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Overall and class-specific scores of pesticide residues from fruits and vegetables as a tool to rank intake of pesticide residues in United States: a validation study

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Abstract

Pesticide residues in fruits and vegetables are among the primary sources of pesticide exposure through diet, but the lack of adequate measurements hinder the research on health effects of pesticide residues. Pesticide Residue Burden Score (PRBS) for estimating overall dietary pesticide intake, organochlorine pesticide score (OC-PRBS) and organophosphate pesticide score (OP-PRBS) for estimating organochlorine and organophosphate pesticides-specific intake, respectively, were derived using U.S. Department of Agriculture Pesticide Data Program data and National Health and Nutrition Examination Survey (NHANES) food frequency questionnaire data. We evaluated the performance of these scores by validating the scores against pesticide metabolites measured in urine or serum among 3,679 participants in NHANES using generalized linear regression. The PRBS was positively associated with a score summarizing the ranks of all pesticide metabolites in a linear fashion (p for linear trend <0.001). Furthermore, individuals in the top quintile of this score had urinary pesticide metabolite levels 13.0% (95% CI 8.3%-17.7%) higher than individuals in the lowest quintile. Similarly, we observed significant associations of the OC-PRBS and OP-PRBS with the levels of lipid-adjusted total serum organochlorine pesticides and urinary creatinine-adjusted organophosphate pesticides, respectively. The relative difference (RD) in average pesticide metabolite rank between extreme quintiles was 17.8% (95% CI:

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11.1%-24.4%, p for trend <0.001) for the OP-PRBS, whereas the RD was marginally significant at 7.0% (95% CI: -0.5%-14.4%, p for trend 0.07) for the OC-PRBS. The PRBS and OP-PRBS had similar performance when they were derived from fruits and vegetables with high vs. low pesticide residues, respectively (p for trend <0.001 for all associations). The OP-PRBS was associated with all measured organophosphate pesticides, whereas the positive association between OC-PRBS and averaged measured organochlorine pesticide residue rank was primarily driven by hexachlorobenzene. OC-PRBS had better performance when derived from more contaminated fruits and vegetables (p for trend 0.07) than from less contaminated Fruits and vegetables (p for trend 0.63), although neither of the associations achieved statistical significance. The PRBS and the class-specific scores for two major types of pesticides were significantly associated with pesticide biomarkers. These scores can reasonably rank study participants by their pesticide residue exposures from fruits and vegetables in large-scale environmental epidemiological studies.

Keywords

Fruits/vegetables pesticide residues; organochlorine pesticide; organophosphate pesticide; validation study; USDA pesticide data program; NHANES

1. Background

A pesticide is defined as any substance or mixture of substances intended for preventing, destroying, repelling, or mitigating any pests (insects, mites, nematodes, weeds, rats, and etc.). Based on their targeted pests, they can be categorized into insecticides, herbicides, fungicides, and various other substances (EPA, 2009). Based on their chemical structure, three main classes of pesticides are carbamates, organophosphates and organochlorinated pesticides. These pesticides are widely applied to fruit and vegetable crops worldwide, and herbicides are mostly used for maize in the developed countries (Zhang et al., 2011). Pesticide Monitoring Program 2012 report by U.S. Food and Drug Administration (USDA) showed that a considerably higher proportions of domestic fruits and vegetables had detectable pesticide residue or had residue levels exceeding the EPA standard, in comparison to other foods, including dairy, grain products and fish (FDA, 2012), suggesting that intake of fruits and vegetables is among the major sources of pesticide residue exposure.

Dietary guidelines have consistently suggested increasing the consumption of fruits and vegetables for the prevention of major chronic diseases (U.S. Department of Health and Human Services and U.S. Department of Agriculture., 2015) based on unequivocal evidence from clinical trials and epidemiological studies (Bazzano et al., 2003, 2002; Hu and Willett, 2002; Joshipura et al., 2001; Krauss et al., 2000; Liu et al., 2000; Mozaffarian et al., 2003; Muraki et al., 2013; Rimm et al., 1996; U.S. Department of Health and Human Services and U.S. Department of Agriculture., 2015). Meanwhile, concerns have been raised regarding increased exposures to pesticide residues resulting from higher consumption of these healthful foods (Bhanti and Taneja, 2007; Boobis et al., 2008). One study specifically evaluated pyrethroid exposure through food consumption and concluded that part of the variation in pyrethrois intake is explained by vegetable intake but not other food sources (Fortes et al., 2013). Data from the USDA Pesticide Data Program (PDP) have revealed that pesticide residues were common for a variety of fruits and vegetables (USDA, 2015a). In Europe and China, pesticide residues have also been identified in multiple fruits and vegetables, and the residues of certain pesticides were found to be more than maximum residue level values recommended by European Union, World Health Organization and Food and Agricultural Organization (Bakırcı et al., 2014; Yu et al., 2016). The concerns regarding the impacts of food-borne pesticides on human health have led advocacy organizations to develop an index to rank food items in terms of pesticide residue levels based on the PDP data (EWG, 2014).

Indeed, several short-term intervention studies have showed that young children's exposure to organophosphate pesticides, the most widely used pesticides in agriculture sectors (Chen et al., 2009; Sharma et al., 2010; Wang et al., 2008), is primarily from diet (Bradman et al. 2015; Lu et al., 2008, 2006). In addition, although some organochlorine pesticides such as hexachlorobenzene have been banned from use in U.S. for 50 years, their residues persist in soil and water because of their long half-lives and thus they may still affect human health (Jones and de Voogt, 1999). Actually, a few organochlorine pesticides are still in use in U.S., such as 2, 4 dichlorophenoxyacetic acid (2,4-D). However, the long-term health effects of exposures to pesticide residues through fruits and vegetables consumption remain to be elucidated.

Quantifying concentrations of pesticide metabolites in human biospecimens to measure pesticide exposures is ideal but challenging. High costs, the lack of reliable assays for some pesticides, and short half-lives of pesticide metabolites poses major challenges for the evaluations of pesticides' health effects in large-scale epidemiological studies. In contrast, pesticide residue scores may be more cost-effective and can be a useful tool to facilitate the preliminary examination of pesticide residues in relation to human health before investigations based on biomarkers are implemented. Chiu et al. recently described a novel pesticide score to summarize the overall exposure to pesticide residues from fruits and vegetables and evaluated its association with semen quality (Chiu et al., 2016, 2015). Results suggested that the pesticide score, but not fruits and vegetables *per se*, were associated with poor semen quality. In the current study, we aimed to improve Chiu's pesticide score algorithm by combining the fruit and vegetable consumption frequency and their respective pesticides residues levels to form a pesticide residue burden score (PRBS) that can reflect the overall pesticide exposures attributed to fruit and vegetable intake. We further derived two class-specific (organochlorine and organophosphate) pesticide scores because pesticides in classes may have heterogeneous effects on human health. We subsequently examined the associations of the overall score and the two class-specific scores with a variety of pesticides measured in urine or serum in the 2003-2004 National Health and Nutrition Examination Survey (NHANES).

2. Material and methods

2.1 USDA Pesticide Data Program (PDP)

In 1991, the USDA PDP was launched to estimate the potential risk of pesticide residues in food (USDA, 2015b). About 15 types of fresh and processed fruits and vegetables have been randomly sampled and measured for pesticide residues each year since 1992, and the sampling procedures were designed to capture actual residues in the food supply as close as possible to the time of consumption. The fruits and vegetables sampled varied over time. In addition, fresh samples were washed or peeled before testing to emulate the practices of the average consumers. The PDP database contains information for over 300 types of environmental pesticides found in fruits and vegetables. In the current study, we used 2003-2006 PDP data to develop the pesticide scores to match the time when pesticide metabolites were measured in 2003-2004 NHANES. A total of 29 fruits and vegetables that were presented in both NHANES food frequency questionnaire and PDP data were considered in the current analysis. Eighteen types of fruits and vegetables were measured in 2003-2004 PDP program. We used 2005-2006 PDP data, which were based on eleven types of Fruits and vegetables, to supplement 2003-2004 PDP data in order to include more fruits and vegetables in the current analysis.

2.2 Development of Pesticide Residue Burden Score (PRBS)

The primary goal of the PRBS is to rank study participants in terms of their overall exposures to pesticide residues from fruit and vegetable intake as previously described (Chiu et al., 2015). Specifically, in the USDA PDP database, we used three indexes to estimate an overall pesticide residue profile for each fruit or vegetable: 1) the percentage of samples with any detected pesticides; 2) the percentage of samples tested with pesticides exceeding the tolerance level; and 3) the percentage of samples with three or more types of pesticides detectable (USDA, 2015c). For each of these three indexes, fruits and vegetables were ranked into tertiles and were assigned a score ranging from 1 (bottom tertile) to 3 (top tertile). Then scores based on these three indexes are summed for each fruit or vegetable to create a pesticide rank score. The possible range of pesticide rank score is from 3 (least contaminated) to 9 (most contaminated). For example, strawberries are in the top tertiles for all three indexes and therefore have a pesticide rank score of 9, whereas onions have a pesticide rank score of 3 because they are in the bottom tertile of all three measurements. We then calculated the PRBS by multiplying the pesticide rank score by the consumption frequency for each fruit and vegetable and subsequently summing the products across all fruits and vegetables. For example, for a participant reporting consuming 5-6 servings of strawberries/week, his or her PRBS for strawberry consumption will be 0.785 (5.5 servings divided by 7 to derive daily consumption frequency) * 9 (the pesticide rank score) = 7.1. Among 29 items, strawberries were found to be most contaminated while onion, orange juice and frozen sweet corn had the minimum level of pesticide residue (supplemental table 1).

2.3 Development of class-specific pesticide score

Based on the class-specific pesticide data in the PDP, we derived organochlorine pesticide score (OC-PRBS) and organophosphate pesticide score (OP-PRBS) to measure exposures to the residues of these two most commonly detected pesticides. For each fruit or vegetable, we calculated average concentrations of these two classes of pesticides in the PDP database and then calculated the OC-PRBS and OP-PRBS by multiplying the mean pesticides values by the consumption frequency for each fruit and vegetable and subsequently summing the products across all fruits and vegetables. Assuming all included fruits and vegetables were treated with the same spectrum of pesticides, missing values due to non-detections were replaced with limit of detection value divided by the square root of 2. Of note, we did not derive scores for other pesticide classes primarily because the concentrations of pesticides of other classes did not have meaningful variability. The individual organochlorine (OC) pesticides organophosphate (OP) pesticides considered in PDP were listed in supplemental table 2.

2.4 NHANES pesticide metabolite measurements

The 2003-2004 NHANES data were used for the validation of the pesticide scores. An array of pesticide metabolites were measured in spot urine samples or serum samples in the NHANES. Laboratory measurements of these metabolites were described elsewhere (CDC, 2014). The pesticide metabolites used for the validation of PRBS included creatinine-adjusted 2, 4 dichlorophenoxyacetic acid, 2, 5-dichlorophenol, o-phenyl phenol, 2, 4-dichlorophenol, 2, 4, 5-trichlorophenol, 2, 4, 6-trichlorophenol, dimethylphosphate, diethylphosphate, dimethylthiophosphate, diethylthiophosphate, dimethyldithiophosphate, diethyldithiophosphate. As the OC pesticides were measured among a different subset of NHANES participants, these metabolites were not included in the PRBS validation. Lipid-adjusted hexachlorobenzene, oxychlordane, trans-nonachlor and heptachlor epoxide were used to validate OC-PRBS and creatinine-adjusted OP pesticides, including dimethylphosphate, diethylphosphate, dimethylthiophosphate, diethylthiophosphate, and dimethyldithiophosphate, were used to validate OP-PRBS. The population for validating PRBS and OP-PRBS was the same while a completely different sample of participant was used for OC-PRBS validation because of data availability. Because the range for these pesticides can be orders of magnitude different (e.g., the mean value of creatinine-adjusted 2, 5-dichlorophenol was 320.4 μg/mg while the mean value of creatinine-adjusted 2, 4, 5-trichlorophenol was only 0.17 μg/mg), we first ranked participants for each pesticide and then averaged the summed ranks for all pesticides within each class to represent the class-specific dietary pesticide exposure. This rank-based method can avoid the total pesticides residuals level dominated by certain pesticides with relative large mean concentrations. A similar approach was used in previous studies to evaluate overall pollutant exposures in relation to disease outcomes (Lee et al., 2010). Of note, we did not use 2005-2006 NHANES data because most of the pesticide metabolite concentrations were below detection limit. All participants provided written informed consent, and the study protocol was approved by the institutional review board at the Centers for Disease Control and Prevention (Atlanta, Georgia).

2.5 Statistical analysis

Mean (standard deviation) for each individual component of OC-PRBS and OP-PRBS was computed according to the quintiles of OC-PRBS and OP-PRBS. In order to improve the precision of the least-squares estimates, univariate linear regression models were fitted to identify potential predictors for the measured pesticide residual levels and we found that age, body mass index, smoking status and physical activity were significant predictors for all three types of measured pesticide levels. Gender was significantly associated with overall measured pesticide level and organophosphate pesticide level but not organochlorine pesticide level. White race was associated with both measured organochlorine and organophosphate pesticide level but not overall measured pesticide level. To ensure the comparability of the results, we decided to include both of them in the models. Although the positive associations for pesticide control were not statistically significant probably due to the relative low frequency (∼18%), we nonetheless adjusted for this variable as it might introduce extraneous variation of measured pesticide levels. A generalized linear model adjusted for age (< 20 years, 20-40 years, 40-60 years and over 60 years), gender (male/female), race (white/non-white), smoking status (never smoker, past smoker, current 1-10 cigarettes/day, current 11-20 cigarettes/day and current 21 more cigarettes/day), body mass index ($<25kg/m^2$, $25\text{-}29.9kg/m^2$, $\geq 30kg/m^2$), physical activity (vigorous or moderate activity over past 30 days, yes/no), and pest control in past month (yes/no) was fitted for PRBS, OC-PRBS and OP-PRBS quintiles, respectively, to calculate the least-squares (LS) means of the corresponding averaged rank of the measured serum and urinary pesticide metabolites in each quintile. P-value for trend was obtained by including the median value of the averaged rank of the measured pesticide metabolites for each quintile in the models. In order to assess the discriminability of the pesticide scores for fruits and vegetables with relative low and high levels of pesticide, we further categorized the fruits and vegetables according to the median pesticide rank score value. Fruits and vegetables with pesticide rank score less than median were deemed to be less pesticide-contaminated and those with pesticide rank score higher than median were classified as relatively highly pesticide-contaminated. Then the three types of pesticide scores were re-calculated for low and high pesticide-contaminated fruits and vegetables, respectively, and we subsequently evaluated these pesticide scores in the same way as it was for total fruits and vegetables. All p values were two-sided. Data were analyzed with SAS 9.3 (SAS Institute, Inc., Cary, North Carolina) and R 3.1.1 (R Foundation, Vienna, Austria).

3. Results

A total of 1960, 1719, and 1918 participants were included in the validation study for PRBS, OC-PRBS and OP-PRBS, respectively. Table 1 shows the demographical information of NHANES participants by quintiles of the PRBS. The PRBS was positively correlated with age. Women and overweight or obese participants had a higher PRBS than men and lean participants, respectively. Pattern for the correlation between other covariates and PRBS was less clear.

Measured values of serum organochlorine and urinary organophosphate pesticide metabolites among NHANES participants by quintiles of OC-PRBS and OP-PRBS are shown in Table 2. The mean value of each OC and OP pesticide increased by quintiles of the OC-PRBS and OP-PRBS scores, respectively. The relative difference in measured mean OC levels between individuals in the top and bottom quintiles of the OC-PRBS score ranged from 33% for hexachlorobenzene to 89% for trans-nonachlor. For OP pesticides, the differences ranged between 14% for diethylphosphate to 122% for dimethylthiophosphate. The spearman correlation coefficients for PRBS, OC-PRBS and OP-PRBS and corresponding measured pesticide metabolites were 0.20 ($p<0.001$), 0.15 ($p<0.001$), and 0.18 ($p<0.001$).

We then examined the relation of the averaged rank of total pesticide metabolites, total OC pesticide metabolites and total OP pesticide metabolites with the PRBS, OC-PRBS and OP-

PRBS scores, respectively, adjusting for age, gender, race, smoking status, physical activity, and pest control in past month. After adjusting for these covariates, especially age, the discriminating ability of OC-PRBS was attenuated in the multiple adjusted models whereas the validity of OP-PRBS was strengthened. The relative difference in average pesticide metabolite rank between extreme quintiles was 13.0% (95% CI: 8.3%-17.7%, *p* for trend <0.001) for the PRBS (Figure 1, Panel A), 7.0% (95% CI: -0.5%-14.4%, *p* for trend 0.07) for the OC-PRBS (Figure 2, Panel A) and 17.8% (95% CI: 11.1%-24.4%, *p* for trend <0.001) for the OP-PRBS (Figure 3, Panel A). PRBS and OP-PRBS were associated with average rank of corresponding measured pesticides with a significant dose-response relationship and we found that the OP-PRBS was also associated with all measured urine organophosphate pesticides metabolites in the multiple generalized linear models. The positive association between OC-PRBS and averaged measured serum pesticide metabolites rank was primarily driven by hexachlorobenzene (Supplemental figure 1, Supplemental figure 2). All three derived scores had slightly better performance for more pesticide-contaminated fruits and vegetables than those with less pesticide contamination (Figure 1, Panel B, C; Figure 2, Panel B, C; Figure 3, Panel B, C).

4. Discussion

In this validation study using NHANES data, we found significant associations among three pesticide indexes and measured urinary or serum pesticide metabolites as biomarkers of integrated exposures to the pesticides. The dose-response relationships were more prominent among fruits and vegetables containing higher concentration of pesticide residues. The derived pesticide scores were able to rank participants according to their relative intake of fruits and vegetables-borne pesticide and had potentials to be used as measures of pesticide exposures in epidemiological studies that aimed to examine pesticide exposure in relation to risk of diseases.

It remains unclear regarding whether the exposure to pesticide residues through diet has significant adverse health effects on human health. Likewise, although organic fruits and vegetables are believed to be more healthful than non-organic counterparts because of less pesticide residues, lower nitrate contents, higher levels of vitamin C (Huber et al., 2011), evidence regarding whether intake of organic fruits and vegetables is associated with health benefits is sparse. The investigation by Chiu et al. that linked pesticide residues from fruit/vegetable intake to lower semen quality represents one of the few research efforts dedicated to examine long-term exposures to pesticide residues from fruits and vegetables in relation to human health (Chiu et al., 2015). The overall pesticide score developed by Chiu et al. provided a useful tool to facilitate quantifying food-borne pesticide residue exposures and can be used in subsequent investigations of pesticide residue-disease association in epidemiological studies. A similar instrument for measuring long-term dietary exposure to pesticide residues was developed by Curl et al., using data from the Multi-Ethnic Study of Atherosclerosis (MESA) (Curl et al., 2015). The MESA score algorithm was also built on USDA PDP (2008-2010) data and self-reported food frequency questionnaire data, although the MESA score primarily used the food consumption-chemical residual (FCCR) method to summarize OP exposures. Briefly, average concentration of each OP measured in each food item was calculated, and then FCCR was calculated as the product of average daily intake, concentration of OP of each food, and its relative toxicity of that particular OP compared with methamidophos, which was subsequently divided by body weight. The generated values were summed across all pesticides and all food items to yield a methamidophos-equivalent estimate of total daily OP exposure. In MESA, the association between the MESA score and measured urinary pesticide levels was similar to what we observed in the current investigation. The top tertile of the FCCR-based exposure estimate had significant higher levels of urinary OP biomarker concentration, and there was also a clear linear trend suggesting a dose-response relationship. The four OP metabolites dimethylphosphate, dimethylthiophosphate, diethylphosphate, and diethylthiophosphate included in the MESA score were all included in our validation study but the dimethyldithiophosphate was additionally added in our analysis. In comparison with the MESA score which only estimated OP pesticide exposures, our scores aimed to estimate overall exposures to all pesticides and both OC and OP exposures. The detailed comparisons of the three pesticide score algorithm were listed in supplemental table 3. Furthermore, we observed somewhat clearer dose-response relationship between three scores derived from the intake of relatively highly-contaminated fruits and vegetables and corresponding pesticide metabolites. These observations suggested that intake of highly-contaminated fruits and vegetables may account for more variability of overall exposure levels than less contaminated fruits and vegetables.

Several limitations in the current study merit discussion. First, measurement errors are apparently inevitable for using the scores to rank individuals in terms of their actual pesticide residue exposures. In addition, the temporal mismatch between the biological marker assessments and the diet information collection may also greatly attenuate the underlying associations. On the other hand, since these multiple sources of measurement errors were largely independent of each other, these modest yet significant correlation coefficients demonstrated that the pesticide scores reasonably reflected actual pesticide exposures. Moreover, we also adjusted variables that might contribute to measured pesticide levels in biospecimens, such as pest control use during past month, to reduce these measurement errors in this study. More importantly, we demonstrated that the scores could rank and differentiate study subjects with high vs. low pesticide exposures, which is usually sufficient to facilitate epidemiologic research to examine pesticide residue exposures in relation to disease outcomes. Second, the measured urinary and serum pesticide metabolites in the NHANES dataset were not necessarily all attributable to fruit and vegetable intake. The derived score system can only capture the pesticide exposure from dietary sources while the pesticide exposure could result from other sources such as gardening and pest control, which may result in the attenuation of the correlation coefficients. Third, we were not able to include some currently used pesticides such as carbamates, sulphonylureas, neonicotinoids, and etc. in the overall score because these data was generally lacking in the NHANES dataset. Finally, as some classes of common pesticides, such as the 2,4-D, in the USDA PDP database were largely missing or lacked variation, we are unable to further derive and examine class-specific scores for these classes.

It is of great interest to investigate whether the pesticide residues from fruits and vegetables may mitigate the beneficial effects of eating fruits and vegetables. Combining the annual USDA PDP data and dietary data as assessed by food frequency questionnaires or other instruments, investigators can use the described pesticide scores as a screening tool to generate the pesticide-disease hypotheses which can be further substantiated by the objectively measured biomarkers in the U.S. population.

5. Conclusion

In conclusion, the overall fruit and vegetable pesticide score, organochlorine pesticide score, and organophosphate score were able to adequately rank individuals in terms of pesticide residue exposures at the population level. These pesticide scores could thus serve as valid tools to assess pesticide residue exposures through fruit and vegetable consumption in epidemiological studies.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

Acknowledgments

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Highlights

- Pesticide residual burden score for overall and specific pesticides are derived.
- Pesticide scores are significantly associated with pesticide metabolites.
- Pesticide scores can reasonably rank people in terms of pesticides exposures.
- Pesticide scores can be used as valid screening tools in population-based studies.

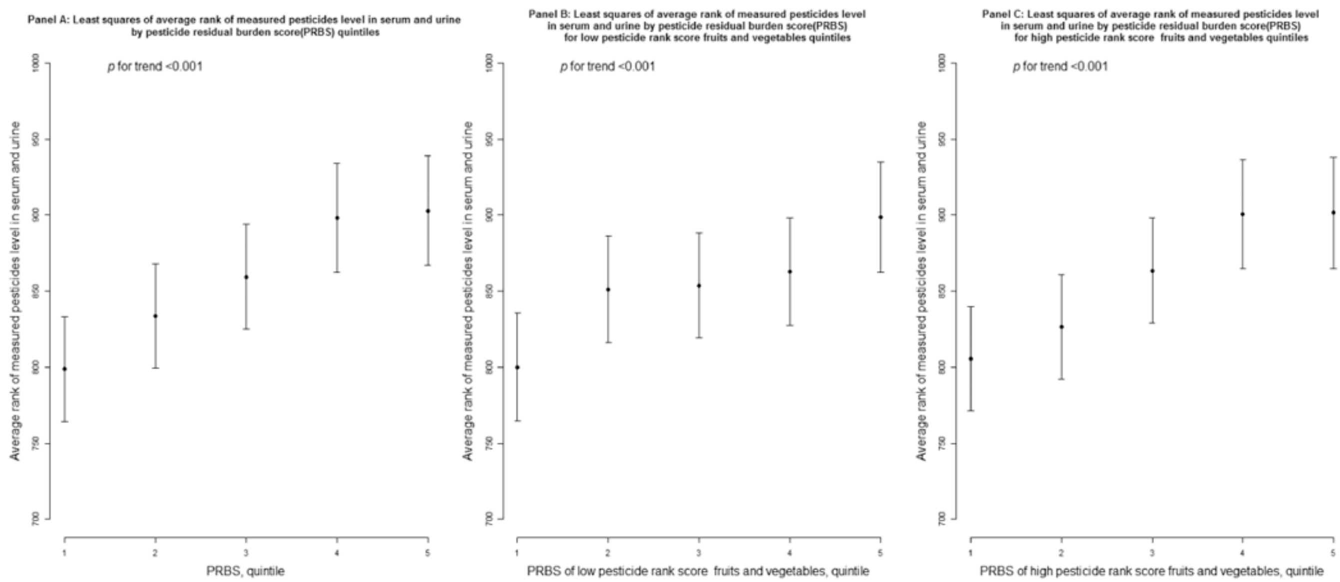

Fig. 1.

The ability of PRBS to differentiate high versus low level of overall dietary pesticides intake. The general linear models adjusted for age (< 20 years, 20-40 years, 40-60 years and over 60 years), gender (male/female), race (white/non-white), smoking status (never smoker, past smoker, current 1-10 cigarettes/day, current 11-20 cigarettes/day and current 21 more cigarettes/day), body mass index (<25kg/m^2, 25-29.9kg/m^2, ≥30kg/m^2), physical activity (vigorous or moderate activity over past 30 days, yes/no) and pest control in past month (yes/no).

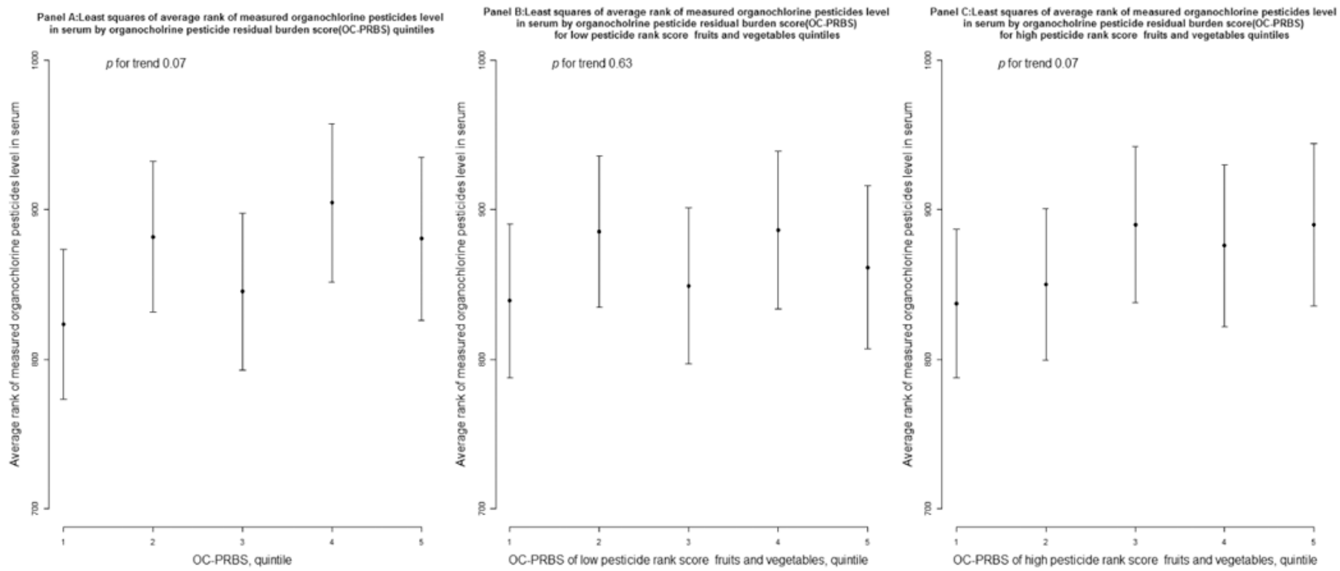

Fig. 2.

The ability of OC-PRBS to differentiate high versus low level of dietary organochlorine pesticides intake. The general linear models adjusted for age (< 20 years, 20-40 years, 40-60 years and over 60 years), gender (male/female), race (white/non-white), smoking status (never smoker, past smoker, current 1-10 cigarettes/day, current 11-20 cigarettes/day and current 21 more cigarettes/day), body mass index ($<25kg/m^2$, $25\text{-}29.9kg/m^2$, $\geq 30kg/m^2$), physical activity (vigorous or moderate activity over past 30 days, yes/no) and pest control in past month (yes/no).

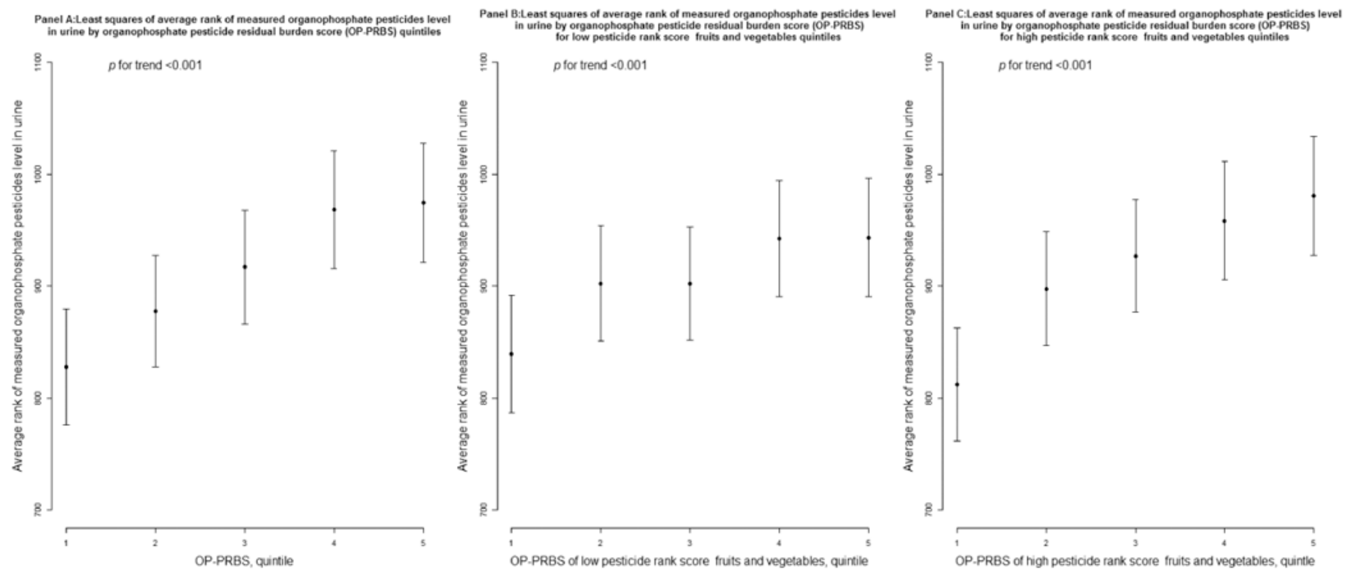

Fig. 3.

The ability of OP-PRBS to differentiate high versus low level of dietary organophosphate pesticides intake. The general linear models adjusted for age (< 20 years, 20-40 years, 40-60 years and over 60 years), gender (male/female), race (white/non-white), smoking status (never smoker, past smoker, current 1-10 cigarettes/day, current 11-20 cigarettes/day and current 21 more cigarettes/day), body mass index ($<25 kg/m^2$, $25-29.9 kg/m^2$, $\geq 30 kg/m^2$), physical activity (vigorous or moderate activity over past 30 days, yes/no) and pest control in past month (yes/no).

Table 1

Demographical information of NHANES participants (2003-2004) by quintile of the overall fruits and vegetable pesticide score (PRBS).[a]

	Overall fruits and vegetable pesticide score (PRBS), quintiles				
Demographical information	**1**	**2**	**3**	**4**	**5**
N	392	392	392	392	392
Age, years					
<20	50.8	43.6	39.0	31.4	34.4
20-40	22.2	20.4	19.1	20.2	16.1
40-60	12.5	14.8	18.6	19.1	18.1
≥60	14.5	21.2	23.2	29.3	31.4
Gender, male	54.6	53.8	46.2	40.1	40.3
White race	46.2	49.5	48.5	49.7	37.8
Body mass index, kg/m^2					
<25	55.8	51.8	48.7	40.8	49.7
25-30	23.5	26.5	26.0	29.9	28.6
≥25	20.7	21.7	25.3	29.3	21.7
Smoking status					
Never smoker	74.5	72.5	68.9	71.7	74.7
Past smoker	12.5	14.8	18.9	20.7	17.4
Current 1-10 cigarettes/day	6.1	5.1	5.6	3.3	4.1
Current 11-20 cigarettes/day	5.1	5.1	5.1	3.8	3.6
Current 21 or more cigarettes/day	1.8	2.6	1.5	0.5	0.3
Vigorous or moderate activity over past 30 days	56.4	60.5	54.6	61.2	57.9
Pest control in past month	20.4	18.9	17.9	15.8	18.9

[a]Data are proportion (%).

Table 2

Measured values of serum organochlorine and urinary organophosphate pesticides among NHANES participants (2003-2004) by quintile of organochlorine and organophosphate pesticide score.[a]

	Organochlorine pesticide residual burden score (OC-PRBS), quintiles						
Organochlorine pesticide, lipid-adjusted (ng/g) [b]	**1**	**2**	**3**	**4**	**5**	**P, trend**	**Q5 vs Q1, % difference (95% CI)**
N	343	344	344	344	344		
Hexachlorobenzene	12.8(9.3)	14.4(9.7)	13.8(8.0)	16.3(14.5)	17.0(14.2)	<0.001	33% (19%-46%)***
Heptachlor Epoxide	4.4(9.7)	4.9(5.1)	5.3(7.4)	6.7(10.0)	6.3(8.1)	<0.001	41% (13%-69%)**
Oxychlordane	8.2(10.5)	11.8(13.9)	12.4(14.1)	15.9(19.7)	15.2(16.8)	<0.001	86%(58%-114%)***
Trans-nonachlor	13.3(18.9)	20.6(28.5)	21.6(31.1)	26.9(39.8)	25.1(30.4)	0.47	89%(55%-123%)***
Total	38.7 (41.3)	51.6(49.2)	53.0(54.0)	65.8(70.9)	63.5(58.3)	<0.001	64%(43%-86%)***

	Organophosphate pesticide residual burden score (OP-PRBS), quintiles						
Organophosphate pesticide, creatinine-adjusted (μg/mg) [b]	1	2	3	4	5	P, trend	Q5 vs Q1, % difference (95% CI)
N	383	384	384	384	383		
Dimethylthiophosphate	0.28(0.48)	0.41(1.2)	0.36(0.60)	0.40(0.66)	0.41(0.69)	0.01	46% (7%-85%)*
Diethylphosphate	0.33(0.74)	0.37(0.85)	0.38(0.65)	0.36(0.63)	0.37(0.54)	0.77	14% (-16%-44%)
Dimethylthiophosphate	0.43(1.1)	0.56(1.2)	0.83(3.4)	1.00(4.3)	0.96(2.4)	0.07	122% (30%-213%)**
Diethylthiophosphate	0.08(0.23)	0.07(0.18)	0.09(0.27)	0.11(0.24)	0.10(0.18)	0.01	28% (-12%-68%)
Dimethyldithiophosphate	0.07(0.44)	0.08(0.25)	0.11(0.42)	0.16(0.55)	0.14(0.41)	0.01	99% (13%-184%)*
Total	1.19(2.0)	1.48(2.5)	1.8(3.9)	2.1(4.8)	2.0(3.3)		67% (25%-108%)**

[a] Data are mean (SD)

[b] Values adjusted for age (< 20 years, 20-40 years, 40-60 years and over 60 years), gender (male/female), race (white/non-white), smoking status (never smoker, past smoker, current 1-10 cigarettes/day, current 11-20 cigarettes/day and current 21 more cigarettes/day), body mass index (<25kg/m^2, 25-29.9kg/m^2, ≥30kg/m^2), physical activity (vigorous or moderate activity over past 30 days, yes/no) and pest control in past month (yes/no).

* $p < 0.05$;

** $p < 0.01$;

*** $p < 0.001$