of exposure than loading or applying agrichemicals.

Usage of safety glasses and gloves were higher in participants when mixing in comparison to any other tasks (Figure 4). There is evidence to suggest that between loading, mixing and applying, mixing is associated with a greater risk of exposure [24]. These findings may be indicative of some awareness of this principle amongst farmers. MacFarlane et al. (2013) supports this, stating although exposure levels may vary widely between operators, mixing and loading are tasks associated with the greatest intensity of exposure to concentrated product. During such high exposure events, spills are also more likely to be low [26]. However, as chemical application is typically a longer duration task than mixing and loading, total contamination incurred whilst applying may exceed exposure during mixing and loading. Furthermore, literature suggests that equipment cleaning at end of application may also be an important source of exposure [27].

An absence of PPE when applying may be due to method of agrichemical application. Most participants use a boom sprayer and are in an enclosed cabin. Therefore, they would have a reduced risk of exposure and consequently would see little need to wear any PPE whilst applying.

There was an increase in usage of PPE pre- and post-PCAP, with the greatest increase observed in respirator usage (Figure 2). Respiratory inhalation and dermal absorption are considered the primary routes of exposure to agrichemicals. A large proportion (96.9%, n = 63) reported that they had not had their respiratory protection professionally fit tested prior to their involvement in PCAP. This proportion remained high (97.6%, n = 41) post-PCAP. A fit test is conducted to ensure that a respirator is both comfortable and correctly fits the user in order to prevent exposure to contaminants [8]. These results suggest that fit testing should be more widely promoted and accessible in the farming community, such as in agricultural supply stores and at field days. Additionally, those who buy respirators need be informed on how to maintain it. Respiratory protective equipment only offers protection when worn properly, when removed safely and when relevant parts (e.g., filters) are replaced or maintained regularly [28].

There was a significant correlation between age and respirator use, as younger participants were observed to be more likely to wear a respirator than older individuals. Australia's farmers are a male-dominated aging population, in an industry with no clear retirement age [29]. WorkSafe Victoria (2018) and Safe Work Australia [30] report that older workers continue to be overrepresented in accident statistics. Age and experience should never be an excuse to forget about safety [8], although, as previous studies have shown, the longer one has farmed, the more resistant to change they are. Attitudes towards exposure risk are influenced by both age and education; a person who perceives little risk in their work environments is less likely to undertake additional training or choose to wear appropriate PPE. A recent European study suggests that experiencing an incident or past intoxication was the highest motivator for increase in use of PPE, followed by perceived toxicity of the chemical in use [31]. Farmers who have experienced health problems from pesticide use demonstrate heightened concern about the health effects from pesticides when compared to farmers who have not experienced such exposure [31,32]. Similarly, farmers in China who are aware of potential risk to consumers from exposure to pesticide residue, purposely avoid consuming vegetables grown in commercial environments, and are more likely to wear PPE when using pesticides [33].

4.2. Role of Training and Education

Traditionally, education is believed to be a valuable tool for promoting positive health and safety practices. However, evidence in this area remains unclear. Research suggests that traditional learning methods (e.g., watching educational videos and learning PPE guidelines) are inferior to immersive learning methods, including active learner involvement using simulations that include feedback on performance [34]. A systematic literature review by Luong et al. (2016) analysed 14 studies that evaluated the effect of training and education on respiratory use. Participants were from a range of backgrounds, including farming. Findings suggested that behavioural interventions—specifically training and educational—did not have a considerable effect on the frequency or 'correctness' of respirator use [27]. However, this study has seen a significant increase in respirator and overall use over time, documented in the post-PCAP survey, completed 12 months following project commencement. It may be that this form of research engagement is also acting as an intervention. This may be due to the point-of-care nature of the research, as well as participants being provided with their individual

AChE and PChE exposure levels. It may provide an improved understanding of the effect, or potential effect, of OP exposure on their body.

Slovic (2001) states that negative beliefs about risk should not be expected to evaporate completely in the presence of evidence or safer alternatives [35]. However, presenting the same information about risk in different ways may alter people's perspective, and thus their actions. Ajzen's Theory of Planned Behaviour explains why increased knowledge alone did not change safety practices. Programs that target attitudes and encourage personal control over implementing change, have better results, which have been confirmed in this follow-up study [36]. For participants, once their understanding of the human impact of OP exposure was explained and reinforced by repeat (monthly) visits, attitudes toward personal protection and agrichemical use began to change. This was further reinforced by being able to track and compare their personal AChE levels with their OP use.

4.3. A Model for Engagement and Behaviour Change

It was clear that participants found taking part in the research to be beneficial. As discussed in the literature, the gap between knowledge and practice needs to be bridged in a more interactive manner. Research determining personal AChE levels (PCAP) has begun to achieve this, with many participants citing the reason for their participation as due to the interactive and participatory nature of program. A recommendation for improvement would be to provide regular follow-up for testing in a community environment. This could attract other farmers interested in the testing procedure, whilst encouraging interaction with farmers who may not be directly participating, but will hear from their peers this important message. Research has shown that the participation in PCAP and measuring AChE resulted in practice change in a large proportion of participants. However, further research is required to identify whether changes to PPE use in this group have been maintained by participants over time.

Individuals pinpointed in their survey responses that improved knowledge of both agrichemicals and personal protection gained from PCAP was very beneficial. This helped to facilitate awareness amongst participants, and also within the wider local farming community. Many suggested that educational institutes such as vocational training centres and agricultural colleges should be at the forefront of change. Participants reported that specific information, such as the type obtained from PCAP, was not widely available unless they knew exactly what they were looking for. A recommendation for improved outcomes regarding agrichemical safety and use of PPE would be to ensure that education involves both industry and community increasing accessibility and improving farmer understanding and health literacy. Not only making formal education widely available, but also providing both education and intervention passively may play a role in increasing knowledge and awareness in the Australian farming community.

4.4. Limitations

In spite of efforts to address as many of the previous identified limitations of the research as possible, this study has its own limitations. The PCAP study did not include a control cohort, therefore no control group has been included in this follow-up study. Due to the lower sample size of the PCAP study, there was a limited number of participants available for recruitment into this follow-up. As a requirement of taking part, participants must have been involved in the previous PCAP research. This recruitment process, however, was only successful in attracting persons who were proactive and willing to be involved in more research within the community. The majority of the sample was male and of Anglo-Celtic heritage within a relatively small geographical area, though the area covered was agriculturally diverse. Methodological limitations were also present, in that a few questions would have benefitted from clearer phrasing in order to obtain results that are more succinct. An online survey was chosen for ease and convenience for both respondent and data collector, as well as cost effectiveness. However, in this study it was found that telephone survey responses had the biggest response rate.

5. Conclusions

This limited follow-up study aimed to (i) evaluate attitudes and behaviours towards the use of PPE amongst farmers who participated in PCAP; and (ii) qualitatively assess the effect of monthly AChE testing results on farmer agrichemical safety practices pre- and post-PCAP. The results demonstrated that a majority of participants reported their involvement changed the way they handled OPs and other agrichemicals. Trends were identified in agrichemical handling prior to and following involvement in PCAP. It was found that older farmers were less likely to wear a respirator and that farmers are more likely to use PPE when mixing and loading agrichemicals compared to applying them. Moreover, translation of research findings with participants provided them with the knowledge to understand how their participation influenced the way they evaluate personal safety and behaviour around agrichemicals, compared to attitudes and practices of the population, highlighting the importance of effective research translation when engaging farmers and farm workers (Table 1).

Ultimately, this follow-up study suggests that research and education may be able to influence practice change, highlighting the importance of an interactive, participatory model in order to bring about change. Future longitudinal research should aim to track these participants, and any others involved in agrichemical research, in order to determine if this positive practice change is constant and for how long it is maintained. This knowledge could be applied to support the further development of education aimed at change behaviour, practice and safety culture within the agricultural sector. Finally, this preliminary work begins to validate the role AChE monitoring can play in providing in farmers with information about their OP exposure, whilst also engaging farmers in conversation with a professional about their use of other agrichemicals and their use of protective equipment.

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Appendix A

Table A1. Chemical usage Survey questions applied pre and post participation in the In-field Personalised Cholinesterase Assessment Project (PCAP).

Question	
1.	I have read the Plain Language Statement & Consent Form, and by signing my name below, I agree to participate in this study
2.	Including yourself, who currently lives in your home?
3.	What is your current degree or level of education you have completed? If currently enrolled, what is your highest degree received?
4.	In general, how would you describe your health?
5.	How often do you consume alcohol?
6.	How often do you have more than 4 standard drinks (if female) or 6 standard drinks (if male) in one day?
7.	Which statement best describes your smoking behaviour?
8.	Do you personally apply agrichemicals on your farm?

Table A1. *Cont.*

Question	
9.	What method/s do you use to apply agrichemicals on your farm? Please select all that apply.
10.	In the past year, which of the following agrichemicals were used on your farm? Were they self-applied?
11.	In the past year, which of the following classes of agrichemicals were used on your farm? Were they self-applied? Insecticides, Herbicides, Fungicides, Fumigants,
12.	Do you read the safety instructions on the label of agrichemicals used on your farm? Always, Sometimes, Never
13	What type of Personal Protective Equipment (PPE) do you usually wear when loading, mixing or applying agrichemicals? None, Overalls, Mask/Respirator, Googles/Safety glasses, Gloves, Face Protection, Safety Boots. (Loading, Mixing, Applying)
14.	How frequently do you wear the following types of PPE when loading, mixing or applying agrichemicals? Always, Sometimes, Never, Not Applicable.
15.	Do you wear respiratory protection? i.e. respirator, face mask. Yes, No.
16.	Do you usually wear your respiratory protection when exposed to: Grain Dust, Sheep, Silo Dust, Treating and processing livestock, Feeding livestock, Washing and Disinfecting, Preparing spray equipment?
17.	If you have a tractor with a cabin, do you use a carbon filter when applying agrichemicals? Yes, No, Not Applicable.
18.	After use, do you take your PPE into the household? Yes, No, Not Applicable.
19.	If you self-apply chemicals; I wear clean washed clothes everyday, I change my clothes immediately after a spill, I wash my clothes separately, I wash my hands before eating, I wash my hands before urinating. (Always, Sometimes, Never)
20.	Do you clean your PPE regularly or when advised? Yes, No, I don't know when is appropriate.
21.	Do you check your PPE for wear and damage? Yes, No
22.	In the past year, how have your work clothes usually been washed when you have been handling agrichemicals? Mix them with family wash, Soak them separately then wash in communal machine, Wash in machine only for this purpose, Wear disposable clothing.
23.	In the past year, when you have been handling agrichemicals, how long would you usually work with the same pair of gloves before changing them for a new pair? Every time, At least once a month, 1–4 times per session, I do not change my gloves until they are visibly worn out, I wear disposable gloves, Do not wear gloves.
24.	In the past year, how has agrichemical-applying equipment usually been washed at the end of application? Clean the nozzle, Rinse the tank, Hose down the sprayer, Hose down the tractor, Do not wash equipment, I don't know, Other (specify)
25.	Do you usually wear sunglasses as a form of PPE when loading, mixing agrichemicals? Yes, No
26.	When you work directly in the sun, what type/s of sun protection do you usually use? Sunscreen, Sunglasses, Baseball cap, Another type of hat with a brim, long sleeved shirt, None of the above
27.	Do you believe that your participation in the In-Field PCAP research has changed the way you handle organophosphates? Likert Scale of responses
28.	Do you believe that your participation in the In-Field PCAP has been beneficial in any way? Likert Scale of responses

Appendix B. Interview Questions

Interview Script
Interview #
Date:
Interviewer's Notes

Before we start, I'd like to quickly explain what's going to happen during the interview, which should take between 45 minutes to an hour. Basically, I'll be asking you a series of questions that were briefly touched upon in your survey. These topics include Health, Attitudes, Barriers to Change and

Risk Perception.

You don't have to answer every question. This interview will be kept strictly confidential and your identity will remain anonymous when I write up the results of the study. Upon completion of the study all records that contain personal identifiers will be destroyed. Do you have any questions before we begin?

Questions

Do you mind telling me a bit about your farming background ie. contractor, own your own farm, predominately cropping or cattle etc.

What type of agrichemicals do you use (OPs)? How often do you apply them?

Health

Have you had an adverse experience with agrichemcials before?

Why did you choose to participate in PCAP?

What have you learnt from your involvement in PCAP?

Has your participation in PCAP been useful in any way?

Has having a visual representation (graph) of your AChE inhibition influenced your opinion/been beneficial?

Why do you think this hasn't changed your behaviour? What do you think would?

Farmer Attitudes

How has your participation in PCAP influenced the way you handle OPs? What about agrichemicals in general?

How do you think regular testing for ChE would be beneficial in helping other farmers change how they handle OPs and/or agrichemicals?

How has your involvement in PCAP changed your ability to communicate with others regarding safe handling of OPs and/or agrichemicals?

Has your involvement changed the way you think about agrichemicals?

Barriers to Change

In relation to agrichemicals, what barriers do you think there are to improving personal safety? How about safety on a larger scale ie. family, employees, neighbours?

What role do you think either attitudes/complacency/negative social influences/perception of control/role of social networks/personal connection play as a barrier to change?

Do you think there is 'work ethic' or 'work culture' in farmers that may act as a barrier to embracing changes to agrichemical safety?

There has been a lot of research both in Australia and internationally regarding PPE use when handling agrichemicals. It probably doesn't come as a surprise, but PPE usage worldwide is low.

Why do you think this might be the case?

Risk Perception

Have you substituted standard PPE for other items? Why?

Do you think you are getting the same level of protection from these items as you would from standard PPE?

What role do you think occupational stressors such as money and time play in your ability or attitude towards wearing PPE?

Do you think lifestyle factors such as fatigue and alcohol impede the use of **PPE**?

Do you think there is a lack of readily accessible information about agrichemical safety (PPE)? How about information about chemical training **courses**?

Do you think that you demonstrate safer behaviour when handling agrichemicals around your family? - in particular children

Closing

And we're done! Thanks for participating in my project. I really do appreciate you taking the time to have a chat. Before we wrap things up and talk about what's next, are there any last comments you have regarding anything we spoke about today?

Thank you for your time.

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