Risk Perception and Behavior in Egyptian Adolescent Pesticide Applicators: An Intervention Study

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Diane S Rohlman
Occupational and Environmental Health, University of Iowa
diane-rohlman@uiowa.edu
ORCiD: https://orcid.org/0000-0002-6697-1577

Jonathan W Davis
University of Iowa College of Public Health
ORCiD: https://orcid.org/0000-0002-5164-1241

Ahmed Ismail
Menoufia University Faculty of Medicine

Gaafar Abdel Rasoul
Menoufia University Faculty of Medicine

Olfat Hendy
Menoufia University National Liver Institute

James R Olson
University at Buffalo - The State University of New York

Matthew R Bonner
University at Buffalo - The State University of New York

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Abstract

**Background:** Adolescents are engaged in agricultural work, including pesticide application, around the world. Adolescent pesticide applicators are more likely to be exposed to pesticides than their adult counterparts because of their application practice and hygiene habits surrounding pesticide use. There is a need for low-cost interventions to reduce pesticide exposure. We evaluated a theoretically-based educational intervention to change perceptions about the risk of pesticide use and hygiene habits during and after pesticide application for adolescent and young adult pesticide applicators in Egypt.

**Methods:** Young adult and adolescent pesticide applicators were given an educational intervention to inform them on the risk of pesticide use and how to reduce pesticide exposure. Changes in perceived susceptibility and effectiveness were measured with a survey pre and post intervention. The same survey was given 8-month post intervention to identify sustained effects. Observational checklists of pesticide application practice were also completed during application seasons before and after the intervention.

**Results:** There was an increase in the proportion of individuals who viewed pesticides as being a long-term health risk (74.7% pre-intervention to 97.9% post-intervention, McNemar test p<0.001). This change remained significant when surveyed at the 8-month follow-up (90.5%, p<0.001). There was also a sustained improvement in regards to participant’s view of proper hygiene practice surrounding pesticide application. Applicators where observed wearing googles, shoes, and mask more frequently post intervention.

**Conclusion:** This theoretically-based intervention is an example of a low-cost solution that can improve adolescent and young adult’s practices regarding pesticide application and personal hygiene practice during and after pesticide application. The intervention can be applied in other countries with similar safety culture surrounding pesticide application.

**Background**

Many children and adolescents throughout the world are engaged in agricultural work, either for pay or on family farms. Studies examining exposure among children have primarily focused on non-
occupational or para-occupational factors (e.g., residential use, diet, or take-home exposure) (1-3). Occupational activities such as mixing, applying, and maintaining equipment, the frequency and duration of spraying, and use of personal protective equipment (PPE) will impact exposure to pesticides (4-6). In addition, personal hygiene factors, such as bathing or laundering clothing are associated with exposure (7, 8). Adolescents applying pesticides are more likely to engage in behaviors that can increase their exposure, wearing shorts instead of pants, wearing clothing containing pesticide residues, and washing less frequently when compared to adults (9).

In addition to the increased potential for exposure, physiologically, a child or adolescent is more susceptible to adverse health effects of pesticides than their adult counterparts (10). Among adolescent pesticide applicators, exposure to pesticides is associated with increased health symptoms (11, 12), reduced lung function (13), neurobehavioral deficits (14-16), and Attention-Deficit/Hyperactivity Disorder (ADHD) symptoms (17). Because of the increased likelihood of exposure and risk for adverse health effects, specific interventions targeting adolescent pesticide applicators is warranted.

In this study, we developed an intervention targeted at changing workplace behaviors and hygiene practices that are associated with increased pesticide exposure for adolescent pesticide applicators. Additionally, the intervention educated participants about the health threat of pesticide use and the efficacy of various protective measures to reduce exposure. Changes in perceptions of pesticide use and measures taken to reduce exposure were evaluated before and after the intervention.

**Methods**

**Study Population and Setting**

This study is a pre-post intervention study nested in a longitudinal study of adolescent and young adult pesticide applicators in Egypt. The original longitudinal study started in 2014 and continued to 2017, with follow up testing in 2018 and 2019. Adolescents under the age of 19 who worked for the Ministry of Agriculture to spray pesticides to cotton in the Nile delta were recruited in 2014 and 2015 from four field stations (Quesna, Shohada, Tala, and Berket El-Sabe’) in Menoufia Governorate, Egypt. The intervention was also available to a subset of applicators who were part of a longitudinal study
characterizing neurobehavioral performance and organophosphate pesticide exposure (n=13, 8.4%) (14). Results where replicated excluding these individuals and no difference in the results were found. Applicators had the following job responsibilities surrounding pesticide use: mixing pesticides, filling backpack sprayers, and application of pesticides.

Agriculture is one of the largest employers in Egypt (18). The primary agricultural product in Egypt is cotton and because of its national economic importance, the use of pesticides on that crop is highly regulated by the Egyptian Ministry of Agriculture (MOA) (19). The national government purchases and sells the country’s entire cotton production and once farmers agree to plant cotton, applications of chemicals on those fields come under control of the Ministry of Agriculture. Thus, all pesticides, equipment and calibration procedures are standardized across the Governorate. Adolescents are hired by the MOA as seasonal workers to apply pesticides and may work for repeated seasons.

To assess pesticide application and hygiene behaviors of pesticide applicators, observational checklists of pesticide application were completed in August 2016 and August 2017. Observational checklists included personal protective equipment worn before and during pesticide application, mixing procedures, and hygiene after pesticide application. In May of 2017, in-between the two observational checklist dates, an intervention was completed training participants on the dangers and potential preventative measures around the application of pesticides.

In total, 119 study participants attended the intervention training in May 2017. Of these participants, 87 had completed observational checklists of pesticide application during August 2016 and 92 had observational checklists completed during August 2017. There were a total of 71 participants that completed the intervention training and had observational checklist data for 2016 and 2017. A follow-up to the intervention questionnaire was administered 8 months post intervention in which 95 individuals responded. Consent of human subjects was obtained from participants and procedures approved by the University of Iowa Institutional Review Board and the Medical Ethics Committee at Menoufia University.

*Intervention Description and Risk Behavior Scale*

We worked with the MOA to identify feasible and appropriate methods to reduce pesticide exposure.
Initial workplace observations had identified behaviors during mixing, loading, and applying pesticides that increased adolescents contact with pesticides (e.g., mixing with hands, contact with pesticides during loading and applying, reentry into sprayed fields), and therefore exposure. In addition, self-reported hygiene practices indicated variability in time to change clothes or bathe after applying pesticides. We also found that increased urinary metabolite levels were associated with increased time applying, and lower urinary metabolite levels were associated with bathing immediately after work and using a stick to mix pesticides (instead of hands) (20). Focus groups held separately with officials from the MOA, adolescents, and parents presented study findings and discussed feasible methods to reduce exposure during application. We found that, while some PPE is supplied by the MOA (masks, gloves, glasses), this is not enough for all workers and some workers had concerns about the quality and effectiveness of the supplied PPE. Although the MOA has adopted procedures to reduce exposure (e.g., point nozzle downward, maintain distance between applicators, consider wind direction when applying), applicators reported receiving no formal training. Most workers reported bathing after work, however, there was variation in how frequently work clothes were washed (e.g., daily, monthly). The intervention incorporated feedback from the focus group in the intervention. An intervention to train applicators on work and hygiene practices to reduce exposure was developed. Three behaviors were targeted: staying out of fields recently sprayed, using a stick (instead of hands) to mix pesticides, bathing/wearing clean clothes. Exposure reduction measures such as elimination or substitution of the hazardous substance or engineering out the exposure are considered superior methods of controlling exposure because they either prevent use of the hazardous substance altogether or control exposure at the source. When properly implemented, these methods can be effective regardless of worker interaction (21). While altering the targeted behaviors is less effective in reducing exposure than elimination or engineering controls, the goal of the intervention was to impact the direct activities taken by the adolescents themselves. This allows the adolescent to reduce their exposure to pesticides regardless of their workplace or available resources. Participants of the intervention were surveyed on their views of pesticide safety and the effectiveness of targeted behaviors to reduce exposure to pesticides before and after the intervention, as well as, 8
months later to assess retention. The results were used to categorize individuals using the Risk Behavior Diagnosis (RBD) Scale based on pathways from the Extended Parallel Process Model (EPPM) (22, 23). The EPPM has been widely used in health promotion and disease prevention to develop interventions among diverse international populations (24-29).

The EPPM pathways identify how individuals are likely to control a health risk based on threat perception and efficacy of controlling that threat (23). These pathways have been used to group individuals into four quadrants of behavior using the RBD Scale: responsive (high threat-high efficacy), pro-active (high threat-low efficacy), avoidant (low threat-high efficacy), and indifferent (low threat-low efficacy) (30, 31). The questions used to assess threat and efficacy were related to the targeted behaviors of the interventions — mixing pesticides with a stick (not your hand), not entering fields, and hygiene around pesticide application. An average response of agree (4) on a 5 point scale of strongly disagree (1) to strongly agree (5) was used to place individuals into levels of high or low efficacy and high or low threat. Individuals were surveyed before the intervention, immediately following the intervention, and 8 months post intervention. In addition to the questions used to construct the RBD Scale, several questions about pesticide safety were asked at the same time periods.

Statistical Methods

Internal reliability of the RBD scale was assessed using Cronbach’s alpha coefficient. The scale was then used to place individuals into the four RBD quadrants of health risk behavior. Differences in demographics and pesticide application practices were compared across the quadrants using the Chi-squared test. Change in behavior post-intervention and 8 months later was compared using McNemar test to detect a difference in the proportion of individuals placed in each RBD quadrant. Similarly, changes in patterns of PPE used found during the 2016 and 2017 observational checklist and changes in feelings regarding pesticide safety were compared with McNemar test. Data analysis was completed with SAS 9.4 (SAS Institute, Cary, NC) with an alpha of 0.05 used for testing significance.

Results

Internal Reliability of Perceived Efficacy and Perceived Threat
During the intervention, 119 individuals completed pre and post-surveys and participated in the educational intervention. The questions used to assess perceived efficacy and perceived threat are given in Table 1. Evaluation of internal consistency of the RBD scale are given in Table 2. The internal consistency of perceived efficacy was calculated using Cronbach’s alpha and found to be 0.641. Cronbach's alpha estimates reliability for measurement scales used in research (32). No absolute cutoff for reliability exists, but a minimum for fair reliability of 0.60 and 0.65 has been suggested for studies of less than 100 participants and studies of 100 to 300 participants respectively (33). Removing any individual question did not meaningfully change the internal consistency (<1% change) of perceived efficacy and removing multiple measures only marginally increased consistency, so the final scale included all 6 questions (removal of Q11 and Q12 increase Cronbach’s alpha to 0.661). The measures of perceived threat had a Cronbach’s alpha of 0.639. Removing Q13 and Q14 improve the internal consistency and were excluded from the scale in analysis (Cronbach’s alpha = 0.690, Table 2).

Table 1: Risk Behavior Diagnosis Scale Questions to classify Adolescent and Young Adult Pesticide Applicators Perceived Efficacy and Threat

| Scale             | Question                                                                                     |
|-------------------|----------------------------------------------------------------------------------------------|
| Perceived Efficacy| Q11 Using a stick instead of my hands to mix pesticides will prevent me from getting sick    |
|                   | Q12 I am able to use a stick instead of my hands to mix pesticides                           |
|                   | Q15 Staying out of fields that were recently sprayed will prevent me from getting sick       |
|                   | Q16 I can stay out of fields that were recently sprayed                                     |
|                   | Q19 Changing into clean clothes after working with pesticides will prevent me from getting sick |
|                   | Q20 I can wear clean clothes with no pesticide residues                                      |
| Perceived Threat  | Q9 Using hands to mix pesticides can cause sickness                                            |
|                   | Q10 If I mix pesticides with my hands it could make me sick                                 |
|                   | Q13 Entering fields that were recently sprayed will cause sickness                           |
|                   | Q14 If I enter a field that was recently sprayed I am likely to get sick                      |
|                   | Q17 Wearing clothes with pesticide residues on them for several hours will cause sickness   |
|                   | Q18 If I wear clothes with pesticide residues for several hours, I am likely to get sick    |
Table 2: Internal consistency of the Risk Behavior Diagnosis Scale for Adolescent Applicators in Egypt

| Scale               | Cronbach’s alpha | Adjustment Made                        | Median Score (range) |
|---------------------|------------------|----------------------------------------|----------------------|
| Perceived Efficacy  | 0.641            |                                        | 24 (17-30)           |
| Perceived Threat    | 0.639            | Remove Q13\(^a\)                        | 0.627                |
|                     |                  | Remove Q14\(^b\)                        | 0.631                |
|                     |                  | Remove Q13&14                           | 0.690                |
|                     |                  |                                        | 16 (10-20)           |

\(^a\)Q13 – Entering fields that were recently sprayed will cause sickness

\(^b\)Q14 – If I enter a field that was recently sprayed I am likely to get sick

Analysis of the Risk Behavior Diagnosis (RBD) Scale

Participants were placed into four quadrants (Responsive, Avoidant, Proactive, or Indifferent) based on their responses to the pre-intervention survey using the RBD scale. Table 3 presents the demographic differences across RBD quadrants. More than a third of individuals (38.7%) were classified as responsive, having both high threat and high efficacy perceptions. The second most common quadrant was indifferent (26.0%) made up of individuals with low threat and low efficacy perceptions. Across the quadrants there was no statistically significant differences in age or pesticide application history, but those classified as indifferent were older and more likely to apply pesticides as a private applicator.

Table 3: Demographic Characteristics of Adolescent Applicators
| Variable                  | Level | Responsive (HT, HE) | Avoidant (HT, LE) | Proactive (LT, HE) | Indifferent (LT, LE) | P-value<sup>a</sup> |
|---------------------------|-------|---------------------|-------------------|--------------------|----------------------|---------------------|
| Age                       | 13-17 | 21 45.7             | 10 58.8           | 13 52.0            | 9 29.0               | 0.171               |
|                           | 18+   | 25 54.3             | 7 41.2            | 12 48.0            | 22 71.0              |                     |
| Applying Pesticides at MOA| No    | 10 21.7             | 4 23.5            | 4 16.0             | 9 29.0               |                     |
|                           | Yes   | 36 78.3             | 13 76.5           | 21 84.0            | 22 71.0              | 0.710               |
| Years worked in applying pesticides for MOA | 3-4   | 10 27.8             | 4 30.8            | 10 47.6            | 8 36.4               |                     |
|                           | 5+    | 26 72.2             | 9 69.2            | 11 52.4            | 14 63.6              | 0.490               |
| Applying Pesticides as Private applicator | No    | 39 84.8             | 15 88.2           | 20 80.0            | 19 61.3              |                     |
|                           | Yes   | 7 15.2              | 2 11.8            | 5 20.0             | 12 38.7              | 0.060               |
| Applying Pesticides at Family fields | No    | 16 34.8             | 8 47.1            | 12 48.0            | 8 25.8               |                     |
|                           | Yes   | 30 65.2             | 9 52.9            | 13 52.0            | 23 74.2              | 0.284               |
| Hours                     | <3    | 15 32.6             | 7 41.2            | 6 24.0             | 12 38.7              |                     |
|                           | >=3   | 31 67.4             | 10 58.8           | 19 76.0            | 19 61.3              | 0.604               |

Note: HT, High Threat; LT, Low Threat; HE, High Efficacy; LE, Low Efficacy; MOA, Ministry of Agriculture
<sup>a</sup> The parametric p-value is calculated by Chi-square test comparing levels of each variable

How the intervention impacted perceived threat and efficacy is presented in Table 4 for individuals who completed surveys at all three time points (n=95, 79.8%; pre-intervention, post-intervention, and 8 months after the intervention). The shift in RBD quadrant post-intervention and 8 months after the intervention were evaluated. Post intervention, there was an increase in the proportion of individuals in the responsive quadrant (90.5%) versus the proportion of responsive individuals pre-intervention.
(42.1%, p<0.001). The proportion of individuals in the two categories of low threat (proactive and indifferent) decreased post-intervention (p<0.001). In the 8-month follow-up, the majority of individuals were in the responsive category, but this was not significantly different from the proportion pre-intervention. There was a significant decrease in the proportion of individuals in the proactive category (p=0.007) with more than half (n=11, 55.0%) becoming responsive.

Table 4: Risk Behavior Diagnosis scale changes over time

| Variable | Level | Pre-Intervention | Post-Intervention | 8-Month Post |
|----------|-------|------------------|-------------------|-------------|
|          | n     | %                | n     | %     | P-valuea | n | %     | P-valuea |
| Responsiveness | No | 55 | 57.9 | 9 | 9.5 | <.001 | 45 | 47.4 |
|          | Yes | 40 | 42.1 | 86 | 90.5 | <.001 | 50 | 52.6 | 0.157 |
| Avoidant | No | 81 | 85.3 | 88 | 92.6 | 0.071 | 72 | 75.8 | 0.083 |
|          | Yes | 14 | 14.7 | 7 | 7.4 | 0.071 | 23 | 24.2 | 0.083 |
| Proactive | No | 75 | 78.9 | 94 | 98.9 | <.001 | 88 | 92.6 | 0.007 |
|          | Yes | 20 | 21.1 | 1 | 1.1 | <.001 | 7 | 7.4 | 0.007 |
| Indifferent | No | 74 | 77.9 | 94 | 98.9 | <.001 | 80 | 84.2 | 0.257 |
|          | Yes | 21 | 22.1 | 1 | 1.1 | <.001 | 15 | 15.8 | 0.257 |

aThe parametric p-value is calculated by McNemar test.

**Intervention Questionnaire Responses**

The responses to the additional questions surveyed before, after, and with an 8-month delay are presented in Table 5. Responses were categorized as the desired response versus a neutral response or worse (e.g., Agree vs. Disagree/Neutral or Disagree vs. Agree/Neutral where appropriate). Similar to the changes in RBD quadrant there was a strong shift in attitudes with a heightened awareness of the dangers posed by pesticide use immediately following intervention, with a drop in this awareness when surveyed 8 months later. The proportion of respondents who viewed pesticides as posing a long-term health risk increased from 74.7% to 97.9% (p<0.001) post-intervention. This change remained significant when survey at the 8-month delay (90.5%), when compared to before
intervention survey (p<0.001). Several questions about hygiene had a sustained change in the proportion of individuals responding positively (Q18: wearing clothes with pesticide residue, Q24: washing hands before eating, Q25: touching pesticides and then touching face). There was a decrease in agreement that staying out of fields would prevent sickness (Q15) or mixing with bare hands (Q22) increased pesticide exposure when comparing initial opinions and opinions 8 months later.

TABLE 5

| Variable | Level       | Pre  | Post | 8-Month Post |
|----------|-------------|------|------|--------------|
|          |             | n    | %    | n    | %    | p  | n    | %    | p  |
| 1. Will exposure to pesticides cause an immediate health risk? | Unlike ly | 29   | 30.5 | 5    | 5.3 | 24 | 25.3 |<.001 |
|          | Likely      | 66   | 69.5 | 90   | 94.7 | 64 | 67.4 |<.001 |
|          | IDK         | 0    | 0.0  | 0    | 0.0  | 7  | 7.4  |0.141 |
| 2. Will exposure to pesticides cause a long-term health risk? | Unlike ly | 21   | 22.1 | 2    | 2.1 | 5  | 5.3  |<.001 |
|          | Likely      | 71   | 74.7 | 93   | 97.9 | 86 | 90.5 |<.001 |
|          | IDK         | 3    | 3.2  | 0    | 0.0  | 4  | 4.2  |<0.001 |
| 3. How much risk are you exposed to while using pesticides? | No Risk/Medium | 88   | 92.6 | 52   | 54.7 | 44 | 46.3 |<.001 |
|          | Significant Risk | 7    | 7.4  | 43   | 45.3 | 51 | 53.7 |<.001 |
| 4. Direct exposure on skin to pesticides | Disagree/Neutral | 60   | 63.2 | 87   | 91.6 | 67 | 70.5 |<.001 |
|          | Agree       | 35   | 36.8 | 8    | 8.4  | 28 | 29.5 |0.286 |
is not harmful to human health.

5. Pesticides are a greater risk to adults than adolescents.

|                | Disagree | Agree | Neutral | p-value | Agree | Neutral |
|----------------|----------|-------|---------|---------|-------|---------|
|                | 47       | 49.5  | 92      | 96.8    | 54    | 56.8    |

6. A pesticide would not be put on the market if it were not safe for humans to use.

|                | Disagree | Agree | Neutral | p-value | Agree | Neutral |
|----------------|----------|-------|---------|---------|-------|---------|
|                | 31       | 32.6  | 39      | 41.1    | 6     | 6.3     |

7. How confident are you that you are able to prevent yourself from being exposed to pesticides?

|                | Not Confident | Confident | Neutral | p-value | Confident | Neutral |
|----------------|---------------|-----------|---------|---------|-----------|---------|
|                | 58            | 61.1      | 19      | 20.0    | 27        | 28.4    |

8. If you need advice on how to

|                | Not Confident | Confident | Neutral | p-value | Confident | Neutral |
|----------------|---------------|-----------|---------|---------|-----------|---------|
|                | 45            | 47.4      | 14      | 14.7    | 21        | 22.1    |
safely handle a pesticide, how confident are you that you would be able to get advice?

9. Using hands to mix pesticides can cause sickness.

|                | Disagree/Neutral | Agree | % 1 | % 2 | % 3 | % 4 | p-value | % 5 | % 6 |
|----------------|------------------|-------|-----|-----|-----|-----|---------|-----|-----|
| Disagree       | 22               | 23.2  | 3   | 3.2 | 18  | 18.9 |         |     |     |
| Agree          | 73               | 76.8  | 92  | 96.8| <.001| 77   | 81.1   | 0.479|

10. If I mix pesticides with my hands it could make me sick.

|                | Disagree/Neutral | Agree | % 1 | % 2 | % 3 | % 4 | p-value | % 5 | % 6 |
|----------------|------------------|-------|-----|-----|-----|-----|---------|-----|-----|
| Disagree       | 21               | 22.1  | 2   | 2.1 | 20  | 21.1 |         |     |     |
| Agree          | 74               | 77.9  | 93  | 97.9| <.001| 75   | 78.9   | 0.869|

11. Using a stick instead of my hands to mix pesticides will prevent me from getting sick.

|                | Disagree/Neutral | Agree | % 1 | % 2 | % 3 | % 4 | p-value | % 5 | % 6 |
|----------------|------------------|-------|-----|-----|-----|-----|---------|-----|-----|
| Disagree       | 23               | 24.2  | 10  | 10.5| 28  | 29.5 |         |     |     |
| Agree          | 72               | 75.8  | 85  | 89.5| 0.003| 67   | 70.5   | 0.411|

12. I am able to use...

|                | Disagree/Neutral | Agree | % 1 | % 2 | % 3 | % 4 | p-value | % 5 | % 6 |
|----------------|------------------|-------|-----|-----|-----|-----|---------|-----|-----|
| Disagree       | 18               | 18.9  | 2   | 2.1 | 16  | 16.8 |         |     |     |
| Agree          |                  |       |     |     |     |     |         |     |     |
1. A stick instead of my hands to mix pesticides.

| Agree | 77 | 81.1 | 93 | 97.9 | <.001 | 79 | 83.2 | 0.683 |

13. Entering fields that were recently sprayed will cause sickness.

| Disagree/Neutral | 28 | 29.5 | 5 | 5.3 | 24 | 25.3 |
| Agree | 67 | 70.5 | 90 | 94.7 | <.001 | 71 | 74.7 | 0.527 |

14. If I enter a field that was recently sprayed I am likely to get sick.

| Disagree/Neutral | 28 | 29.5 | 6 | 6.3 | 28 | 29.5 |
| Agree | 67 | 70.5 | 89 | 93.7 | <.001 | 67 | 70.5 | 1.000 |

15. Staying out of fields that were recently sprayed will prevent me from getting sick.

| Disagree/Neutral | 18 | 18.9 | 6 | 6.3 | 32 | 33.7 |
| Agree | 77 | 81.1 | 89 | 93.7 | 0.005 | 63 | 66.3 | 0.023 |

16. I can stay out of fields that were recently sprayed.

| Disagree/Neutral | 20 | 21.1 | 7 | 7.4 | 30 | 31.6 |
| Agree | 75 | 78.9 | 88 | 92.6 | 0.002 | 65 | 68.4 | 0.096 |
17. Wearing clothes with pesticide residues on them for several hours will cause sickness.

|                      | Disagree/Neutral | Agree | p-value |
|----------------------|------------------|-------|---------|
| Disagree/Neutral     | 29               | 0     | 0.0     |
| Agree                | 66               | 95    | 100.0   |
| p-value              | 10               | 10.5  | <.001   |

18. If I wear clothes with pesticide residues for several hours, I am likely to get sick.

|                      | Disagree/Neutral | Agree | p-value |
|----------------------|------------------|-------|---------|
| Disagree/Neutral     | 27               | 1     | 1.1     |
| Agree                | 68               | 94    | 98.9    |
| p-value              | 7                | 7.4   | <.001   |

19. Changing into clean clothes after working with pesticides will prevent me from getting sick.

|                      | Disagree/Neutral | Agree | p-value |
|----------------------|------------------|-------|---------|
| Disagree/Neutral     | 13               | 1     | 1.1     |
| Agree                | 82               | 94    | 98.9    |
| p-value              | 10               | 10.5  | 0.001   |

20. I can wear clean clothes with no pesticide residues.

|                      | Disagree/Neutral | Agree | p-value |
|----------------------|------------------|-------|---------|
| Disagree/Neutral     | 6                | 1     | 1.1     |
| Agree                | 89               | 94    | 98.9    |
| p-value              | 5                | 5.3   | 0.059   |
21. I can be exposed to pesticides by breathing in pesticides when they are sprayed.

| Agree | Disagree/Neutral |
|-------|------------------|
| 83    | 12               |
| 93    | 12.6             |
| 97.9  | 2                |
| 0.002 | 2.1              |
| 88    | 7                |
| 92.6  | 7.4              |
| 0.225 |                  |

22. I can be exposed to pesticides by mixing pesticides with bare hands.

| Agree | Disagree/Neutral |
|-------|------------------|
| 86    | 9                |
| 95    | 9.5              |
| 100.0 | 0                |
| NA    | 0.0              |
| 76    | 19               |
| 80.0  | 20.0             |
| 0.050 |                  |

23. I can be exposed to pesticides by eating food in the field.

| Agree | Disagree/Neutral |
|-------|------------------|
| 81    | 14               |
| 92    | 14.7             |
| 96.8  | 3                |
| 0.002 | 3.2              |
| 82    | 13               |
| 86.3  | 13.7             |
| 0.847 |                  |

24. I can be exposed to pesticides by not washing hands before

| Agree | Disagree/Neutral |
|-------|------------------|
| 80    | 15               |
| 93    | 15.8             |
| 97.9  | 2                |
| <.001 | 2.1              |
| 92    | 3                |
| 96.8  | 3.2              |
| 0.005 |                  |
After applying pesticides.

| Question                                                                 | Disagree | Neutral | Agree | p-value | Disagree | Neutral | Agree | p-value |
|--------------------------------------------------------------------------|----------|---------|-------|---------|----------|---------|-------|---------|
| 25. I can be exposed to pesticides by touching pesticides and then touching your eyes or other parts of your face. | 22       | 23.2    | 1     | 1.1     | 6        | 6.3     |       |         |
| 26. I can be exposed to pesticides by splashing pesticides on my clothes. | 39       | 41.1    | 2     | 2.1     | 28       | 29.5    |       |         |
| 27. I can be exposed to pesticides by walking in fields that were recently sprayed. | 22       | 23.2    | 5     | 5.3     | 32       | 33.7    |       |         |
| Question                                                                 | Disagree/Neutral | Agree | p-value | p-value | Disagree/Neutral | Agree |
|-------------------------------------------------------------------------|------------------|-------|---------|---------|------------------|-------|
| 28. I can be exposed to pesticides by storing pesticides in the field station. |                  |       |         |         |                  |       |
| 29. Bathing immediately after applying pesticides will reduce my exposure to pesticides. |                  |       |         |         |                  |       |
| 30. Wearing clothes with pesticide residues will reduce my exposure to pesticides. |                  |       |         |         |                  |       |
| 31. Getting pesticides on your skin will reduce my exposure to pesticides. |                  |       |         |         |                  |       |
PPE Change

The results of observed PPE usage in 2016 and 2017 are presented in Table 6. There were 71 participants who completed all three intervention surveys and had observational checklists completed in 2016 and 2017. From 2016 to 2017, there was a significant increase in the proportion of adolescents using a respirator or molded face mask, a hat, and goggles/glasses when mixing or applying pesticides. Fewer adolescents were wearing shoes during mixing and application of pesticides in 2017 compared to 2016. Only one adolescent was observed wearing gloves in 2017 compared to none in 2016. When mixing was observed, hands were never used to directly mix pesticides. Instead, adolescents used a tool such as a stick to mix the pesticides (data not shown).

Table 6: Observed Protective Equipment Use, Adolescent Pesticide Applicators in Egypt

| Variable | Level | 2016 | 2017 |
|----------|-------|------|------|
|          |       | n    | %    | n    | %    | Parametric P-value<sup>a</sup> |
| Mixing   |       |      |      |      |      |                                |
| Goggles/glasses | Yes | 10  | 14.1 | 31  | 43.7 | <.001                           |
| Gloves   | Yes  | 0   | 0.0  | 1   | 1.4  | NA                              |
| Long sleeves | Yes | 11  | 15.5 | 3   | 4.2  | 0.020                           |
| Pants    | Yes  | 66  | 93.0 | 71  | 100.0 | NA                              |
| Shoes    | Yes  | 25  | 35.2 | 2   | 2.8  | <.001                           |
| Mask     | Yes  | 15  | 21.1 | 51  | 71.8 | <.001                           |
| Spraying |       |      |      |      |      |                                |
| Goggles/glasses | Yes | 10  | 14.1 | 33  | 46.5 | <.001                           |
| Gloves   | Yes  | 0   | 0.0  | 1   | 1.4  | NA                              |
| Hat      | Yes  | 20  | 28.2 | 67  | 94.4 | <.001                           |
| Shoes    | Yes  | 21  | 29.6 | 7   | 9.9  | 0.004                           |
| Mask     | Yes  | 15  | 21.1 | 52  | 73.2 | <.001                           |

Note: NA, Not Applicable: McNemar test not calculated when a level has zero participants

<sup>a</sup>The parametric p-value is calculated by McNemar test

Discussion
Adolescent and young adult pesticide applicators’ attitudes about the health risk from the use of pesticides and their ability to control this risk were investigated. We demonstrated that a theoretically-based educational intervention can impact these attitudes. Using RBD quadrants (30, 31), we found an immediate increase in the number of individuals who would be classified as responsive or high-threat-high efficacy. These individuals are the most motivated to take the necessary precautions to reduce their exposure. The effect was not sustained except for those originally identified as proactive (low threat-high efficacy). The intervention was most effective at increasing proactive individual’s knowledge of the threat. The RBD Scale allows for the tailoring of risk communication to an individual’s perception of the risk (23). We demonstrate that a sustained change in an individual perception of risk is possible for those who initially have a proactive view of that risk. Proactive individuals are motivated by remaining disease free rather than the perception that the exposure will adversely impact their health (31). For those in other quadrants of the RBD Scale an immediate change to responsive behavior was possible for adolescent and young adult’s view of pesticide application risk. Responsive individuals are aware of risk posed by pesticide use and are confident in their ability to reduce exposure. Therefore, responsive individuals are expected to be the most likely group to take the action necessary to reduce their exposure (31). The ability to move individuals into the responsive category suggests interventions can be effective across RBD quadrants if provided after the educational component. This strategy of using education to move an individual to responsive behavior may have applications to other risk settings and should be evaluated further.

While not the most effective method for controlling exposure, PPE use is often recommended when working with pesticides. However, only a single individual was observed wearing gloves for spraying or mixing pesticides during the 2017 observational checklist. Additionally, fewer individuals believed they could be exposed with their bare hands while mixing pesticides when comparing the 8-month survey to the initial intervention survey. This suggests a reduced perception in the exposure potential from mixing pesticides without gloves. Despite this decrease, the vast majority of applicators still believed there was a potential for exposure from this activity, but almost all adolescents observed
were not wearing gloves. No adolescents were observed using their bare hands to mix pesticides directly and instead used a stick for mixing. Despite no observed use of hands, nearly a quarter of individuals did not agree that mixing pesticides with hands could cause sickness (Q9). Because mixing with a stick reduces direct contact with the pesticide, those mixing the pesticide may believe gloves were unnecessary. Exposure through the hands remains a significant route of exposure and should be the focus of future efforts to reduce pesticide exposure in similar populations (34). Previous research with adult applicators in this region has identified dermal exposure as the primary route of exposure.

Chlorpyrifos exposure was measured for Egyptian cotton field workers (n=12) using 24-hour urine. Dermal load was calculated by the difference in total dose and inhalation dose via workplace air samples. Dermal exposure accounted for 94-96% of the exposure (35).

The greatest sustained benefit of the intervention was in attitudes towards personal hygiene practices during or after the application of pesticides. Poor personal hygiene in bathing or washing clothes can increase an individual’s pesticide exposure (7, 8). Adolescents are also more likely to exhibit poor workplace safety habits increasing the likelihood of exposure. Based on a cross-sectional study of 87 North Carolina youth age 10-17, youths reported not practicing proper safety behavior. In the study, poor perceptions of workplace safety were related to hygiene behaviors that could increase pesticide exposure (9). Additionally, education has been previously associated with safer activity around pesticide application. In a study of 335 Egyptian farmers, farmers with school education were more likely to report pesticides have a negative effect on health and wash after pesticide application when compared to farmers with no school education (36). We provide new evidence that adolescent pesticide applicators are particularly susceptible to change their perceptions regarding personal hygiene after receiving an educational intervention and that this change can be sustained over time.

Limitations

Using the RBD scale we were able to identify shifts in risk behaviors after an educational intervention. The application of the scale is limited by the individual measures. We found attitudes around entering a field recently sprayed to be a poor measure of perceived threat and had to remove this question from our classification of threat of pesticide use. More precision in this question may have allowed for
inclusion in the final scale and would have more accurately separated individuals into quadrants. Instead we relied on beliefs around mixing with a stick and hygiene to classify threat beliefs. The longitudinal nature of the study resulted in some loss to follow up. We did not find any differences in RBD scale classification, hours worked, or age when comparing those with complete information to those only available for the first intervention. Therefore, we believe loss to follow up did not bias our results.

Strengths

The development of the intervention began with observations of work practices and surveys of adolescents to identify specific behaviors associated with exposure. This information was presented to stakeholders (MOA, parents, adolescents) and feedback sought to develop a feasible intervention. The intervention considers the individual circumstance impacting exposure control. Cost can be a barrier to the adoption of protection measures. PPE, which needs to be maintained and regularly replaced, also has a cost associated with its use. Educational interventions are low cost and can be easily tailored to the workplace. However, data presented here shows the need for regularly training - since results did not last into the 8-month period. Regular training and targeted behavior change can improve an individual’s approach to protecting their health.

Conclusions

This study used a theoretical model to develop an educational intervention to reduce occupational pesticide exposure among adolescents. The intervention incorporated the EPPM to target individual behavior change on hygiene practices and behaviors that adolescents can control. While there are other methods of controlling exposure higher on the exposure control hierarchy (elimination, substitution, engineering controls) (21), these were beyond the direct control of the adolescent applicators. Policies and workplace programs may also be effective in controlling exposure but rely on buy in from other stakeholders. This intervention, administered on a regular basis, is a low-cost solution that can be applied in other low and middle income countries to reduce adolescent pesticide exposure.

Abbreviations
ADHD: Attention-Deficit/Hyperactivity Disorder; EPPM: Extended Parallel Process Model; MOA: Ministry of Agriculture; PPE: Personal protective equipment; RBD: Risk Behavior Diagnosis

**Declarations**

*Ethics approval and consent to participate*

Consent of human subjects was obtained from participants and written informed consent was obtained from a parent or guardian for participants under the age of 16. Procedures were approved by the University of Iowa Institutional Review Board and the Medical Ethics Committee at Menoufia University.

*Consent for publication*

Not applicable

*Availability of data and materials*

The datasets analyzed during the current study are available from the corresponding author on reasonable request. To gain access, data requestors will need to sign a data access agreement.

*Competing interests*

The authors declare that they have no competing interests.

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*Authors’ Contributions*

DR, AI, GAR, OH, JO, and MB were involved in the conceptualization and planning the study. DR, AI, GAR, OH, JO, and MB collected the original data and provided support in data management. JD and DR analyzed the data and prepared the first draft of the manuscript. All authors read, critically revised, and approved the final manuscript.

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