

## Job Demands and Pesticide Exposure Among Immigrant Latino Farmworkers

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The goal of this study was to understand the potential threat of job stressors to farmworker health. To accomplish this goal we studied pesticide exposure, an issue with immediate and long-term health consequences, and predictions from the Demands-Control model of occupational stress. Longitudinal, self-report data and urine samples were collected at monthly intervals from a cohort of Latino farmworkers ( $N = 287$ ) during the 2007 agricultural season. The primary hypothesis was that greater exposure to psychological demands, physical exertion, and hazardous work conditions are associated with greater odds of detecting dialkylphosphate (DAP) urinary pesticide metabolites, biomarkers indicating exposure to pesticides. Contrary to this hypothesis, results indicated that none of the elements of the Demands-Control model were independently associated with detection of DAP urinary pesticide metabolites. However, analyses produced several interaction effects, including evidence that high levels of control may buffer the effects of physical job demands on detection of DAP urinary pesticide metabolites.

*Keywords:* Demands-Control model, job stress, pesticides, Latinos, farm work

Farmworkers, the vast majority of whom are immigrants from Mexico and Central America, constitute a population at risk for excess morbidity and mortality, including elevated occupational injury and illness (Arcury & Quandt, 2007; Villarejo, 2003).

These health problems arise from and are exacerbated by a variety of physical and psychological stressors inherent in employment in a dangerous industry, social isolation, and discrimination. Although they confront a variety of stressors in their daily lives on the job, few studies of immigrant Latino farmworkers examine the potential effect of stressors on general indicators of physical health (Grzywacz, Quandt, & Arcury, 2008) or specific health threats, such as pesticide exposure. Thus, the role that job stress plays in the health, illness, and subsequent health disparities confronted by the very workers whose toils bring food to the American table remains unknown.

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The goal of this study was to elucidate the potential threat of job stressors to farmworker health. We focus specifically on pesticide exposure, an issue with immediate and long-term health consequences for farmworkers and their families. Informed by Demands-Control theory of occupational stress (Karasek & Theorell, 1990), we differentiated between psychological and physical job demands and hypothesized that (1) greater exposure to psychological demands, heightened physical exertion, and hazardous work conditions are associated with greater

pesticide exposure, as indicated by the presence of urinary dialkylphosphate (DAP) metabolites of organophosphorus (OP) pesticides; and (2) the effects of psychological demands, physical exertion, and hazardous work conditions on detection of DAP urinary metabolites is greater for workers with low levels of control. We also explored the possibility of double-demand and asked if the deleterious effects of physical exertion and hazardous conditions are exacerbated by elevated psychological demands.

## Background

Pesticide exposure is a serious threat to the health of farmworkers and their families. Evidence suggests that pesticide exposure can have dire immediate and long-term health consequences (Bassil et al., 2007; Sanborn et al., 2007). Acute pesticide exposure can result in unconsciousness, coma, and death depending on actual dose, whereas long-term exposure to even modest doses of pesticides has been implicated in asthma (Hoppin et al., 2008), diabetes (Montgomery, Kamel, Saldana, Alavanja, & Sandler, 2008), cancer (Clapp, Jacobs, & Loechler, 2008), and spontaneous abortion (Frazier, 2007). The potential threat of pesticide exposure to farmworker health is further elevated by evidence indicating that most farmworkers have physical evidence of exposure. Thompson and colleagues (2008) reported that 30 to 90% of adults in farmworker families had detectable levels of organophosphate pesticides in their urine. Specifically, in samples collected in 2004, 29.2% of adults had detectable levels of one urinary DAP metabolite, dimethylphosphate (DMP), whereas 92.6 and 55.0% of adults had detectable levels of dimethylthiophosphate (DMTP) and dimethyldithiophosphate (DMDTP), respectively. In the most comprehensive study of farmworker pesticide exposure to date, Arcury and colleagues (2009a) documented that over three quarters (78.2%) of farmworkers had metabolites of 1 or more of 14 distinct pesticides in their urine during the 2007 agricultural season, suggesting virtually ubiquitous exposure to known neurotoxins. Thus, the combination of widespread exposure and wide-ranging health implications suggests that pesticide exposure is a significant health threat confronted by farmworkers.

Identification of the work-related factors contributing to variation in pesticide exposure remains elusive, particularly among farmworkers. In a comprehensive review of the literature Quandt and colleagues (2006) concluded that “. . . the research connecting characteristics of workers’ environments

and behaviors with actual measures of pesticide exposure [among farmworkers] is meager” (p. 950). The weak evidence base results from multiple conspiring factors including the relative inattention given to farmworkers, and the absence of solid measures of pesticide exposure (Quandt et al., 2006). Additionally, pesticide exposure research is undermined by the absence of strong conceptual models for organizing and identifying potential work-related sources of pesticide exposure. Research to date has focused on discrete behaviors in the workplace, such as the use of personal protective equipment (PPE) or frequency of hand washing (Hernandez-Valero, Bondy, Spitz, & Zahm, 2001) or specific aspects of farmworkers’ jobs such as the number of tasks that bring farmworkers in contact with pesticides (Hernandez-Valero et al., 2001). Although potentially useful for informing specific interventions, this variable specific approach does little to develop a comprehensive understanding of how farmworkers become exposed to pesticides. Frequent hand washing and adherence to other advocated safety practices to minimize pesticide exposure such as use of recommended PPE or avoiding fields where pesticides have been recently applied require a work environment that is designed and managed in a way that supports safe work practices. Without considering the broader environmental characteristics underlying worker behavior, policy, or behavioral attempts to minimize pesticide exposure will meet with limited success, and they have the potential of blaming the victim.

## Theoretical Foundation

Occupational stress theories offer a valuable alternative for studying possible determinants of pesticide exposure among farmworkers. Occupational stress theories emphasize general dimensions of work that transcend different types of jobs rather than job-specific attributes or characteristics. The Demands-Control model (Karasek & Theorell, 1990), for example, emphasizes two main concepts: (1) the relative level of psychological and physical demand imposed on workers (emphasizing primarily psychological demand), and (2) the relative level of control or decision making workers have over the selection and execution of work-related tasks. Systematic reviews of the Demands-Control literature indicate that higher levels of control and lower levels of psychological demands are independently associated with better outcomes in a variety of health domains (Belkic, Landsbergis, Schnall, & Baker, 2004; de Lange, Taris, Kompier, Houtman, & Bongers, 2003). The

focus on general dimensions of work is potentially valuable for understanding farmworkers' exposure to pesticides because environmental characteristics such as demands and control likely shape a variety of more specific activities or worker behaviors that reduce pesticide exposure, thereby providing a more systematic understanding of this health threat.

Previous research has not examined the potential effect of job demands and control on pesticide exposure; however, there is good theoretical and empirical reason to believe that these concepts may affect pesticide exposure. Theoretically, Quandt and colleagues (2006) argued that variables reflecting the organization of farm work, specifically workers' level of control over how they perform their work and the level of demands placed on workers by superiors (e.g., farm operators, crew leaders) or environmental conditions (e.g., temperatures, anticipated rain), should be systematically incorporated into studies of pesticide exposure among farmworkers. The primary rationale for including these concepts in their comprehensive model is the idea that workers who have greater control or autonomy in their jobs are more likely to adhere to safe work practices (Parker, Axtell, & Turner, 2001). Moreover, workers who confront production demands from either an unrealistic superior or from environmental conditions, such as forecasts of heavy rain during harvest, are more likely to attend to production demands than to adhere to safety precautions (Hoffmann & Stetzer, 1996; Mearns, Flin, Gordan, & Fleming, 2001) such as using personal protective equipment and frequent hand washing.

Expectations that control and job demands contribute to health-related outcomes like pesticide exposure via behavioral mechanisms has well-developed empirical precedent in nonfarmworker samples. Geller and colleagues (1993), for example, reported that workers with greater sense of control were more likely to engage in "actively caring" behaviors, or those that promote group adherence to established safety precautions. Similarly, Parker and colleagues (2001) showed that greater job autonomy was associated with greater safety compliance and conscientiousness. Research conducted primarily with offshore platform workers consistently documents that job-related demands, particularly production demands, encourage workers to eschew safety behaviors (Hoffmann & Stetzer, 1996; Mearns et al., 2001). Other research with nonfarmworker samples also shows that higher levels of control and lower demands are associated with greater adherence to ad-

vocated workplace safety practices (e.g., Turner, Chmiel, & Walls, 2005).

However, there is little data connecting job demands and control with health or behavioral outcomes among Latino farmworkers. Physical demands of work like the frequency in which work required heavy physical exertion and the extent to which it required maintaining awkward postures for extended periods were have been associated with poorer physical health-related quality of life, particularly for those with low levels of control over their work (Grzywacz, Quandt, & Arcury, 2008). Notably, the psychological demand of work was unassociated with either physical or mental health-related quality of life, suggesting that physical job demands may have greater relevance for worker health than psychological demands among those in labor intensive and dangerous occupations like farm work. Workers' perception of control in the workplace has been associated with greater adherence to advocated pesticide safety behavior in qualitative research with farmworkers (Austin et al., 2001). Others have not measured demand or control, but make reference to these concepts in describing workers' safety behavior. Thu (1998), for example, suggests that the narrow temporal window for growing and harvesting, long work hours in isolated work conditions, and the psychological stress associated with farm work can push farmworkers to minimize safety standards. Similarly, others have argued that the psychological and physical demands confronted by day-laborers, including farmworkers, directly promote accidents and injuries through fatigue and distraction (Kidd, Scharf, & Veazie, 1996; Walter, Bourgois, Margarita Loinaz, & Schillinger, 2002).

### The Present Study

The goal of this study was to develop a better understanding of pesticide exposure among immigrant Latino farmworkers. To accomplish this goal we use concepts and key propositions from the Demands-Control model of occupational stress to predict exposure to OP pesticides, assessed with lab analyses of urine samples. The primary rationale underlying the use of an occupational stress theory is that concepts like "control" and "demands" capture social attributes of the work environment that either promote or undermine a variety of individual safety behaviors pertaining to pesticides, thereby providing a more systematic view of pesticide exposure etiology. Although it is not assessed in this study, our model argues that control and demand likely promote

exposure to pesticides by undermining workers adherence to safety precautions. Safety precautions advocated for minimizing pesticide exposure include waiting for the re-entry interval to pass before entering a field that has had pesticides applied recently or washing hands frequently to remove pesticide residues require workers to exercise some discretion over how and when their daily activities are conducted. Likewise, heavy psychological and physical job demands may undermine frequent hand-washing by focusing workers' attention on overall production, rather than safety, or it may leave workers feeling as though danger is simply part of the job (Hofmann & Stetzer, 1996). Simple exhaustion from the demands of farm work can also interfere with other advocated behaviors, such as keeping work clothes separate from nonwork clothes to avoid cross-contamination of personal clothing and showering immediately after work to remove pesticide residues (Thu, 1998). We focus specifically on pesticide exposure, an issue with immediate and long-term health consequences for farmworkers and their families. Informed by Demands-Control theory of occupational stress, we differentiated between physical and psychological job stressors and hypothesized that:

*H1:* Greater exposure to psychological demands, physical exertion, and hazardous work conditions are associated with greater odds of being exposed to pesticides, as indicated by detection of urinary DAP metabolites for OP pesticides.

*H2:* The effect of psychological demands, physical exertion, and hazardous work conditions on pesticide exposure is greater for workers with a low level of control than for those with a high level of control.

The notion that discrete demands have independent and interactive effects on health-related outcomes remains understudied in occupational stress research (Koslowsky, 1998). Stress researchers in other disciplines such as family science and environmental psychology use concepts like "stressor density" to recognize the potential deleterious effects of stressor accumulation (Habarth, Graham-Bermann, & Bermann, 2008; McKenry & Price, 2005). Evidence suggests the possibility that the deleterious effects of physical demands may be exacerbated by psychological demands. For example, a negative daily event or stressor has been found to have a particularly deleterious effect on mood when it is

coupled with other ongoing physical stressors such as living in a poor neighborhood and socioeconomic disadvantage (Caspi, Bolger, & Eckenrode, 1987; Grzywacz, Almeida, Neupert, & Ettner, 2004). Drawing on the idea of stressor density and the reality that farmworkers confront a wide variety of physical and psychological job demands in their work, it is important to consider how psychological demands may exacerbate (or be exacerbated by) physical job demands. Given the substantial depth and variety of demands confronted by farmworkers, coupled with the broader notion of "cumulative burden" from the general stress literature, we explored possible synergistic effects physical and psychological job demands on pesticide exposure. Specifically, we asked if high psychological demand moderates associations of physical exertion and hazardous conditions with risk for pesticide exposure.

## Method

The data used in this analysis were collected in 2007 as part of the PACE3 project, a community-based participatory research project conducted in east central North Carolina. This research study used a longitudinal design in which data were collected from participants up to four times at monthly intervals. A detailed description of the PACE3 project methods and descriptive findings is available elsewhere (Arcury et al., 2009a). To avoid redundancy in publishing we summarize the sampling and data collection procedures here; readers interested in a more detailed description of the field methods are encouraged to consult Arcury and colleagues' article.

## Sampling and Study Participants

Data collection for this study focused on 11 counties in North Carolina that have large migrant and seasonal farmworker populations. A two-stage cluster sampling procedure was used to select farmworkers to participate in this research study. First, an extensive list of farmworker residential sites or camps in the study counties was prepared. Camps were approached in random order until 41 inhabited camps were located which were willing to participate in the study; all camps that were approached agreed to participate. Problems with access led to replacing three of the original camps after the start of data collection. Therefore, 44 farmworker camps participated in the study. Second, participants in each of the camps were recruited to participate. In camps with seven or fewer residents, all farmworkers were in-

vited to participate. In camps with eight or more residents, 8 to 10 farmworkers were invited to participate on a first come, first serve basis.

The sample was comprised of predominantly men (91.3%), most of whom were over 30 years of age (58.9%). Nearly all participants were born in Mexico (94.8%) and most reported that Mexico was their permanent residence (85.0%). Over one half of the sample (51.9%) reported having six or fewer years of formal education, and 88.5% were classified as being a migrant farmworker, defined as an individual who travels greater than 75 miles from his or her permanent residence for purposes of performing agricultural work (Carroll, Samardick, Gabbard, & Hernandez, 2005). Most participants (90.6%) lived in grower provided housing, and slightly more than half of the sample (52.3%) reported having a temporary work visa (H2A visa).

## Data Collection

Data collection was completed from May through September 2007. Data collectors included eight fluent Spanish speakers, divided into three teams. One team was affiliated with each of the camps served by each of the community partners. At the beginning of data collection, each team of interviewers was accompanied by a field research supervisor to help ensure that data collection procedures were properly followed. After the first 6 weeks of data collection, a supervisor accompanied each team of interviews at least once each week to assure that no drift in data collection procedures occurred.

A detailed interview was completed with the farmworker participants at each of the four rounds of data collection. At the first contact, participants answered questions about personal characteristics (e.g., age, educational attainment) as well as measures from the Job Content Questionnaire (Karasek & Theorell, 1990) to assess job demands and control. The questionnaires used at the baseline and follow-up interviews also asked about living conditions and recent (i.e., 3 days before the interview) risk factors for pesticide exposure, including workplace activities and behaviors. The baseline interviews took about 45 minutes to complete, whereas the second through fourth interviews took ~25 minutes to complete. The questionnaires used in these interviews were developed in English and translated by an experienced translator who was a native Spanish speaker familiar with Mexican Spanish. Validated Spanish language versions of scales were used when available.

After each interview participants were given a urine collection container with a Centers for Disease Control (CDC)-provided label attached. Participants were instructed to fill the container with their first void upon rising the next morning. They were assured that the urine sample would be tested for agricultural chemicals only, and not for the use of alcohol, drugs or any other health condition. They were asked specifically to only provide their urine in the container, not that of any other worker in the camp. They were asked specifically not to put any other fluid in the urine container (e.g., water). Finally, they were asked specifically not to put any chemicals (e.g., pesticides) in the urine container. The members of each camp placed their urine containers in a cooler with blue ice that was provided to them. Each morning a project interviewer stopped by the camp and retrieved the containers, transported them to the nearest study field site, aliquoted the samples into two 10 ml labeled containers and a 2 ml labeled container, and placed the samples in a laboratory freezer where they were stored at  $-20^{\circ}\text{C}$ . Urine samples were shipped on dry ice to CDC each week using an overnight delivery service.

## Lab Procedures

Urine samples were analyzed for the DAP metabolites of OP pesticides by the National Center for Environmental Health within the Centers for Disease Control and Prevention in Atlanta, GA, using established and validated procedures (Bravo et al., 2004). Urine samples were thawed to room temperature. A 2-mL aliquot of each sample was fortified with isotopically labeled internal standards, and then mixed. The urine samples were lyophilized overnight to remove all traces of water. The residue was dissolved in acetonitrile and diethyl ether and the DAP metabolites were chemically derivatized to their respective chloropropyl phosphate esters. The reaction mixture was concentrated, and the phosphate esters were measured using gas chromatography-positive chemical ionization-tandem mass spectrometry in the multiple reaction monitoring mode. Unknown analyte concentrations were quantified using isotope dilution calibration with calibration plots generated with each sample run. The reported limits of detection (LOD) were 0.6  $\mu\text{g/L}$  for DMP, 0.2  $\mu\text{g/L}$  for DMTP, 0.1  $\mu\text{g/L}$  for DMDTP, 0.2  $\mu\text{g/L}$  for DEP, 0.1  $\mu\text{g/L}$  for DETP, and 0.1  $\mu\text{g/L}$  for DEDTP. To ensure quality data, additional quality control materials, fortified samples, and blank samples were analyzed in parallel with all unknown samples.

## Measures

**Dependent variables.** Pesticide exposure is assessed by the presence of pesticide metabolites in farmworkers' first morning void urine samples. Analyses are limited to the six DAP metabolites of OP pesticides measured in each sample: DMP, DMTP, DMDTP, DEP, DETP, and DEDTP. Associations among the DAP urinary pesticide metabolites using tetrachloric correlations to accommodate the binary structure of the variables ranged from small ( $r = .12$ ) to moderate ( $r = .62$ ) with the greatest correlation observed between DMTP and DMDTP (see Table 1). Whereas correlations among the three dimethyls (i.e., DMP, DMTP, and DMDTP) were generally moderate in size, the correlations among the three diethyls (i.e., DEP, DETP, and DEDTP) were more modest ranging from  $r = .35$  to  $r = .42$ . The modest to moderate intercorrelation and the chemical reality that different pesticides metabolize into distinct DAP urinary metabolites support treating detection of each metabolite as a separate outcome.

**Independent variables.** Items from the Job Content Questionnaire (Karasek & Theorell, 1990) were used to measure distinct job demands (i.e., psychological demands, physical exertion, and hazardous conditions) and control (i.e., decision authority) at the baseline interview. Farmworkers frequently have low levels of education (Carroll, Samardick, Bernard, Gabbard, & Hernandez, 2005) and have difficulty responding to standard survey items, particularly those using affectively based response categories (Grzywacz, Quandt, & Arcury, 2008). Therefore, the JCQ items were modified to replace the affective response categories ("strongly agree" to "strongly disagree") with a four-point frequency-based response set (1 = "seldom or never," 2 = "sometimes," 3 = "often," and 4 = "always").

Grzywacz, Quandt, and Arcury (2008) used a similar strategy in another study of farmworkers. *Psychological demand* was assessed with three items (e.g., "How often are you given enough time to get your job done?"). *Physical demand* was assessed with two measures. *Physical exertion*, was assessed with five items (e.g., "How often does your job require a lot of physical effort?" or "How often does your job in farmwork require you to work for long periods with your body in physically awkward positions?"). *Hazardous condition* was assessed with eight items (e.g., "How often does your job in farmwork require working with tools, machinery or equipment that could be dangerous?" or "How often does your job in farmwork require you to work in areas where dangerous materials are placed or stored?"). Control was assessed with three items (e.g., "How often are you allowed to make your own decisions about your work?"). All variables were constructed by summing constituent items and scored such that higher values indicate greater control or greater exposure to job demands.

**Personal characteristics.** Age was assessed in years. Potential direct contact with pesticides was controlled by creating a variable reflecting the total number of days in the past 3 days in which participants spent time mixing, loading, or applying a pesticide, sucker dope or yellowing agent to crops. Additionally, the total number of hours worked in the 3 days before collection of each urine sample was controlled in all analyses.

## Analysis

Analyses were limited to observations wherein individuals reported working at least one of the previous 3 days ( $N = 910$  observations obtained from 285 distinct participants). Before fitting models for hypothesis testing, preliminary analyses evaluated if associations of control and job demands (i.e., psychological demands, physical exertion, and hazardous conditions) with detection of the OP metabolites varied over time. These preliminary models included the main effect of the variable of interest (e.g., control), time, and the interaction of the variable of interest with time to test for possible differences across time in the associations of demands and control with detection of DAP urinary pesticide metabolites. None of these interaction terms were significant, indicating that associations of control or demands with detection of the OP metabolites did not differ over time. Consequently, in subsequent analyses only the

Table 1  
Correlation<sup>a</sup> Among the DAP Urinary Pesticide Metabolite Outcome Variables

	DEDTP	DETP	DEP	DMDTP	DMTP	DMP
DEDTP	1.00					
DETP	0.42	1.00				
DEP	0.35	0.37	1.00			
DMDTP	0.37	0.52	0.30	1.00		
DMTP	0.38	0.41	0.12	0.62	1.00	
DMP	0.36	0.30	0.52	0.58	0.52	1.00

<sup>a</sup> Estimates are from tetrachloric correlations to accommodate the binary structure of the variables ( $N = 839$ ).

Table 2  
*Descriptive Statistics, Estimated Correlations Among, and Reliabilities (on the Diagonal) for Job Demand and Control Variables*

	<i>M</i>	<i>SD</i>	Range	PD	PE	HC	CN
Psychological demands (PD)	7.35	2.68	3–12	0.87			
Physical exertion (PE)	11.68	3.37	5–20	0.61	0.72		
Hazardous conditions (HC)	12.92	4.18	8–32	0.29	0.41	0.83	
Control (CN)	5.26	2.34	3–12	–0.06	–0.02	0.17	0.78

Note. *N* = 285.

odds ratios (OR) averaged across the entire agricultural season are reported.

A generalized estimating equation (GEE) approach was used to accommodate the clustered longitudinal design of our study (Fitzmaurice, Laird, & Ware, 2004). A variety of methods can be used in GEE to model the correlation structure within clusters. For the correlated binary outcomes in our study (i.e., detection of DAP urinary metabolites), we specified a GEE using the 1-nested log-OR model to generate two log-OR parameters

reflecting the intercorrelation of observations at each specified level of clustering. The first generated parameter is the log-odds that an individual’s observation at time *t* is conditional on other observations for that individual over time, thereby accommodating the clustering of observations within study participants. The second generated parameter is the log-odds that an individual’s observation in camp *c* is conditional on other individuals’ observations in camp *c*, thereby accommodating the clustering of observations obtained from farm-

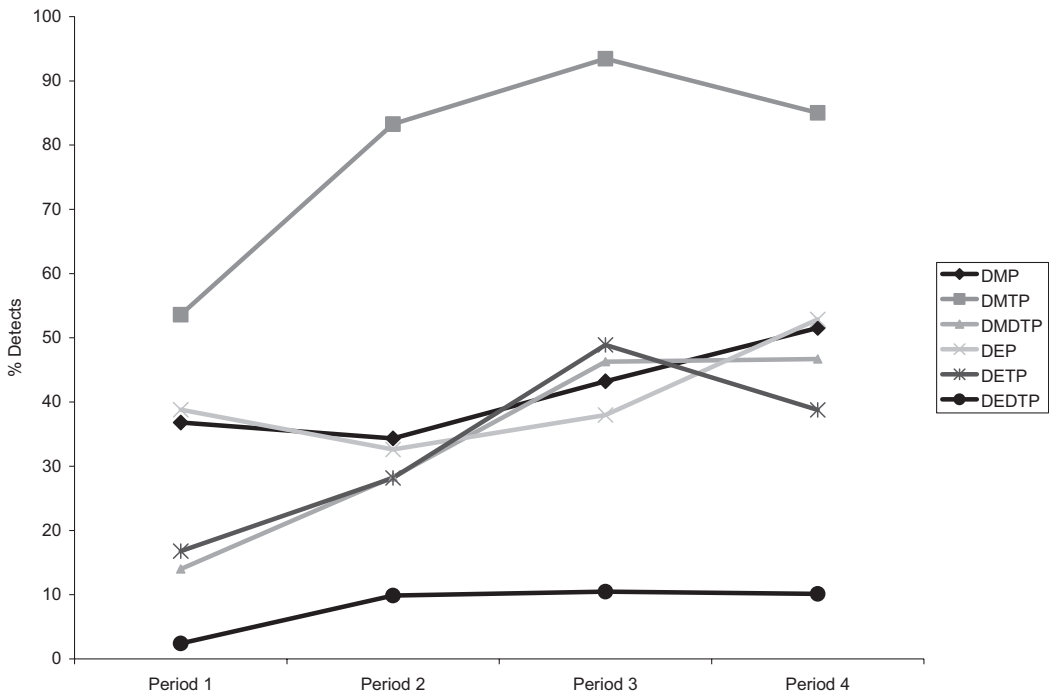


Figure 1. Percentage of Latino farmworkers with detectable levels of DAP organophosphorus pesticide metabolites across the agricultural season.

workers in the same camp. GEE provides robust regression estimates of the association of control and demands with detection of DAP urinary pesticide metabolites by explicitly modeling the log-odds parameters reflecting correlation at each level of clustering (Stokes, Davis, & Koch, 2000).

The study hypotheses were tested by fitting multivariate GEE models. To test the first hypothesis one model was fit for each of the six DAP metabolites. Each model included the main effects of control, psychological demand, physical exertion, and hazardous conditions as well as time and covariates (i.e., farmworker age and whether the farmworker loaded or mixed pesticides in the past 3 days). Then, appropriate interaction terms were added to the models to test the hypothesized moderating effect of control on associations between job demands and exposure to pesticides. The research question about possible the extent to which psychological demand accentuate associations of physical exertion and hazardous conditions with pesticide exposure was also explored by adding appropriate interactions to the models. All data analyses were performed using SAS 9.1 (SAS Institute, Cary, NC).

**Results**

The level of physical and psychological demand confronted by farmworkers and their level of control over their daily tasks is reported in Table 2. Farmworkers reported having moderate levels of psychological job demand and physical demand, as indicated by the mean values located at the approximate midpoint of the possible range of scores. Self-reported exposure to hazardous conditions, on average, and levels of control over work conditions were both lower than the midpoint of the possible range of scores. Psychological demands was moderately correlated with physical exertion ( $r = .61$ ), whereas hazardous conditions had a small to moderate association with psychological demand ( $r = .29$ ) and physical exertion ( $r = .41$ ). Control was modestly associated with hazardous conditions ( $r = .17$ ) but unrelated to psychological demand or physical exertion.

The percentage of farmworkers with detectable levels of DAP pesticide metabolites generally increased across the agricultural season (see Figure 1). This pattern is clearly evidenced with the DMTP metabolite. In the beginning of the season, 53.6% of farmworkers had DMTP in their urine, but the percentage of workers with detectable levels of this

Table 3  
Odds Ratios Estimating Unadjusted Associations of Job Demand and Control With Each DAP Urinary Pesticide Metabolite<sup>a</sup>

	DEDTP		DETP		DEP		DMDTP		DMTP		DMP	
	OR	(95% CI)	OR	(95% CI)	OR	(95% CI)	OR	(95% CI)	OR	(95% CI)	OR	(95% CI)
Psychological demands	1.00	(0.90-1.11)	0.94*	(0.89-1.00)	0.93*	(0.88-0.98)	1.00	(0.93-1.07)	1.05	(0.99-1.11)	0.98	(0.92-1.04)
Physical exertion	1.02	(0.94-1.11)	0.94*	(0.90-0.98)	0.99	(0.94-1.04)	0.99	(0.96-1.03)	1.00	(0.97-1.04)	0.99	(0.96-1.04)
Hazardous conditions	0.99	(0.93-1.06)	0.97‡	(0.94-1.01)	1.00	(0.97-1.04)	1.00	(0.97-1.03)	1.00	(0.97-1.04)	1.00	(0.97-1.03)
Control	1.04	(0.96-1.12)	1.00	(0.95-1.04)	1.01	(0.95-1.07)	1.02	(0.96-1.08)	0.95	(0.89-1.02)	1.03	(0.98-1.09)

<sup>a</sup> Associations estimated using a General Estimating Equation to accommodate repeated assessments of the binary outcome. Odds ratio represents the average increased odds of being exposed to pesticide across the agricultural season for each unit (SD) increase of exposure.  
 \*  $p < .10$ . †  $p < .05$  (two-tailed).



Table 4

Multivariate Odds Ratio Estimating Associations of Job Demand and Control With Each DAP Urinary Pesticide Metabolite<sup>a</sup>

	DEDTP		DETP	
	Odds Ratio (95% CI)		Odds Ratio (95% CI)	
Model 1				
Psychological demands (PD)	0.97 (0.87–1.09)		0.98 (0.92–1.04)	
Physical exertion (PE)	1.03 (0.93–1.14)		0.95 (0.90–1.01)	
Hazardous conditions (HC)	0.99 (0.92–1.07)		0.99 (0.95–1.03)	
Control (CN)	1.04 (0.96–1.13)		1.00 (0.95–1.05)	
Models with interaction terms				
Model 1 + CN*PD	–0.016	(–0.036, 0.005)	–0.004	(–0.020, 0.012)
Model 1 + CN*PE	–0.029***	(–0.050, –0.009)	–0.004	(–0.015, 0.007)
Model 1 + CN*HC	–0.014	(–0.031, 0.003)	0.001	(–0.005, 0.007)
Model 1 + PD*PE	–0.023	(–0.057, 0.010)	–0.010	(–0.029, 0.008)
Model 1 + PD*HC	–0.024**	(–0.046, –0.002)	–0.004	(–0.018, 0.009)

<sup>a</sup> Associations estimated using a General Estimating Equation to accommodate repeated assessments of the binary outcome. Models account for sample clustering (within individuals and farmworker camps), and include controls for farmworker age, total hours worked in the 3 days before collection of the urine sample, and whether the farmworkers loaded or mixed pesticides. The total number of observations used in the reported models is 839 obtained from 273 study participants. Observations with missing values for DAP pesticide metabolites ( $n = 21$ ) were not included in the reported models.

‡  $p < .10$ . \*  $p < .05$ . \*\*  $p < .01$ . \*\*\* (two-tailed).

metabolite increased to 83.3, 93.5, and 85.2% at the subsequent observations. Similarly, at the beginning of the season 16.8% of farmworkers had the DETP urinary metabolite, and the percentage of workers with detectable levels of this metabolite increased to 28.2, 48.9, and 38.8% across the season. More detailed descriptions of seasonal trends in farmworker pesticide exposure are available elsewhere (Arcury et al., 2009a, 2009b).

Bivariate analyses yielded little consistent evidence that job demands and control may influence farmworkers exposure to pesticides as indicated by detection of DAP urinary pesticide metabolites (see Table 3). Significant associations that did emerge were generally in the opposite direction of predictions from the Demands-Control model articulated in the first hypothesis. A one unit increase in psychological demands was associated with a 6% reduction in the odds of detecting the DETP urinary pesticide metabolite and a 7% reduction in the odds of detecting the DEP metabolite. Similarly, for every unit increase in physical exertion the odds of detecting DETP in provided urine samples decreased by 6%. There was little evidence linking hazardous conditions to any of the DAP metabolites, apart from a trend-level ( $p < .10$ ) association suggesting that greater exposure to hazardous conditions was associated with lower odds of detecting DETP. Control was not associated with detection of any of the individual DAP urinary pesticide metabolites.

Results from multivariate analyses yielded no support for our first hypotheses from the Demands-Control model that distinct types of job demands and control would have independent effects on our specified measures of pesticide exposure (see Table 4). Only one association was found and it contradicted the hypothesis: for every one unit increase in psychological demands, the odds of detecting the DEP metabolite in provided urine samples decreased by 10%. Additionally, trend-level ( $p < .10$ ) suggests that increased psychological demand may be associated with an increased odds of detecting the DMTP urinary metabolite.

However, the multivariate analyses yielded several interaction effects. The interaction of physical exertion with control was significant for the DEDTP and the DMTP urinary metabolites. The interaction of hazardous conditions with control also emerged for DMTP. Figures 2 and 3 illustrate the interaction effects for DEDTP and DMTP, respectively, and they show associations consistent with our second hypothesis that associations of job demands with detection of DAP urinary pesticide metabolites would be greater for workers with little job control. Among individuals with high levels of control, there is no association between physical exertion and detection of DEDTP in provided urine samples (see Figure 2). However, among individuals with low control, greater physical exertion is associated with a greater probability of detecting DEDTP. The potential buffering effect of control on physical exertion is clearer for the DMTP metabolite: for individuals with

DEP	DMDTP	DMTP	DMP
Odds Ratio (95% CI)	Odds Ratio (95% CI)	Odds Ratio (95% CI)	Odds Ratio (95% CI)
0.90** (0.85–0.96)	1.00 (0.91–1.10)	1.07* (0.99–1.16)	0.97 (0.91– 1.03)
1.02 (0.97–1.08)	0.98 (0.93–1.03)	0.98 (0.93–1.04)	1.00 (0.96– 1.04)
1.02 (0.98–1.05)	1.01 (0.98–1.06)	1.01 (0.96–1.05)	1.01 (0.98– 1.05)
1.00 (0.95–1.06)	1.02 (0.96–1.09)	0.95 (0.88–1.03)	1.04 (0.98–1.09)
0.004 (–0.016, 0.025)	0.006 (–0.014, 0.026)	–0.018 (–0.044, 0.007)	0.002 (–0.013, 0.017)
0.009 (–0.012, 0.030)	–0.006 (–0.017, 0.005)	–0.021*** (–0.035, –0.008)	0.0004 (–0.012, 0.013)
–0.003 (–0.016, 0.011)	–0.005 (–0.013, 0.002)	–0.010** (–0.020, –0.0003)	–0.0032 (–0.013, 0.007)
–0.0004 (–0.019, 0.018)	–0.016 (–0.037, 0.005)	–0.008 (–0.027, 0.012)	–0.024** (–0.043, –0.006)
–0.015** (–0.027, –0.003)	–0.014*** (–0.023, –0.004)	–0.012** (–0.021, –0.003)	–0.009 (–0.024, 0.006)

low control there is a positive association between physical exertion and detection of DMTP, but this association is negative for individuals with a high level of control (see Figure 3).

Models exploring our research question about potential interaction effects of high psychological demands and high physical demands (i.e., physical exertion and hazardous conditions) on pesticide

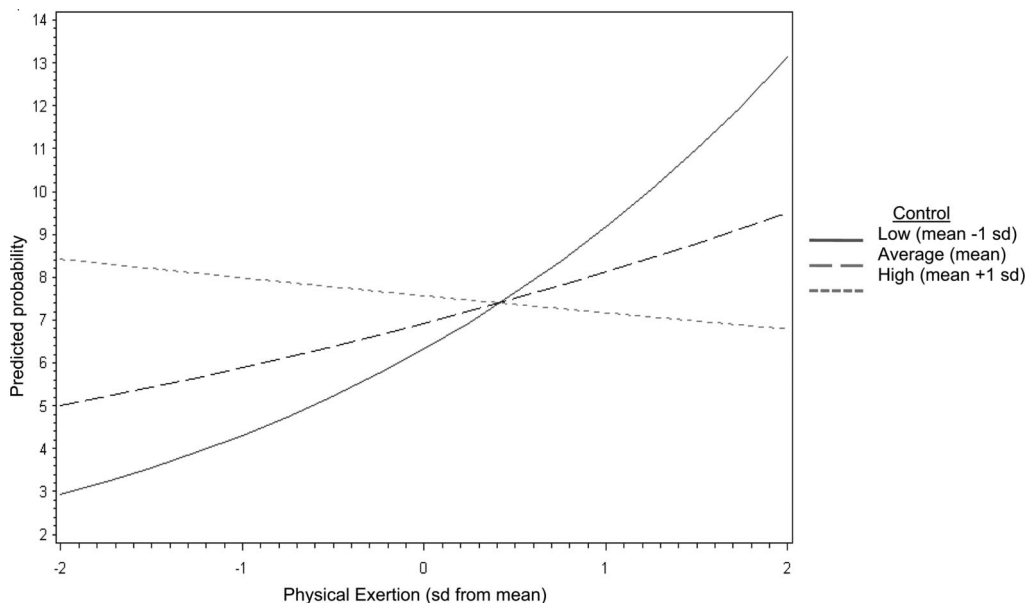


Figure 2. The effect of physical exertion on the probability of detecting the DEDTP urinary pesticide metabolite by level of job control.

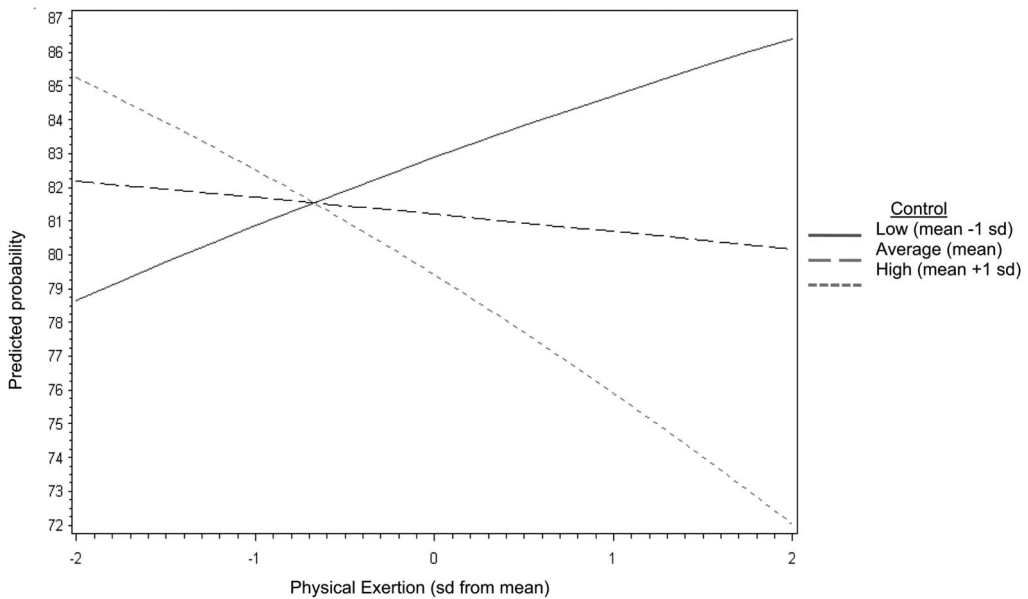


Figure 3. The effect of physical exertion on the probability of detecting the DMTP urinary pesticide metabolite by level of job control.

exposure yielded consistent effects for five of the six DAP metabolites (see Table 4). The interaction of psychological demands and physical exertion on detection of DMP (see Figure 4) illustrates the pattern that is observed across all of the double demands interaction effects. Figure 4 shows that greater physical exertion is associated with greater probability of detecting DMP among individuals with low psychological demand, but that physical exertion is associated with lower probability of detecting DMP among those with high psychological demand. A similar pattern emerges for the other four significant interaction effects of psychological demands and hazardous conditions: each unit increase in hazardous conditions is associated with greater probability of detecting DAP metabolites when psychological demand is low, but when psychological demand is high, increases in hazardous conditions are associated with lower probability of detecting pesticide.

### Discussion

Farmworkers confront multiple threats to their health as they toil in the fields to bring fresh food and products to consumers in the U.S. and abroad. One of these threats, pesticide exposure, is be-

lieved to have widespread and long-term health consequences. Unfortunately, understanding of pesticide exposure remains poor because of problematic measurement of pesticide exposure and the absence of a strong, evidence based conceptual framework for guiding pesticide exposure research (Quandt et al., 2006). Research to date has focused on concrete and discrete behaviors, like frequency of hand washing, without giving sufficient attention to characteristics of the job that may underlie the very behaviors that protect workers from harm. The goal of this study was to develop a better understanding of pesticide exposure among immigrant Latino farmworkers. To accomplish this goal we applied key concepts and propositions from the Demands-Control model (Karasek & Theorell, 1990) to predict pesticide exposure as assessed by the presence of DAP metabolites of organophosphate pesticides in farmworker urine samples. The results of this study contribute to both the pesticide exposure and the Demands-Control literatures.

### Contributions to the Pesticide Literature

The results of this study suggest that the basic organization of farm work, or the way in which farm work is managed and performed, may shape

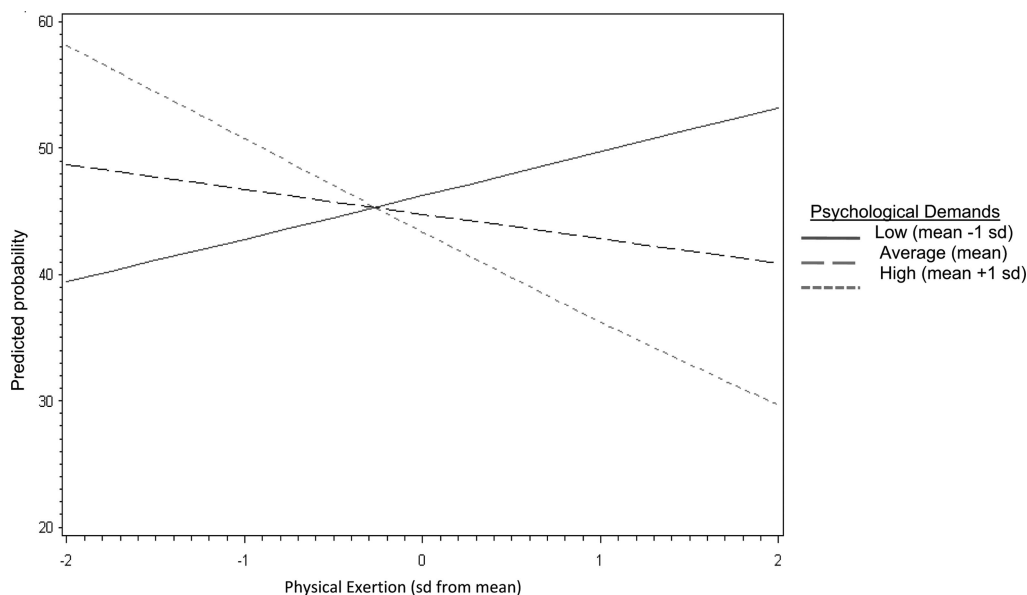


Figure 4. The interactive effect of psychological job demands and physical exertion on the probability of detecting the DMP pesticide metabolite.

farmworkers' exposure to pesticides. The results of this study suggest that farmworkers who lack control over daily work tasks may be at particular risk for pesticide exposure when they are exposed to heavy physical demands or other hazardous conditions. Although this pattern of results awaits replication and extension, including evaluation of safety behavior mechanisms, the general importance of control in minimizing pesticide exposure is consistent with results from pesticide exposure studies conducted with pesticide applicators (Mage et al., 2000). It is also consistent with previous research suggesting that control contributes to greater adherence to advocated pesticide safety behavior among farmworkers (Austin et al., 2001) and with Quandt and colleagues' (2006) comprehensive model of farmworker pesticide exposure.

A second contribution to the pesticide exposure literature is the relative consistency of results across the six DAP urinary pesticide metabolites that served as indicators of pesticide exposure. Identification of consistent predictors of pesticide exposure has been an ongoing challenge among researchers (Quandt et al., 2006). In this study, we found that interactions between indicators of physical job demand (i.e., physical exertion and hazardous conditions) and control were significantly

associated with two DAP urinary pesticide metabolites. Importantly, a comparable effect for both interactions was observed for the DMTP metabolite. Further, interactions between physical job demand and psychological job demand were associated with five of the six metabolites. Although the meaning of these associations is unclear, particularly the interactions between hazardous conditions and psychological job demand, the consistency of associations is virtually unparalleled in the pesticide exposure literature. Indeed, several studies in the pesticide exposure literature openly lament difficulties finding significant and consistent predictors of pesticide exposure (Arcury et al., 2009a, 2009b; Coronado, Thompson, Strong, Griffith, & Islas, 2004). The results provide a compelling foundation for future research examining how characteristics of farm work may shape risk for pesticide exposure, as well as potential strategies for minimizing pesticide exposure.

### Contributions to the Demands-Control Literature

Occupational stress research in general and the Demands-Control research in particular have tended

to overlook some highly vulnerable worker populations. There is a noteworthy absence of research with immigrant Latinos, despite the fact that Latinos will become more common in the labor force (Toossi, 2002) and that they frequently work in dangerous and frequently marginalized jobs (Mosisa, 2002). There is also comparatively little attention given to farmworkers (cf. Grzywacz, Quandt, & Arcury, 2008). The utility of the Demands-Control model, or any other theoretical paradigm, rests in part on its applicability in different segments of society as well as its applicability to diverse outcomes (Schnall et al., 1994). Consequently, the simple application of the Demands-Control model to a distinct worker population (i.e., immigrant farmworkers) and outcome (i.e., pesticide exposure) is a contribution to the literature.

A second contribution of this study to the Demands-Control literature is the evidence suggesting that control may buffer the effects of physical demands on pesticide exposure. A compelling feature of the observed associations is the fact that they are consistent with a core proposition of the Demands-Control model: Karasek and Theorell (1990) explicitly point out that control is a "crucial moderating variable" (p. 40) shaping the effects of environmental demands on health-related outcomes. We interpret these results indicating that farmworkers with control may be better able to adhere to basic safety principles when they confront demanding situations than are workers with little control. If this interpretation is supported by future research, the results suggest that worker control plays an important role in understanding and promoting safety behavior (Parker, Axtell, & Turner, 2001). The observed buffering effects is also compelling because they highlight the relative salience of physical job demands over psychological demands in predicting health-related outcomes, an association similar to what has been observed elsewhere (Grzywacz, Quandt, & Arcury, 2008). The occupational stress literature has tended to overlook physical job demands, despite the fact that Karasek and Theorell (1990) recognized the importance of physical demands when they outlined their theory. Our results, therefore contribute to the literature by reintroducing the potential importance of physical job demands to Demands-Control researchers, especially those studying workers in labor intensive occupations.

The results of the exploratory analyses considering potential interactive effects of physical and psychological job demands also contribute to the Demand-Control literature. Surprisingly, the predominant pattern of results indicated no evidence that a high level of psychological demand exacerbates the effect of

high physical demands. Instead, it appears that elevated psychological demands may actually dampen the effect of physical demands on pesticide exposure. This consistent finding across five of the six DAP urinary metabolites is compelling, although difficult to interpret. Perhaps combined forms of demands create added vigilance so that workers meet their physical demands with greater caution. Although speculative, this explanation is consistent with Karasek and Theorell's (1990) point that demands may have either positive or negative health effects depending on other work-related factors. While this may be true, it is also important to acknowledge that combined physical and psychological demands may be beneficial for pesticide exposure, but prolonged exposure to these demands may be detrimental for health outcomes that progress slowly (e.g., cardiovascular disease). This is an important area for future research.

The contributions of this research need to be interpreted in light of its limitations. Data were obtained from one discrete agricultural region in the country. Although it awaits systematic research, evidence suggests that there is substantial regional variation in the composition of the farmworker populations, the types of work performed, and their potential exposure to pesticides (Arcury & Quandt, 2009); consequently, the extent to which the results of this study generalize to other regions is unknown. A second limitation is that the instruments used to assess job demands and control have not been widely used in samples comparable to farmworkers, who tend to be low education, limited literacy, and Spanish speaking (Carroll et al., 2005). Farmworkers' unique profile raises distinct challenges for measuring concepts relevant in occupational stress research (Grzywacz et al., 2008); consequently, the results of this study should be viewed as preliminary. Next, this study did not study the behavioral mechanisms believed to link demands and control with exposure to pesticides, such as frequent hand-washing during the workday and adherence to the re-entry intervals. Future research should replicate the current findings and extend them by systematically examining mediating mechanisms. Finally, there are four limitations in our assessment of pesticide exposure. The first is that the DAP urinary metabolites only capture exposure to one possible class of pesticides (OP pesticides), the second is that one commonly used OP pesticide, Acephate, does not metabolize to a DAP, third is that pesticides are typically metabolized and excreted within 72 hr of exposure, and the fourth is that urinary DAP metabolites may also be derived from

exposure to the preformed metabolites in the environment. Thus, the extent to which the results of this study help us understand exposure to all forms of pesticides remains unknown.

Despite these limitations, this study has several strengths and unique features. This is one of the largest studies of occupational pesticide exposure ever conducted, and it is the first to collect repeated assessments of pesticide exposure. This is important, as pesticides are typically metabolized and excreted from the body within a 72 hr time period. The use of biologically based outcome variables eliminates common method variance, a problem that undermines a significant proportion of the occupational stress literature. This study begins to build a bridge between two distinct literatures, the occupational stress literature and the pesticide exposure assessment literature. This bridging is important because it brings a quantifiable biological marker with significant health implications to the occupational stress literature, and it brings needed theory of human behavior to the pesticide exposure literature. Finally, this study is unique because little occupational stress research has been conducted with immigrant Latino workers. As the immigrant labor force continues to grow and find itself in dangerous occupations like farmwork, it is imperative that researchers fully evaluate and resolve the threats confronted by these workers to ensure health equity for all.

In summary, the results of this study provide compelling evidence suggesting that the Demands-Control model of occupational stress is useful for understanding pesticide exposure among farmworkers. The results suggest that job-related demands, especially physical demands of the job, contribute to pesticide exposure. However, the potential threat of these demands is lessened among workers who have greater control over how they perform their jobs. Collectively, these results suggest that interventions to reduce pesticide exposure among farmworkers need to move beyond individual behaviors like hand washing into interventions that redesign farm work jobs by minimizing exposure to physical job demands and providing workers with greater control over their daily lives while on the job.

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