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POPULATIONS AT RISK ACROSS THE LIFESPAN: POPULATION STUDIES

Potential Health Effects Related to Pesticide Use on Athletic Fields

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ABSTRACT ***Objectives:*** Children come in contact with athletic fields on a daily basis. How these fields are maintained may have an impact on children's potential exposure to pesticides and associated health effects. ***Design and Sample:*** This is a cross-sectional, descriptive study that utilized a survey to assess playing field maintenance practices regarding the use of pesticides. Athletic fields (N = 101) in Maryland were stratified by population density and randomly selected. ***Measures:*** A survey was administered to field managers (n = 33) to assess maintenance practices, including the use of pesticides. Analysis included descriptive statistics and generalized estimating equations. ***Results:*** Managers of 66 fields (65.3%) reported applying pesticides, mainly herbicides (57.4%). Managers of urban and suburban fields were less likely to apply pesticides than managers of rural fields. Combined cultivation practice was also a significant predictor of increased pesticide use. ***Conclusions:*** The use of pesticides on athletic fields presents many possible health hazards. Results indicate that there is a significant risk of exposure to pesticide for children engaged in sports activities. Given that children are also often concurrently exposed to pesticides as food residues and from home pest management, we need to examine opportunities to reduce their exposures. Both policy and practice questions are raised.

Key words: athletic fields, exposure, nursing, pesticide, public safety.

Many children, teens, and adults come in contact with athletic fields almost on a daily basis; even multiple times a day if they are in school and also participate in recreational sports. Maintenance of these fields, including pesticide application, could have a major impact on the likelihood of exposure to hazardous chemicals and subsequent health effects. This study represents an initial attempt to characterize pesticide exposure to children who come in contact with athletic fields.

Background

The US Environmental Protection Agency (2008) (EPA) defines a pesticide as "any substance intended for preventing, destroying, repelling, or mitigating any pest," including insect, plant, fungus, rodent, or bacteria. Pesticides include insecticides, herbicides, fungicides, rodenticides, and biocides and are ubiquitous in our environment. The usual biological targets of pesticides are the pests' nervous or reproductive system, although they may affect other organisms, including humans.

Human populations are exposed to pesticides at home, work, and in the community through consumption of food and water, ambient air, and contact with soils or surfaces. These exposures are leading to increased body burdens of potentially harmful chemicals, according to the Centers for

Disease Control and Prevention (2009) (CDC) *National Report on Human Exposure to Environmental Chemicals*. The CDC reported that levels of certain herbicides and organochlorine, organophosphate, pyrethroid, carbamate, and other pesticides were detected at higher levels in human blood in the 2003–2004 NHANES than in the prior two surveys (1999–2000, 2001–2001). The human health effects associated with the detected levels of pesticides are the subject of much research.

Animal and human data demonstrate that pesticide exposures have acute and chronic health effects in many systems, including neurologic and neurodevelopmental (Beseler et al., 2006; Eskenazi et al., 2007; Handal, Lozoff, Breilh, & Harlow, 2007; Kofman, Berger, Massarwa, Friedman, & Jaffar, 2006; Lee et al., 2007; Ribas-Fito et al., 2007; Rohlman et al., 2007; Rothlein et al., 2006), reproductive and endocrine (Damgaard et al., 2006; Meeker, Barr & Hauser, 2006; Saldana et al., 2007), and immune (Colosio, Birindelli, Corsini, Galli, & Maroni, 2005; Weselak, Arbuckle, Wigle, & Krewski, 2007). They also may play a role in cancer development (Clark & Snedeker, 2005; Dharmani & Jaga, 2005; McNally & Parker, 2006; Menegaux et al., 2006; Zahm & Ward, 1998). Most of the toxicological data related to health effects from exposure, however, are based on studies focusing on one chemical via one route. There has been little exploration taking into consideration the many possible combinations of chemicals, routes of exposures, and exposed individuals that actually occur in real life (Ray & Fry, 2006), such as those exposures that may occur on athletic fields.

Recognizing that pesticides can affect the health of the general population, certain subpopulations warrant special attention. There are critical periods of human development, such as conception, pregnancy and puberty, when exposures to pesticides can result in increased risk for negative health outcomes (Weselak et al., 2007). Vulnerable populations, including children and the fetus and embryo, are likely to be the most sensitive to environmental exposures. Children are the primary users of athletic fields, whereas their mothers, most of whom are of child bearing age or may be pregnant, are likely to be spectators.

Exposure to pesticides on athletic fields has not been previously assessed. Although many studies have assessed the use of pesticides in workplaces (Barr et al., 2006; Rohlman, Bodner, Arcury, Quandt, & McCauley, 2006; Rothlein et al., 2006; Ward et al., 2006), homes (Butte & Heinzow, 2002; Coronado, Vigoren, Thompson, Griffith, & Faustman, 2006; Curl et al., 2002), schools/day cares (Morgan et al., 2005; Tulve et al., 2006), and in food (Lu, Barr, Pearson, Bartell, & Bravo, 2006), no previous studies have examined pesticide use on athletic fields.

Research questions

It remains unknown how many different types of pesticides are being used, in what quantities, on what type of fields, and how often and by whom they are applied. Although a large portion of daily cumulative exposure to pesticides is assumed to come from food and the home environment, exposure on athletic fields is a potentially important route. Depending on the child's activities, contact with the field could occur during physical education time at school and after school during practice and games. Exposure would be increased if the child plays more than one sport. Athletic fields also constitute part of the workplace for field maintenance workers, teachers, and day care providers who come in contact with fields on a regular basis. Therefore, the goal of this study was to describe current practices and to assess any differences in pesticide use on athletic fields among fields located in rural, suburban, and urban areas; related to the type of field and other related field characteristics; and related to maintenance practices.

Population density (rural, suburban, urban) is thought to impact pesticide use as a proxy for budget or acceptability of pesticides. Field conditions, such as proximity to farmland, water and residential areas; lighted fields; whether the field was in poor, fair, good, excellent condition; and total number of sports played might impact the need for use of pesticides on the fields. Maintenance practices, including main problem needing chemical application, soil testing, aeration, and overseeding could be related to the need for/use of pesticides (Puhalla, Krans, & Goatley, 2010).

Methods

Design and sample

This cross-sectional descriptive study investigated athletic field maintenance practices, including use of pesticides. Power analysis was conducted based on Tabachnick & Fidell's (2001, p. 117) equation with six predictors in a medium effect size multiple regression, $\alpha = .05$, and power = .80, yielding a sample size of 110 fields. A medium effect size was assumed without prior data for guidance. Presuming some non-response, a 30% oversample resulted in selecting 143 fields for surveys to yield the desired sample of 110. Based on lower than anticipated response rates, additional fields were sampled. Surveys were distributed for 185 fields.

An exhaustive list of 915 fields in the Central Maryland region (Anne Arundel, Baltimore, Carroll, Harford, and Howard Counties and Baltimore City) constituted the sampling frame and was developed by reviewing Internet maps and calling a list of schools and public parks in the six-jurisdiction area. It included fields associated with public and private K-12 schools, colleges and universities, local government, recreation councils, and State Parks. These fields were selected as they were most likely to be frequented by children up to age 18. The sampling unit was an individual field, reported on by the responsible field manager. The list of fields was stratified by three levels of population density: rural, suburban, and urban fields. Population density was defined according to the National Center for Education Statistics (2011) definition based on proximity of an address to an urbanized area. Two samples of 143 were randomly drawn using SPSS from the overall sampling frame of 915. The density distributions of the two samples were approximately equal. The sample with more variability was used for the full study and the other was used for the pilot study. Reporters for individual fields were the field maintenance personnel for the selected fields.

The process of recruitment included first identifying the field maintenance personnel associated with each field. Field maintenance personnel were contacted by phone and/or e-mail to explain the study and obtain their consent to participate. The survey was administered over the phone or via email, based on participant preference, to assess information about athletic fields and maintenance practices, including the use of pesticides. Prior to data collection, approval for the study was sought and obtained from the University of Maryland Institutional Review Board (IRB).

Measures

As no instrument existed that specifically addressed the assessment of pesticide use on athletic fields, a measurement tool was created via review of existing tools related to pesticides and adding new questions related to athletic fields and their maintenance practices. The instrument was validated via external content review and then piloted with nine fields from all six jurisdictions. Parks, public schools, and colleges were represented. For both the pilot and full study, data were collected via researcher-administered phone interview or self-report email survey (Cook, 2011; East, Jackson, O'Brien, & Peters, 2008).

The pilot study was meant to test items and method of administration. Based on feedback from the pilot participants, several survey items were changed to improve clarity and flow. An average of 2 weeks was allowed for return of emailed surveys with weekly follow-up calls and/or emails until completed.

Pesticide use, as the main dependent variable, was assessed by a 60-item survey including: history of field use and frequency of chemical application, the names of the chemicals applied (fertilizers and pesticides), type of pest addressed, and frequency and type of field care (irrigation, soil testing, mowing, composting, thatch removal). Most responses were dichotomous or nominal level measurements, although there were several ordinal and two interval ratio level questions. A composite variable, combined cultivation practices, was created. It was coded yes if soil testing, aeration, and over-seeding were all conducted and no if some or none of these practices were used.

Analytic strategy

Data were analyzed using SPSS 17.0 (PASW Statistics GradPack; SPSS Inc., 2009, Chicago, IL, USA). Frequencies and descriptive statistics were performed to assess errors in data entry and to assess missing data. One key variable, what is the general condition of the field, had greater than 5% missing data ($n = 13$, 12.9%). A dummy coded variable was created where 1 = missing, 0 = not missing and put in as the outcome variable with individual predictors and all were non-significant in predicting missingness, therefore satisfying the requirement of missing completely at random (MCAR).

Generalized Estimating Equations (GEE) were used to address the research questions with fields nested within field managers as there were many cases of one field manager reporting on multiple fields. Pesticide use was a dichotomous outcome. An independent working correlation matrix was used. (Norusis, 2008).

Results

Sample demographics

Surveys from 101 fields were returned and constituted the final sample. No responses were received for 84 (45%) fields managed by 42 field maintenance personnel. This left 101 fields in the final sample.

Survey data were provided by 33 field managers reporting on 101 athletic fields in the targeted study area. Field managers reported on 1–19 fields each (media $n = 1$). Sixty percent of fields were suburban, 23.8% were rural, and 15.8% were urban density. The highest percentage were public schools (56.4%) followed by public/park fields (29.7%). Of the participating schools, the highest percentage were elementary (39.4%) followed by high schools (30.3%), consisting of both public and private. The highest percentage of fields were in good condition (44.6%), although 38.6% were fair or poor. All 101 fields were used for organized sports and 69.3% were used informally. As expected, all fields were used in the spring with only 34.7% used in the winter (See Table 1).

The characteristics of the fields for which responses were not received were compared with those for which responses were received. Likelihood of receiving responses differed significantly according to population density. Those in rural areas were more likely to complete the survey (25% non-responders) compared with urban (48% non-responders) and suburban (50% non-responders, $X^2(2) = 6.52$, $p < .05$). Responses also differed significantly according to jurisdiction. Responders from two counties were less likely to complete the survey (73.7% and 67.3%, respectively, for non-responders) whereas those from three counties (10.5% 13.6%, and 4.3%, respectively, for non-responders) were more likely to complete the survey ($X^2(5) = 56.80$, $p < .01$). Managers of college/universities fields (62.5% responders) and public

TABLE 1. *Description of Fields*

	Total (n = 101)	
	n	%
Density		
Rural	24	23.8
Suburban	61	60.4
Urban	16	15.8
Category		
Public school	57	56.4
Private school	9	8.9
College/university	5	5.0
Public field	30	29.7
Condition		
Poor	21	20.8
Fair	18	17.8
Good	45	44.6
Excellent	4	4.0
Missing	13	12.9
Low lying		
No	92	91.1
Yes	9	8.9
Proximity to farmland		
No	72	71.3
Yes	29	28.7
Lighted field		
No	75	74.3
Yes	26	27.7
Total number of sports played		
1–9	47	52.2
10–24	43	47.8
Educational level of person responsible for maintenance		
High school or equivalent	26	25.7
Technical degree	7	6.9
Some college	21	20.8
Associates degree	29	28.7
Bachelor's degree	10	9.9
Master's degree and above	5	5.0
Don't know	3	3.0
Percent done in-house		
<50%	8	7.9
≥50%	91	90.1
Missing	2	2.0
Perception of adequate resources		
No	82	81.1
Yes	15	14.9
Missing	4	4.0
School level		
Elementary	26	39.4
K-8	5	7.6
Middle	9	13.6
High	20	30.3
K-12	5	7.6
Other	1	1.5

fields (62.5% responders) were more likely to complete the survey whereas private schools were less likely to respond (29.0% responders, $X^2(5) = 12.87$, $p < .05$). Response rates also differed according to school level. High schools were more likely to participate than the other levels ($X^2(5) = 11.48$, $p < .05$).

Description of maintenance practices and pesticide use

The primary reasons for chemical application were soil nutrients (63.4%) and weeds (58.4%). The most common maintenance practices included aerating and over-seeding. About half the fields had soil testing conducted and were irrigated. Synthetic fertilizer was applied to 41.6% and pesticides were applied to 65% of the fields. The most common pesticides applied were herbicides (See Table 2).

Variables not associated with pesticide use included the category (school or park) and condition of the fields, if the field was low-lying or in close proximity to farmland, if the field had stadium lights, the education level of the field manager, percent of maintenance done in-house, and perception of adequate resources (including labor, supplies, and monetary) (See Tables 3).

Density and pesticide use

Rural fields ($n = 24$) were more likely than suburban ($n = 61$, $p < .01$) or urban fields ($n = 16$, $p < .01$) to have pesticides applied. Urban fields were 77 times less likely to have pesticides applied than rural fields and suburban fields were almost five times less likely to have pesticides applied than rural fields. This indicates a substantial difference in pesticide use based on population density as rural fields were significantly more likely to have pesticides applied (See Table 3).

Maintenance practices and pesticide use

Combined cultivation practices (soil testing, aeration, overseeding) ($n = 53$) was a significant predictor of increased pesticide use ($p = .04$). Managers of fields using combined cultivation

TABLE 2. *Field Maintenance Practices and Chemical Use*

	Total (n = 101)	
	n	%
Reason for chemical application		
Disease	23	22.8
Insects	17	16.8
Weeds	59	58.4
pH	37	36.6
Soil nutrients	64	63.4
Maintenance practices[a]		
Soil testing	54	53.5
Aeration	94	93.1
Over-seeding	91	90.1
Irrigation	53	52.5
Thatch management	22	21.8
Compost used as topdress	20	19.8
Fertilizer[a]		
Natural	9	8.9
Synthetic	42	41.6
Pesticides		
No	35	34.7
Yes	66	65.3
Type[a]		
Disease	6	5.9
Insecticides	33	32.7
Herbicides	58	57.4

[a]Only the yes response is presented.

TABLE 3. *Generalized Estimating Equations Analysis of Contributions of Individual Predictors to Use of Pesticides on Athletic Fields With Fields Nested within Field Managers* (n = 101 Fields)

Variable	B	OR (95% CI)
Population density (rural is reference)		
Suburban	−1.61	.20 (.06–.72)*
Urban	−4.34	.01 (.00–.419) **
Combined cultivation practices		
Yes	2.22	9.17 (1.06–76.92)*
Condition of field (poor/fair is reference)		
Good/excellent	1.23	3.35 (.43–27.78)
Category of school (not school for 18 yo or less is reference)		
School for 18 yo or less	.36	1.43 (.21–9.90)
Low lying field		
Yes	−.44	.66 (.07–5.68)
Proximity to farmland		
Yes	1.55	4.71 (.71–31.25)
Lighted field		
Yes	−.44	.64 (.19–2.22)
Total number of sports played (0–9 is reference)		
10–24	1.52	4.57 (.77–27.13)
Educational level (<college is reference)		
College	1.36	3.79 (.54–27.75)
% Done in-house (<50% is reference)		
≥50%	.76	2.14 (.30–15.39)
Adequate resources		
No	.07	1.08 (.24–4.81)

*$p < .05$ (two-tailed); **$p < .01$ (two-tailed).

practices were 9.17 times as likely as fields not receiving such practices to have pesticides applied. This is possibly an indication that the better monitoring and pesticide use both were related to a larger budget for, or more attention to, field maintenance (See Table 3).

The total number of sports played and proximity to farmland approached significance ($p = .095$ and .109, respectively). As the number of sports played on the field increased and the closer to farmland the field was, the likelihood of applying pesticides increased.

A follow-up analysis was to enter combined cultivation practices and population density into one model to see if prediction of pesticide use improved. Population density predicted pesticide use (rural compared to urban and suburban $p < .01$) and, although not significant by itself ($p = .06$), combined cultivation practices improved prediction of pesticide use beyond the model that included only population density ($X^2(1) = 12.583$, $p < .01$) (See Table 4).

Discussion

This study is the first to characterize and quantify the potential for pesticide exposure from application of pesticides to athletic fields. Specifically, this study furthers understanding of the factors associated with pesticide application on athletic fields.

This study found that pesticides were applied to 65% of fields; herbicides were applied to 57% of those fields. The most commonly named herbicide was Roundup (glyphostate). Roundup is a general use postemergent herbicide used mainly for eliminating weeds in cracks on paved surfaces and around fences and structures so that personnel do not have to use weed-eaters. Although acute exposure to Roundup causes irritation of skin, mucous membranes, and respiratory system, chronic exposure is associated with errors in DNA transcription and higher rates of hyperactivity and attention deficit disorder. (Bolognesi et al., 2009; Marc et al., 2005, Garry et al., 2002). DNA is the basic building block of everything in the cell and interference with transcription could alter cellular structure and function and lead to dysfunction, disease, or death.

TABLE 4. *Generalized Estimating Equations Analysis of the Contribution of Both Combined Cultivation Practices and Population Density to Pesticide Use with Fields Nested within Field Managers (n =* 101 Fields)

Variable	*B*	OR (95% CI)	X^2 for Change QICC
Population density (rural is reference)			
Urban	−4.01	.018 (.00–.17)**	12.58 [$X^2(1)$ = 12.58]**
Suburban	−1.89	.152 (.05–.51)**	
Combined cultivation practices			
Yes	2.01	7.463 (.92–62.50)	

**$p < .01$ (two-tailed).
QICC, corrected quasi likelihood under independence model criterion.

Given what is known about pesticides and their associated health risks, particularly for pregnant women and children combined with the results of this study, there is support for invoking the precautionary principle (ANA, 2003) regarding pesticide use on children's playing fields. The precautionary principle states "that if it is within one's power, there is an ethical imperative to prevent rather than merely treat disease, even in the face of scientific uncertainty." (p. 1)

In this study, population density and certain cultivation practices (soil testing, aeration, and over-seeding) predicted pesticide application. In rural areas pesticides were more likely to be applied. This could be related to the agricultural nature of rural areas and comfort with pesticide use. Also use of cultivation practices may have been related to budget available for both the maintenance of the fields and for chemical purchase.

There are several policy implications related to pesticide use on athletic fields. One such policy is to require an Integrated Pest Management (IPM) plan for all athletic fields. As defined by Beyond Pesticides, IPM "utilizes pest prevention and management strategies that exclude pests from school facilities through habitat modification, entry way closures, structural repairs, sanitation practices, natural organic management of playing fields and landscapes, other non-chemical, mechanical and biological methods, and the use of least-toxic pesticides only as a last resort" (Owens, 2009). An IPM program also includes a notification component, even if no pesticides are used. (See Box 1 for an outline of steps for an outdoor IPM program).

Box 1 Steps for an outdoor IPM program (US EPA, 2009)

- Detection and monitoring
  - Develop background on local pests
  - Gather background data on the site
  - Develop pest tolerance levels
  - Evaluate pest management practices
- Management options
  - Reduce stressful conditions to prevent infestations
  - Maintain healthy soil
  - Plant appropriate grass species
  - Reduce soil compaction
  - Raise mower height
  - Careful irrigation
  - Keep thatch to a minimum
  - Fertilize with restraint
  - Direct pest suppression
    - Physical
    - Biological
    - Chemical (using lowest toxicity option first)

In 2009, 35 states including Maryland had IPM policies for schools (Owens, 2009), but they were not uniform in their content or enforcement. Some only covered the building and not the grounds. These existing policies need to be enforced and extended to private and non-school-based playing and athletic fields. In MD, for example, there is no mention of athletic fields in the School IPM regulations from the MD Department of Agriculture.

Such changes in pesticide use policy have the potential to improve health of workers, athletes, and observers, thereby reducing health care costs and missed work and school days. Example of a national policy is School IPM 2015 (2009), which is a strategic plan to implement IPM programs in all school districts nationally by 2015. This policy has yet to be adopted.

Two potential models for non-school playing fields could be the Ontario (Canada) ban on "cosmetic" pesticides (Ministry of the Environment, 2009) or the Quebec (Canada) ban on lawn maintenance pesticides (Pesticide Management Code, 2003). Cosmetic pesticides are landscape chemicals used solely to improve appearance. Several US cities also have a policy that bans pesticide use on government properties like public parks and fields. Greenwich, CT (Blake, 2008) and Marblehead, MA (Goodman et al., 2005) are examples that can be used as models.

In addition to policy changes, changes in education and practice can increase the use of IPM and decrease pesticide use. An IPM education and training program for field managers could be implemented with follow-up evaluation to see if behavior change has occurred. School nurses can be vital in educating the stakeholders about IPM and advocating for its use in schools; public health nurses could do the same for non-school fields.

The purpose of this study was to begin to understand the extent to which pesticides are used by assessing athletic field maintenance practices. Data were collected via phone interview or via email from 33 field managers reporting on 101 fields. The strengths of this study include a data collection tool that was administered over the phone or via email to meet the time constraints and convenience for the field managers. For the most part the responders were open to sharing information.

Some of the limitations were consistent with other descriptive studies. By nature of descriptive design and the small sample size, it is not possible to generalize findings beyond Central Maryland or to meet the assumptions necessary to establish causality. The significant differences between responders and non-responders in density, jurisdiction, category of field, and school level of school fields limits generalizability. Also the study was slightly underpowered as is evident from the wide confident intervals. Results that approached significance may prove statistically significant in a larger sample.

Future research

Further research using this exposure assessment method can assist in documenting levels of pesticides children are exposed to and in creating policies regarding IPM and the amount of time to wait before using the fields. In this study, population density and combined cultivation practices were significant predictors of increased pesticide use. As a next step, the study area could be expanded beyond Central Maryland to see if the results remain the same. Another extension of this study would be to estimate actual exposures on the playing fields by assessing time spent on the field and using personal monitoring, such as air monitoring and urine samples.

Implications for Nursing

Education. Nurses play a combined role in education and advocacy, both for individuals and for communities. Findings from this study can be used by school nurses and others to educate local government officials, field maintenance personnel and the general public on health effects related to pesticides and non-toxic management of lawns and playing fields. School nurses and public health nurses, can develop presentations and educational materials like flyers, brochures, and bulletin boards for schools, PTA's, field maintenance personnel and others.

Practice. As individuals, nurses can implement IPM programs in their homes and yards. Professionally, school nurses and public health nurses can investigate if there are environmental teams at the schools or in the community and if they are addressing the issue of pesticide use on athletic fields. Nurses could join or help form them and encourage working toward implementing IPM programs on playing fields and throughout the community. Also, as noted by Rudant and colleagues (Rudant et al., 2007), anticipatory guidance regarding avoiding hazardous pesticides, safer chemicals, and integrated pest management (IPM) are important for nurse midwives, obstetricians, pediatric nurse practitioners, and pediatricians.

Policy. There are a number of levels at which policies might be developed about pesticide use on playing fields – at the institutional, local government or federal level. School nurses, public health nurses, and nurses in citizen roles (coaches, parents) can advocate for policies through a variety of avenues. These include letters to the editor, press conferences, testimony at the state and federal level, and via state and national nursing organizations to pass resolutions (American Public Health Association, American Nurses Association, and State Nursing Associations).

This study was a first step in assessing another area of potential pesticide exposure for children related to athletic field maintenance practices, including the factors that were related to pesticide use. Findings from this study suggest the need for education and policy changes to protect users of the fields and for further research into exposures to pesticides on athletic fields.

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