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Lifetime and Current Pesticide Exposure among Latino Farmworkers in Comparison to Other Latino Immigrants

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Abstract

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Background—Pesticide exposure poses a health risk for farmworkers. This analysis documents lifetime and current pesticide exposure of North Carolina Latino migrant farmworkers, with comparison to non-farmworker Latino immigrants.

Methods—During May–October 2012, 235 Latino farmworkers and 212 Latino non-farmworkers completed interviews with items to construct measures of lifetime, current residential and occupational pesticide exposure.

Results—Farmworkers experience levels of lifetime and residential pesticide exposure that are consistently greater than among non-farmworkers. Farmworkers report a large number of occupational pesticide exposures. Lifetime exposure and current residential pesticide exposure are related to social determinants. Education is inversely related to lifetime pesticide exposure for farmworkers and non-farmworkers; farmworkers with H-2A visas report greater residential pesticide exposure than those without H-2A visas.

Conclusions—Occupational safety policy needs to consider these patterns of lifetime exposure when setting standards. Health care providers should be aware of the lifetime and current exposure of this vulnerable population.

Introduction

Migrant and seasonal farmworkers in the US are consistently exposed to pesticides at work. For example, Arcury and colleagues [2009a, 2009b, 2010] examined pesticide urinary metabolites among farmworkers in North Carolina from samples collected in 2007 and reported that farmworkers are commonly exposed to many different pesticides, including organophosphorous (OP), carbamate and pyrethroid insecticides, and several herbicides. They reported that: (1) farmworkers are exposed to different pesticides at different points in the agricultural season; (2) each individual farmworker is exposed to many different pesticides during an agricultural season, and (3) each individual farmworker experiences repeated exposure to specific pesticides several times during the agricultural season. Farmworkers and their families are also consistently exposed to pesticides in the places where they live [Quandt et al., 2004; Arcury et al. 2013; Bradman et al., 2011; Coronado et al., 2004, 2010; Harnly et al., 2009; Huen et al., 2012; McCauley et al., 2006; Quirós-Alcalá et al., 2011]. For example, Quandt et al. [2004] found that among 41 farmworker family dwellings in North Carolina, 20 dwellings had at least one agricultural pesticide detected and 39 had at least one household pesticide detected, with as many as 8 different pesticides detected in a dwelling. Quirós-Alcalá et al. [2011] found 7 organophosphorous, 9 pyrethroid and 3 other pesticides in the homes of 15 farmworkers in California. Arcury and colleagues [2013] reported the presence of 11 different OP and 14 different pyrethroid pesticides in North Carolina migrant farmworker houses in samples tested for 14 OP and 16 pyrethroid pesticides.

Exposure to pesticides increases the risk of immediate and long-term health consequences. The Agricultural Health Study [Alavanja et al., 1996; Tarone et al., 1997] (http://aghealth.nci.nih.gov/publications.html) has been able to document the degree of pesticide exposure across the lives of over 89,000 farmers who are licensed pesticide applicators in Iowa and North Carolina. Extensive analyses of Agricultural Health Study data has linked lifetime pesticide exposure to increased risk for cancer, neurological conditions, respiratory, and reproductive problems among farmers and their spouses. No such large scale study has investigated the associations of pesticide exposure and health for the more vulnerable population of hired farmworkers, although, in any year, over 1 million hired farmworkers labor across the US, with over 100,000 working in North Carolina alone [Kandel, 2008]. The documented health effects of pesticide exposure in the farmworker population are limited. Zahm and Blair [1997, 2001] led an effort to conduct life history research with farmworkers to document their lifetime exposure to pesticides; but this goal was not achieved. Quandt and colleagues [2010] report cholinesterase depression among adult farmworkers is associated with OP exposure. Bouchard and colleagues [2011] show effects of prenatal pesticide exposure on child cognitive (IQ) development.

Documenting the level of lifetime pesticide exposure experienced by farmworkers is necessary for determining the potential chronic health effects of this exposure. This analysis has two aims. The first aim is to document lifetime and current pesticide exposure of Latino migrant farmworkers in North Carolina based on life-history interviews. Farmworker lifetime pesticide exposure and current pesticide exposure are compared to that of non-farmworker Latino immigrants who have not been employed in occupations in which pesticide exposure is a regular occurrence. The second aim is to examine differences in farmworker lifetime and current pesticide exposure in terms of personal characteristics.

Methods

This analysis uses data collected by the PACE4 project (R01 ES008739) in 2012. PACE4 is based on a community-based participatory research approach with Latino communities to examine the cognitive and neurological outcomes of pesticide exposure. PACE4 compares Latino farmworkers with Latino non-farmworkers using a longitudinal design in which participants completed a baseline interview and four follow-up contacts. PACE4 examines the associations of lifetime and current pesticide exposure with subclinical neurological outcomes. This comparison provides the opportunity to document whether farmworkers differ from other Latino communities in pesticide exposure. The primary community partners for the projects are the North Carolina Farmworkers Project (Benson, NC) and El Buen Pastor Latino Community Services (Winston-Salem, NC). PACE4 was reviewed and approved by the Wake Forest School of Medicine Institutional Review Board. All participants gave signed informed consent.

Locales

Participants were recruited in two areas of North Carolina (Figure 1). Latino farmworkers were recruited in counties surrounding the town of Benson, the location of the North Carolina Farmworkers Project, in the east central region of the state. These counties include Harnett, Johnston, and Sampson. Latino non-farmworkers were recruited from Forsyth County in the west central region of the state. Agriculture is practiced in both locales, but it is far more extensive in the east central region.

Sample

Participants for PACE4 were men aged 30 to 70 years. All participants self-identified as Latino or Hispanic and almost all spoke Spanish as their primary language. Male farmworkers recruited to PACE4 had to be currently employed as farmworkers and to have worked in agriculture for at least three years. Male non-farmworkers could not have been employed for the past 3 years in jobs that expose workers to pesticides, including farm work, forestry, landscaping, grounds keeping, lawn maintenance, and pest control. Potential farmworker and non-farmworker participants were excluded if they reported being told by a healthcare professional that they had diabetes.

Recruitment was accomplished with the assistance of community partners. NC Farmworkers Project staff approached the farmworker camps that they served. They explained the project to the residents of each camp, including the inclusion and exclusion criteria, time commitments and incentives, and asked for volunteers. Volunteers were screened to ensure that they met the inclusion criteria. Winston-Salem staff worked with El Buen Pastor Latino Community Services and other community organizations to identify potential participants. Potential participants were then contacted by project staff. Project staff explained the project, including the inclusion and exclusion criteria, time commitments and incentives, and asked if the individual wanted to volunteer. Volunteers were screened to ensure that they met the inclusion criteria.

The number of participants who completed the baseline interview and the subsequent contacts varied between the farmworkers and non-farmworkers (Table I). A total of 235 farmworkers and 212 non-farmworkers completed the baseline interviews, with 210 farmworkers and 163 non-farmworkers completing the first follow-up contact, and 138 farmworkers and 117 non-farmworkers completing the fourth follow-up contact. As groups of farmworkers were asked to volunteer, only the number who agreed to volunteer is available (the denominator is not known); generally, all of the farmworkers in a camp who met the inclusion criteria volunteered. However, individual farmworkers who did not want to participate could have avoided contact with the project staff or may have indicated that they did not meet the inclusion criteria to avoid refusal. Among the non-farmworkers, 101 individuals were contacted who did not meet the inclusion criteria. Of those contacted and meeting the inclusion criteria, 87 individuals refused to participate for a participation rate of 70.9% (212/(87+212)). Reasons given for refusing included the time commitment and length of the study (51), blood draws (27), need to come to a clinic for data collection (31), and providing contact information (30) (individuals could give more than one reason for refusing).

Data Collection

Farmworker participants completed data collection from May through September, and non-farmworkers completed data collection from June through October. Participants completed up to five questionnaires, one each for the baseline interview and the four follow-up contacts. The baseline questionnaire contained items used to construct the measures of lifetime pesticide exposure for all participants; it also included items to construct personal characteristic measures. Questionnaires for each of the four follow-up contacts contained items to construct measures of recent residential exposure for all participants and recent occupational exposure for farmworker participants. Each of the questionnaires was developed in English and translated into Spanish. When possible, existing Spanish items and scales were used. The Spanish and English versions were checked for comparable meaning for each item, and item wording was adjusted as needed. The Spanish versions of the questionnaires were each pre-tested with several native Spanish speakers, and final corrections were made. Study data were collected and managed using Research Electronic Data Capture (REDCap) electronic data capture tools hosted at Wake Forest School of Medicine [Harris et al., 2009]. REDCap is a secure, web-based application designed to support data capture for research studies.

Interviewers included native Spanish speakers who completed training that addressed questionnaire content and proper technique for conducting interviews. Baseline interviews with farmworkers were conducted in their camps, and baseline interviews with non-farmworkers were conducted in their homes or in a neutral site, such as a church. Interviews for the first and last follow-up contacts for farmworkers and non-farmworkers were conducted in a clinic setting in which additional data collection activities were completed. Interviews for the second and third follow-up contacts for farmworkers and non-farmworkers were conducted in their camps and in a clinic setting, respectively, with additional data collection activities being completed.

Measures

Measures were constructed to indicate lifetime pesticide exposure among all participants, recent residential pesticide exposure among all participants, and recent occupational pesticide exposure among farmworker participants. Measures indicating participant personal characteristics were also constructed.

Measures of lifetime pesticide exposure are based on items selected from the National Institute of Neurological Disorders and Stroke (NINDS) Common Data Elements (http://www.commondataelements.ninds.nih.gov/PD.aspx#tab=Data_Standards) [Grinnon et al., 2012]. In the baseline interview, participants provided information about residential and occupational pesticide exposure for up to 7 age periods (0 to 17 years, 18 to 25 years, 26 to 35 years, 36 to 45 years, 46 to 55 years, 56 to 65 years, 66 years or older) (Table II). Two sets of measures were based on this information. First, for each age period, the residential and occupational pesticide exposure items (Table II, items a through m) were summed, providing a measure with the values 0 to 13 for each age period. Second, four summary measures were constructed. Lifetime Exposure was the sum of age period specific exposures, without accounting for age, and had the values 0 to 91. Index of Exposure Sources was lifetime exposure divided by age. Exposure Years was the sum of total years individuals reported that they had jobs in which they mixed, applied, or were exposed in some other way to pesticides (Table II, item n) summed across age periods, without accounting for age. Index of Exposure Years was exposure years divided by age. These measures were calculated for farmworker and non-farmworker participants.

Current residential exposure events were based on a set of questions asked at the four follow-up contacts with each participant. At each of the four data points, participants were asked if, during the past week: (1) their residence was located within one-half mile or less of an agricultural field on which pesticides had been sprayed; (2) pesticides had been sprayed in their residence; and (3) pesticides had been sprayed in their yard. Responses were summed, and values for this measure could range from 0 to 3 at each time point. The measure was calculated for farmworker and non-farmworker participants. Average Total Current Residential Exposure was calculated for each participant by summing scores across the contacts and dividing by the number of contacts.

Current occupational exposure events were based on a set of questions asked at the four follow-up contacts with farmworker participants; they were asked whether in the last 3 days they had (1) done any farm work; (2) mixed, loaded or applied any pesticide (including growth regulators); (3) worked in an area within view of a field where pesticides or fertilizers were being applied; (4) worked in an area where pesticides had been applied in the previous 7 days; (5) washed their hands with soap at least once per day (reverse coded); and (6) showered immediately after work (reverse coded). Responses were summed for each contact and values could range from 0 to 6. Average Total Current Occupational Exposure was calculated for each participant by summing scores across contacts and dividing by the number of contacts. These measures were calculated only for farmworker participants.

Participant characteristics included age (30 to 34, 35 to 44, 45 and older), marital status (not married, currently married or living as married), education (0 to 6 years, 7 to 11 years, 12 years or more), country of birth (Mexico; Other), having an H-2A or H-2B visa; dominant language (Spanish, Other), and occupation (farm work, construction, manufacturing, food preparation/restaurant, maintenance/cleaning, sales, transportation/truck driver, mechanic, other, unemployed).

Analysis

Descriptive statistics (counts, percentages) were calculated for participant characteristics of interest, and chi-square tests or Fisher's Exact Tests as appropriate were performed to test the difference between farmworkers and non-farmworkers across the sample characteristics. The distribution of the lifetime exposure measures (within age periods and summary measures) were derived (mean, standard deviation, minimum, maximum), and non-parametric Wilcoxon rank-sum tests were used to test the difference between farmworkers and non-farmworkers within each lifetime exposure measure. Next, non-parametric tests were used to examine the association between each of the four lifetime exposure summary measures (lifetime exposure, index of exposure sources, exposure years, and index of exposure years) and educational attainment within farmworkers and non-farmworker groups. Furthermore, we examined the association of H-2A visa status (for farmworkers), country of birth and occupation (for non-farmworkers) against each of the four lifetime exposure summary measures using non-parametric tests for association. For both residential and occupational exposures the counts and percentages of the number of exposures as well as the average number of exposures for both farmworkers and non-farmworkers are reported at each contact. Total current residential and occupational exposures were described using counts and percentages falling into exposure event categories as well as the average across exposure event categories. Finally, for both residential and occupational exposures, non-parametric tests were used to examine the association between the average number of exposures at each contact and total with age and education (for both farmworkers and non-farmworkers), H-2A status (for farmworkers only), and occupation and country of birth (for non-farmworkers). All analyses were performed using SAS 9.3 (SAS Institute, Cary, NC), and p values <0.05 were considered statistically significant.

Results

Personal Characteristics

The farmworkers and non-farmworkers differed significantly across personal characteristics (Table III). Farmworkers were younger, and more farmworkers were married than were non-farmworkers. Farmworkers had lower education attainment. All of the farmworkers were from Mexico; 70.3% of non-farmworkers were from Mexico. Most farmworkers and non-farmworkers reported Spanish to be their dominant language. The predominant occupations of non-farmworkers were in construction and manufacturing; 6.6% of non-farmworkers were unemployed.

Lifetime Pesticide Exposure

Farmworkers reported significantly greater age period specific pesticide exposure (excluding age 66 years and older due to small sample size), as well as lifetime pesticide exposure, exposure sources, exposure years, and index of exposure years than non-farmworkers ($p < 0.001$ for all) (Table IV). Differences between farmworkers and non-farmworkers in the number of exposures increased with age group. The number of exposures reported by farmworkers increased with age, while the number of exposures reported by non-farmworkers decreased with age.

Indicators of lifetime pesticide exposure differed by education for farmworkers and non-farmworkers, with those having more education having less lifetime exposure (Table V). Among farmworkers, those with H-2A visas had fewer exposure years and a lower index of exposure years. Lifetime exposure varied among non-farmworkers by country of birth, with those born in Mexico having greater lifetime exposure, although only the Index of Exposure Sources attained statistical significance. Lifetime exposure did not vary by occupation among non-farmworkers; data not shown.

Current Pesticide Exposure

Farmworkers reported more residential pesticide exposure events in the previous week than did non-farmworkers (Tables VI and VII). All but a few of the farmworkers reported at least one residential pesticide exposure in the previous week, with the mean number of residential pesticide exposure events reported being between 1.11 (SD=0.51) (at the beginning of the agricultural season) to 1.35 (SD=0.69) (in the middle of the agricultural season). A major component of the farmworker residential pesticide exposure is the location of their homes near agricultural fields. Three-quarters or more of non-farmworkers reported no residential pesticide exposure in the previous week at each of the 4 interviews.

The average number of recent residential pesticide exposure events did not vary by age or education (farmworkers and non-farmworkers), or by country of birth and occupation (non-farmworkers). Recent residential pesticide exposure events did vary among farmworkers by visa status. Those with H-2A visas had a significantly higher average number of recent residential pesticide exposure events at Contact 1 (1.14 (SD=0.51) versus 0.70 (SD=0.48) (p = 0.0049) and Contact 3 (1.17 (SD=0.54) versus 0.71 (SD=0.49) p = 0.0239), as well as Total (1.20 (SD=0.42) versus 0.77(SD=0.55), p = 0.0209).

Farmworker recent occupational exposure events indicate that they experienced multiple pesticide exposure events in the past 3 days (Tables VIII and IX). At the first contact, 3.81% of the farmworkers reported no exposure events, and, at the second contact, 6.1% of the farmworkers reported no exposure events; only one farmworker at Contact 3 and no farmworkers at Contact 4 reported no exposure events. The mean number of reported exposures grew from 2.01 (SD=1.16) at the first contact in June, to 2.52(SD=1.21) at the second contact in July, and then declined to the 2.42 (SD=1.17) at the third contact in August, and to 1.78 (SD=1.00) at the fourth contact in September. Recent occupational exposure was not associated with age or visa status. However, recent pesticide exposure did vary by education at Contact 1, Contact 3, and Total. Those with 7 to 11 years of education, versus those with 0 to 6 or 12 or more years of education, had more exposure events on average at Contact 1 (2.27 (SD=1.19) versus 1.75 (SD=1.08) and 1.89 (SD=1.13), respectively; p = 0.0071), Contact 3 (2.66 (SD=1.19) versus 2.22 (SD=1.10) and 2.07 (SD=1.22), respectively; p = 0.0239), and Total (2.31 (SD=0.81) versus 1.94 (SD=0.76) and 2.06 (SD=0.85), respectively; p = 0.0061).

Discussion

Latino immigrants experience pesticide exposure across their lives. That these immigrants live in situations in which they are exposed to pesticides is not surprising. Analyses consistently indicate that pesticide exposure is ubiquitous among Latinos in their communities of origin [Domínguez-Cortinas et al., 2013; Meza-Montenegro et al., 2013; Payán-Rentería et al., 2012; Sánchez-Guerra et al., 2011], as well as in their US communities, whether the US communities are agricultural or urban [Arcury et al. 2009a, 2009b, 2010; Coronado et al. 2011 Fenske et al. 2013; Lu et al. 2013; Julien et al. 2007; McConnell et al. 2005; Quirós-Alcalá et al. 2011].

Four different measures of lifetime pesticide exposure are presented in this analysis; each provides a different perspective on individual potential pesticide exposure and for comparing pesticide exposure across different populations. Lifetime Exposure is a measure of total exposure events, with the Index of Exposure Sources adjusting the number of exposures for the individual’s age. These measures are based on questions asking about discreet experiences for each age category the individual has completed. They are measures of potential exposure, as the individual participant may not know that each item in the list reflects a source of potential pesticide exposure. For example, items address the actual use of pesticides in a participant’s home, as well as location of residence near farm fields and work experience. Exposure Years is a measure of the total number of years a participant reports working with pesticides, with the Index of Exposure Years adjusting the number of years of exposure for the individual's age. Again, the number of years of exposure is asked in terms of specific age categories. This is an **actual** measure of exposure, as the participant is clear that he or she is being asked about work with pesticides. The measures not adjusted for age provide an absolute indicator of potential exposure, with those adjusted for age providing a relative indicator of potential exposure. For example, two individuals may have the same value for Exposure Years (the same absolute number of years working with pesticides), but the older individual will have a smaller Index of Exposure Years because his age provides a larger denominator in calculating the index. The Lifetime Exposure measures provide a better indicator of the larger context in which an individual could be exposed to pesticides, with the Exposure Years measures providing a better indicator of the occupational context in which individuals know they were exposed to pesticides.

This analysis documents the high degree of potential pesticide exposure of Latino immigrants, and that this exposure is consistently greater among Latinos who are employed as farmworkers compared to those employed in other occupations. Latino farmworkers reported a greater number of lifetime exposures, and they reported a greater number of current residential exposures than Latino non-farmworkers. Latino farmworkers also reported a large number of current occupational pesticide exposures. Care should be taken in using this measure of current occupational pesticide exposure; for one of the six elements, the participants may have actually seen fertilizer rather than pesticide being applied.

Latino immigrant workers and the members of their families in the US are a vulnerable population. Pesticide exposure among these immigrants, particularly among those who are farmworkers, raises concerns for environmental justice and health equity [Arcury & Quandt, 2003, 2011; Arcury et al., 2002; Quandt et al., 2006]. This exposure is socially determined and reveals explicit social gradients [Marmot, 2005] across occupation and education. Farmworkers had more lifetime exposure than non-farmworkers. This is expected, in part, as farmworkers work around pesticides and non-farmworkers who work around pesticides were excluded from participation. However, farmworkers had more exposure even for the 0 to 17 age period. Further, non-farmworkers were not excluded if they were employed in a pesticide-related occupation more than three years before recruitment to the study. Finally, farmworker exposure increased with age, while the exposure of non-farmworkers decreased with age. Farmworkers also had more current residential exposure than non-farmworkers, thus increasing the relative health risks for farmworkers. Environmental measures of specific residential exposure for Latino farmworkers and non-farmworkers, as well as other vulnerable populations, are available [Arcury et al., 2013; Lu et al., 2013; Quandt et al., 2004; Quirós-Alcalá et al., 2011].

Education was inversely related to lifetime pesticide exposure among farmworkers and non-farmworkers, indicating that, even among this generally vulnerable population, variation in social position affects risk [Marmot, 2003]. Recent residential exposure events were not associated with education for farmworkers or non-farmworkers. Occupational exposure events among farmworkers were not directly related to education, those with 7 to 11 years of education report more exposure events than those with less education (0 to 6 years) and more education (12 or more years). This association requires further investigation.

Farmworkers with H-2A visas had less lifetime exposure than workers without H-2A visas, but greater recent residential exposure. The H-2A visa program has been criticized for its potential abuses due to the control and intimidation exerted over these workers [Bauer, 2007]. However, employers of farmworkers with H-2A visas experience greater regulatory scrutiny than do other agricultural employers. Peer-reviewed analyses document that the occupational safety and living conditions of farmworkers with H-2A visas are consistently better than the conditions experienced by other farmworkers [Arcury et al., 1999; Robinson et al., 2011; Whalley et al., 2009; Vallejos et al., 2011]. The houses in which workers with H-2A visas live are more often inspected [Arcury et al., 2012a, 2012b] than the houses of other workers, with greater potential for pesticide application to reduce the presence of insects. The multiple recent occupational exposure events across the season among farmworkers are consistent with the levels of pesticide urinary metabolites documented for farmworkers [Arcury et al., 2010]. We would expect research in which few farmworkers have H-2A visas to show greater levels of lifetime and current pesticide exposure events.

Individuals are seldom exposed to only one toxicant. The lifetime pesticide exposure of these immigrants alone raises concern of the long-term health effects of this exposure; as the Agricultural Health Study has shown for American pesticide applicators, long-term exposure to pesticides can have substantial health affects in terms of cancer, neurological disease, respiratory disease, and mental health [Beard et al., 2013; Hoppin et al., 2002; Kamel et al., 2012; Koutros et al. 2013]. Other investigations also document the long-term negative health effects of pesticide exposure [e.g., Band et al., 2011; Hancock et al., 2008; Charles et al., 2010]. However, the pesticide exposure experienced by Latino migrants must be viewed in the context of exposure to other environmental toxicants that can have additive or multiplicative effects. The home communities of Latino migrants expose them to mixtures of toxicants that include metals like lead and arsenic, as well as poorly regulated pesticides [Domínguez-Cortinas et al., 2013; Meza-Montenegro et al., 2013]. Quandt and colleagues [2010b] report that Latino farmworkers in North Carolina have high levels of lead and arsenic relative to reference data from the 2003–2004 National Health and Nutrition Examination Survey (NHANES). The potential health effects of pesticide exposure for Latino farmworkers must be understood in the context of these other exposures [Uversky et al. 2002; Charles et al., 2010]. For example, many pesticides are neurotoxins, as are lead and arsenic. The implications of the combined effects of these groups of toxicants must be considered in occupational safety policy and procedures for pesticide safety, such as the US Environmental Protection Agency [1992] Worker Protection Standard.

This analysis should be interpreted in light of its limitations. The participants were limited to men aged 30 to 70, and the participants were not randomly selected. These factors limit the generalizability of the results. Younger men and women, and Latino immigrants living in other regions may have different experiences with pesticide exposure. Data on lifetime exposure are retrospective, so differences in recall ability could influence information that is reported. The greater occupational familiarity of farmworkers with pesticides might make them more cognizant of pesticide use. Finally, the self-reported data used for each of the measures cannot provide information on the specific pesticides to which they were exposed, on whether the participants actually experienced a dose of any pesticide to which they were exposed, or the size of any dose that they may have experienced.

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This study is limited to self-reported information, and does not include actual measurement of exposure. In this way it is similar to the Agricultural Health Study, which relied solely on recall. It cannot be exhaustive of all the potential exposures as the list of potential exposures would be extremely long; for example, although the questionnaire used in this study does include questions on the presence of animals, it does not include the use of pesticides to treat pets. The limited number of questions was selected to include major events for which participants' memories would have the greatest reliability.

Nevertheless, this study is unique. It provides the first documentation of the lifetime and current pesticide exposure of farmworkers and other Latino immigrants, reflecting efforts that others suggested over a decade ago [Zahm & Blair, 2001; Zahm et al., 1997]. In particular Engel and Colt [Engel et al., 2001; Colt et al., 2001] used a life-time calendar to document the lifetime pesticide exposure of Latino farmworkers. However, although the method they developed appeared to be reliable and valid, the calendar method they used is cumbersome, it was applied to small samples (89 farmworkers and non-farmworkers), and it has not been replicated in other studies. Future analysis of biological data collected by the PACE4 study will allow comparison of self-reported current pesticide exposure with biomarkers of exposure, including cholinesterase depression and the detection of a limited set of OP, carbamate and pyrethroid pesticide urinary metabolites. The self-reported lifetime and current pesticide exposure measure will be compared to PACE4 outcome measures, including measures of cognition and olfactory function.

Farmworkers experience substantial pesticide exposure across their lives, even in comparison to other Latino immigrants. This may reflect the rural and agricultural context from which many farmworkers come, as well as their current work. That many of the farmworker participants in this analysis have H-2A visas indicates that they return to their home communities (generally in Mexico) each year. They are potentially exposed to pesticides in Mexico, such as organochlorine insecticides [Domínguez-Cortinas et al. 2013], which are no longer used in the US. Occupational safety policy and procedures need to consider these patterns of lifetime exposure when setting standards. Those providing health care to farmworkers should be aware of the lifetime exposure and current sources of exposure of this vulnerable population.

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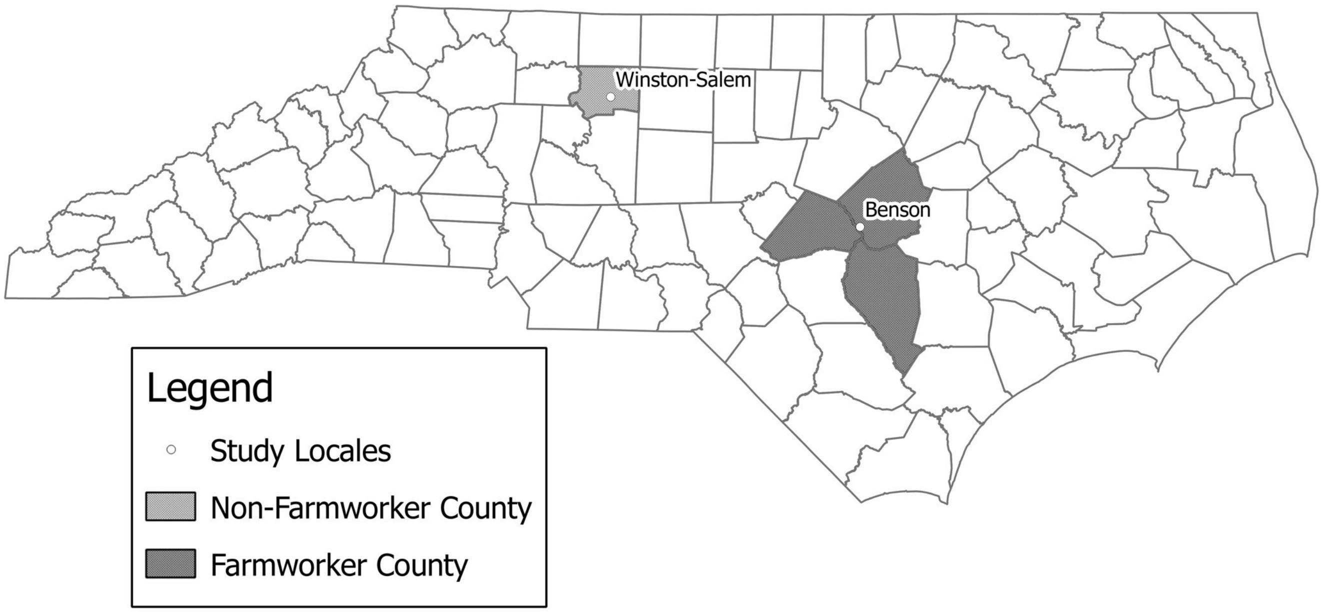

Figure 1.
Map of North Carolina Counties Showing Counties Included in the PACE4 Study

Table I

Number of Farmworker and Non-Farmworker Participants Completing the Baseline Interview and Follow-up Contacts, PACE4, 2012

Contacts	Farmworkers		Non-Farmworkers		Total	
	n	%	n	%	n	%
Number Completing each Contact						
Baseline	235	100.0	212	100.0	447	100.0
Contact 1	210	89.4	163	76.9	373	83.4
Contact 2	171	72.8	101	47.6	272	60.9
Contact 3	165	70.2	46	21.7	211	47.2
Contact 4	138	58.7	117	55.2	255	57.0
Number of Contacts Completed						
Completed all contacts	121	51.5	40	18.9	153	34.2
Completed 4 contacts	40	17.0	52	24.5	91	20.4
Completed 3 contacts	31	13.2	40	18.9	77	17.2
Completed 2 contacts	18	7.7	29	13.7	50	11.2
Completed 1 contact	25	10.6	51	24.0	76	17.0

Table II

Items Included for Age Group and Lifetime Pesticide Exposure Measures

Item Number	Item Name
	Residential Exposure
a	Residence located within ¼ mile of farm fields
b	Insecticides used in home
c	Fungicides used in home
d	Herbicides used in home
	Occupational Exposure
e	Job mixed or applied pesticides
f	Work in farming
	Work in
g	Other agricultural applications
h	Forestry
i	Landscaping
j	Nursery
f	Pest control
l	Building maintenance
m	Other job with exposure to pesticides
n	Total years you had jobs in which you mixed, applied, or were exposed in some other way to pesticides

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Table III

Participant Characteristics PACE4 Project, 2012, n=447.

Participant Characteristics	Farmworkers n=235		Non-farmworkers n=212		p-value
	n	%	n	%	
Age					0.2418
30 to 34 years	86	36.6	65	30.7	
35 to 44 years	87	37.0	77	36.3	
45 years and older	62	26.4	70	33.0	
Married/living as married	221	94.0	150	70.8	<.0001
Education*					<.0001
0 to 6 years	104	44.4	73	34.6	
7 to 11 years	109	46.6	71	33.6	
12 or more years	21	9.0	67	31.8	
Country of Birth – Mexico	235	100.0	149	70.3	<.0001
H-2A or H-2B Visa	218	92.8	0	-	
Dominant Language – Spanish	232	98.7	211	99.5	0.5632
Occupation					
Farm work	235	100.0			
Construction			92	43.4	
Manufacturing			34	16.0	
Food preparation/restaurant			14	6.6	
Maintenance/cleaning			18	8.5	
Sales			14	6.6	
Transportation/Truck driver			9	4.2	
Mechanic			13	6.1	
Other			4	1.9	
Unemployed			14	6.6	

* missing observations

Table IV

Lifetime Pesticide Exposure for Farmworker and Non-Farmworker Participants Completing the Baseline Interview, PACE4, 2012, n = 447.

	All Baseline Interview Participants									
	Farmworkers					Non-Farmworkers				
	N	Mean	SD	Min	Max	N	Mean	SD	Min	Max
Number of Exposures										
Reported for Ages										
0 to 17 years*	235	2.83	1.90	0.00	10.00	212	2.25	1.92	0.00	9.00
18 to 25 years*	235	3.28	1.89	0.00	9.00	212	1.56	1.70	0.00	10.00
26 to 35 years*	235	3.77	1.65	0.00	9.00	211	1.28	1.24	0.00	6.00
36 to 45 years*	139	3.92	1.37	0.00	7.00	141	1.24	1.14	0.00	6.00
46 to 55 years*	55	3.96	1.09	2.00	6.00	57	1.05	1.01	0.00	5.00
56 to 65 years*	10	3.90	1.45	2.00	7.00	16	0.81	1.05	0.00	3.00
66 years or older	1	3.00		3.00	3.00	2	0.50	0.71	0.00	1.00
Lifetime Exposure*	235	13.30	5.49	1.00	33.00	211	6.28	4.17	0.00	28.00
Index of Exposure Sources*	235	0.34	0.13	0.03	0.75	211	0.16	0.10	0.00	0.63
Exposure Years*	235	15.15	8.30	0.00	45.00	211	5.09	6.44	0.00	36.00
Index of Exposure Years*	235	0.38	0.18	0.00	0.77	211	0.12	0.14	0.00	0.67

*Comparisons of farmworkers to non-farmworkers significantly different at $p < 0.001$.

Table V

Lifetime Pesticide Exposure for Farmworker and Non-Farmworker Participants Completing the Baseline Interview by Education and Country of Birth, and Visa Status, PACE4, 2012.

	Lifetime Exposure		Index of Exposure Sources		Exposure Years		Index of Exposure Years	
	Farmworker	Non-farmworker	Farmworker	Non-farmworker	Farmworker	Non-farmworker	Farmworker	Non-farmworker
	Mean (SD)	Mean (SD)	Mean (SD)	Mean (SD)	Mean (SD)	Mean (SD)	Mean (SD)	Mean (SD)
Education								
0 to 6 years	14.70 (5.58)	7.60 (4.27)	0.35 (0.12)	0.18 (0.10)	17.26 (8.82)	7.58 (7.21)	0.41 (0.18)	0.18 (0.14)
7 to 11 years	12.48 (5.29)	5.86 (3.87)	0.34 (0.13)	0.16 (0.11)	13.71 (7.35)	4.83 (6.55)	0.36 (0.17)	0.12 (0.15)
12 or more years	10.95 (4.34)	5.36 (4.06)	0.30 (0.12)	0.13 (0.09)	12.71 (8.21)	2.70 (4.14)	0.34 (0.20)	0.07 (0.10)
p-value	0.0026	0.0017	0.258	0.0013	0.0048	<0.0001	0.0995	<0.0001
H-2A Visa								
Yes	13.17 (5.36)	-	0.34 (0.12)	-	14.72 (8.04)	-	0.37 (0.18)	-
No	15.00 (6.90)	-	0.36 (0.16)	-	20.76 (9.74)	-	0.48 (0.18)	-
p-value	0.2109		0.5423		0.0072		0.0112	
Country of Birth								
Mexico	-	6.55 (4.25)	-	0.16 (0.09)	-	5.44 (6.63)	-	0.13 (0.14)
Other	-	5.67 (3.94)	-	0.14 (0.11)	-	4.27 (5.96)	-	0.10 (0.14)
p-value		0.1991		0.0477		0.1008		0.095

Table VI

ber of Current (in the Past Week) Residential Exposures Events at Each Contact for Farmworkers and non-Farmworkers, 2012.

	Contact 1				Contact 2				Contact 3				Contact 4			
lential Exposure Events	Farmworker N=210		Non-Farmworker N=161		Farmworker N=171		Non-Farmworker N=101		Farmworker N=165		Non-Farmworker N=46		Farmworker N=138		Non-Farmworker N=117	
	n	%	n	%	n	%	N	%	n	%	n	%	n	%	n	%
0	11	5.2	129	80.1	7	4.1	78	77.2	9	5.5	36	78.3	5	3.6	91	77.8
1	170	81.0	24	14.9	111	64.9	20	19.8	127	77.0	9	19.6	112	81.2	20	17.1
2	23	10.9	8	5.0	39	22.8	3	3.0	24	14.6	1	2.2	20	14.5	6	5.1
3	6	2.9	0		14	8.2	0		5	3.0	0		1	0.7	0	
Mean/SD	1.11	0.51	0.25	0.54	1.35	0.69	0.26	0.50	1.15	0.55	0.24	0.48	1.12	0.44	0.27	0.55

Table VII

Average Total Current (in the Past Week) Residential Exposures Events for Farmworkers and non-Farmworkers, 2012.

Residential Exposure Events	Farmworker N=210		Non-Farmworker N=161	
	n	%	n	%
0 to 0.99	12	5.7	144	89.4
1 to 1.99	182	86.7	15	9.3
2 to 2.99	16	7.6	2	1.2
Mean/SD	1.18	0.43	0.25	0.44

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Table VIII

Number of Current (in the Past 3 Days) Occupational Exposure Events at Each Contact for Farmworkers, 2012.

Occupational Exposure Events	Contact 1 N=210		Contact 2 N=164		Contact 3 N=165		Contact 4 N=138	
	n	%	n	%	n	%	n	%
0	8	3.8	10	6.1	1	0.6	0	
1	79	37.6	28	17.1	47	28.5	73	52.9
2	54	25.7	29	17.7	38	23.0	35	25.4
3	47	22.4	65	39.6	43	26.1	18	13.0
4	15	7.1	29	17.7	33	20.0	11	8.0
5	7	3.3	2	1.2	3	1.8	1	0.7
6	0		1	0.6	0		0	
Mean/SD	2.01	1.16	2.52	1.21	2.42	1.17	1.78	1.00

Table IX

Average Total Current (in the Past 3 Days) Occupational Exposure Events for Farmworkers, 2012.

Occupational Exposure Events	n	%
0 to 0.99	3	1.4
1 to 1.99	74	35.2
2 to 2.99	92	43.8
3 to 3.99	36	17.1
4 to 4.99	5	2.4
Mean/SD	2.12	0.81