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Exposure to gun violence and asthma among children in Puerto Rico

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Summary
Background and objectives: Although community violence may influence asthma morbidity by increasing stress, no study has assessed exposure to gun violence and childhood asthma. We examined whether exposure to gun violence is associated with asthma in children, particularly in those reporting fear of leaving their home.
Methods: Case-control study of 466 children aged 9–14 years with (n = 234) and without (n = 232) asthma in San Juan, Puerto Rico. Lifetime exposure to gun violence was defined as hearing a gunshot more than once. We also assessed whether the child was afraid to leave his/her home because of violence. Asthma was defined as physician-diagnosed asthma and wheeze in the prior year. We used logistic regression for the statistical analysis. All multivariate models were adjusted for age, gender, household income, parental asthma, environmental tobacco smoke, prematurity and residential distance from a major road.
Results: Cases were more likely to have heard a gunshot more than once than control subjects (n = 156 or 67.2% vs. n = 122 or 52.1%, $P < 0.01$). In a multivariate analysis, hearing a gunshot more than once was associated with asthma (odds ratio [OR] = 1.8, 95% confidence interval [CI] = 1.1–1.7, P = 0.01). Compared with children who had heard a gunshot not more than once and were not afraid to leave their home because of violence, those who had heard a gunshot more than once and were afraid to leave their home due to violence had 3.2 times greater

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odds of asthma (95% CI for OR = 2.2–4.4, P < 0.01).
Conclusions: Exposure to gun violence is associated with asthma in Puerto Rican children, particularly in those afraid to leave their home. Stress from such violence may contribute to the high burden of asthma in Puerto Ricans.

Introduction

Asthma is the most common chronic disease of childhood in the United States (U.S.). In this country, asthma causes 46.7 million school, work and activity days lost per year [1]. For unclear reasons, there is marked racial or ethnic variability in asthma morbidity. Compared with non-Hispanic whites, Puerto Ricans and African Americans have greater morbidity from asthma [2].

Puerto Ricans are often exposed to violence in their communities [3–5]. Moreover, current evidence suggests that Puerto Ricans are particularly susceptible to developing psychosocial stress after exposure to violent events [6,7]. For example, Puerto Ricans were more likely to have post-traumatic stress disorder (PTSD) symptoms or panic attacks after September 11th of 2001 than members of other ethnic groups [6]. Increased stress resulting from exposure to violent or traumatic events (such as physical or sexual abuse) may partly explain the high burden of childhood asthma in Puerto Ricans [5,8].

The U.S. has the highest rate of firearm-related deaths of all industrialized countries [9]. The recent and highly publicized mass shootings in Newtown, CT; Aurora, CO; Oak Creek, WI; and Tucson, AZ, have raised concerns about harmful effects of firearms. Fatal and nonfatal firearm violence not only poses a serious threat to public safety, but may have detrimental effects on both psychiatric and somatic health [10].

We previously reported that exposure to violence at the individual or community level is associated with asthma in Puerto Rican children [5,8]. On the basis of these findings, we hypothesized that exposure to gun violence (a severe form of violence) affects asthma risk in Puerto Rican children. Moreover, we hypothesized that this detrimental effect is worse in children expressing fear related to violence. To test these hypotheses, we examined exposure to gun violence and asthma in 466 Puerto Rican children with (n = 234) and without (n = 232) asthma living in San Juan (Puerto Rico).

Methods

Subject recruitment

From March of 2009 to June of 2010, children in San Juan (PR) were chosen from randomly selected households, as previously described [11]. In brief, households in metropolitan San Juan were selected using a multistage probability sample design [11]. Primary sampling units (PSUs) were randomly selected neighborhood clusters based on the 2000 U S. census, and secondary sampling units were randomly selected households within each individual PSU. A household was eligible if ≥1 resident was a child 6–14 years old. Of the 7073 eligible households, 6401 (91%) were contacted. Of these 6401 households, 1111 had at least one child who met inclusion criteria: age 6–14 years, four Puerto Rican grandparents (to ensure Puerto Rican descent) and residence in the same household for at least one year. Of these 1111 households, 438 (39.4%) had ≥1 eligible child with asthma (a case, defined as having physician-diagnosed asthma and at least one episode of wheeze in the prior year). From these 438 households, one child with asthma was selected (at random if there was more than one such child). Similarly, only one child without asthma (a control subject, defined as having neither physician-diagnosed asthma nor wheeze in the prior year) was randomly selected from the remaining 673 households. In an effort to reach a target sample size of ~700 children (which would give us ≥90% power to detect an odds ratio ≥2 for exposures with a prevalence ≥25%), we attempted to enroll a random sample (n = 783) of these 1111 children. Parents of 105 (13.4%) of these 783 children refused to participate or could not be reached, leaving 678 study participants (351 cases and 327 control subjects). There were no significant differences in age, gender, or area of residence between eligible children who did (n = 678) and did not (n = 105) agree to participate. Of the 678 study participants, 472 were aged 9 years and older, and thus eligible to complete a questionnaire on exposure to violence; 466 (98.7%) of these 472 children completed this questionnaire and are included in the current analysis (see below).

Study procedures

Study participants completed a protocol that included questionnaires and collection of blood samples. The child's mother completed a questionnaire on the child's respiratory and general health, which was used to obtain information about demographics, socioeconomic status, family history, and exposure to environmental tobacco smoke (ETS) [12]. Exposure to violence was ascertained using a modified version of the Survey of Children's Exposure to Community Violence (ETV), which was designed for children older than 8 years [13]. Children ages 9 years and older completed this ETV Survey and another questionnaire on perceived neighborhood safety, and were thus included in this analysis [14–16]. The ETV survey specifically measures both witnessing and direct victimization for five specific events: (a) shoving, punching or kicking; (b) knife attacks; (c) shootings; (d) hearing gunshots; and (e) witnessing verbal abuse of their primary caregiver (see Table E1 in the

online supplement). The survey also accounts for event circumstance information, including events occurring more than once [15]. Internal consistency, test-retest reliability and validity have been established for both the English and Spanish versions [17].

Serum levels of IgE specific to common allergens (dust mite [Der p 1], cockroach [Bla g 2], cat dander [Fel d 1], dog dander [Can f 1], and mouse urinary protein [Mus m 1]) were determined by using the UniCAP 100 system (Pharmacia & Upjohn, Kalamazoo, Mich). For each allergen, an IgE level of 0.35 IU/mL or greater was considered positive.

Written parental consent was obtained for participating children, from whom written assent was also obtained. The study was approved by the Institutional Review Boards of the University of Puerto Rico (San Juan, PR), Brigham and Women's Hospital (Boston, MA), and the University of Pittsburgh (Pittsburgh, PA).

Statistical analysis

Our primary outcome was asthma, defined as physician-diagnosed and at least one episode of wheeze in the previous year. Our exposure of interest was hearing gunshots (a marker of gun violence). Of the questions used to generate the score from the ETV Survey that we previously linked to asthma (Table E1) [5], the only individual question significantly associated with asthma was that on hearing gunshots. For this analysis, the variable "hearing a gunshot" was first analyzed as categorical (0 = never, 1 = once, or 2 = more than once). Given that the number of children in each of the first two categories (never hearing a gunshot or hearing a gunshot once) was relatively small, and that the estimated effect of either of these two categories on asthma was similar, the variable "hearing a gunshot" was analyzed as binary (hearing a gunshot not more than once vs. hearing a gunshot more than once). Because exposure to violent or traumatic events is likely to be most detrimental in children with highest resulting stress, we also examined whether a combination of hearing a gunshot more than once and being afraid to leave home because of violence is associated with asthma. In this analysis, a composite score was categorized as: 1) 0 if the child was not afraid to leave home because of violence and reported hearing a gunshot not more than once, 2) 1 if the child was either afraid to leave home because of violence or reported hearing a gunshot more than once, but not both, and 3) 2 if the child was afraid to leave home because of violence and reported hearing a gunshot more than once.

Bivariate analyses were conducted using Fisher's exact tests and two tailed t-tests, as appropriate. Logistic regression was used to examine the relation between exposure to gun violence and asthma while adjusting for potential confounders. Because of their potential correlation with gun violence and asthma, the following covariates were examined in bivariate analyses: age, gender, parental history of asthma (paternal or maternal), parental education (at least one parent completed high school vs. none), household income (<vs. $\geq$ $15,000 [near the median income for households in Puerto Rico in 2008–2009]) [11], prematurity [21], distance from the child's residence to a major road (a marker of traffic-related air pollution) [19], exposure to ETS in early life (*in utero* or before age 2 years), current exposure to ETS [20], and being afraid of leaving the home because of violence (from the perceived neighborhood safety questionnaire). A stepwise approach was used to build the multivariate models. All final models included age, sex, household income, prematurity, and parental history of asthma. Other covariates (see above) remained in the final models if they were significant at $P < 0.05$ or if they satisfied a change in estimate criterion ($\geq$10%) in the parameter estimate (β coefficient). Since risk factors for atopic asthma may differ from those for non-atopic asthma [21], we tested for an interaction between exposure to gun violence and atopy (defined as at least one positive IgE to common allergens) in the final models. SAS version 9.2 (SAS Institute, Cary, NC) was used for all analyses.

Results

The main characteristics of the 466 study participants are summarized in Table 1. Compared with control subjects, children with asthma (cases) were slightly and significantly younger, and also significantly more likely to be: male, premature, atopic, exposed to ETS currently or in early life, and afraid to leave their home because of violence. Cases were also more likely to have a parental history of asthma, to live closer to a major roadway, and to have heard a gunshot more than once during their lifetime. There were no significant differences in household income, parental education or breastfeeding between cases and control subjects.

Table 2 shows the multivariate analysis of the relation between hearing a gunshot more than once and asthma. In an analysis adjusting for household income, current exposure to ETS and other covariates, hearing a gunshot more than once was significantly associated with 1.8 times greater odds of asthma (Model 1). We then repeated the analysis after additional adjustment for being afraid to leave home because of violence, obtaining similar results (Model 2).

We next examined the relation between the composite score (for hearing gunshots and fear of violence) and asthma. Compared to children with a composite score of 0, those with composite scores of 1 and 2 were more likely to have asthma (Fig. 1). In a multivariate analysis, each 1-point increment in the composite score was significantly associated with 1.6 times greater odds of asthma (Table 3). In this analysis, children who were afraid to leave home because of violence and reported hearing a gunshot more than once (e.g. a score of 2) had 3.2 times higher odds of asthma than those who heard a gunshot no more than once and were not afraid to leave their home because of violence (e.g. a score of 0).

We found a non-statistically significant trend for an interaction between the composite score (for hearing gunshots and fear of leaving the home due to violence) and at least one positive IgE to allergens (atopy, $P = 0.15$). Given previous findings and our priori hypothesis [21], we conducted an exploratory multivariate analysis after stratification by atopy (Table 4). In this analysis, each 1-point increment in the composite score was significantly associated with 1.9-fold increased odds of asthma and at

Table 1 Main characteristics of participating children (n = 466)[b].

Covariate	Controls (n = 234)	Cases (n = 232)
Age (years)	11.8 (1.8)	11.5 (1.8)*
Female gender	126 (53.9)	103(44.4)*
Household income ≥$15,000/year	96 (42.3)	84 (36.4)
At least 1 parent graduated from high school	196 (83.8)	193 (83.2)
Maternal history of asthma	49 (21.2)	115 (49.8)**
Paternal history of asthma	33 (14.7)	70 (32.1)**
Parental history of asthma	74 (31.8)	151 (65.1)**
Early-life exposure to ETS	91 (39.1)	113 (48.7)*
Current exposure to ETS	78 (33.3)	100 (43.1)*
Prematurity	11 (4.8)	22 (9.6)*
Breastfeeding		
Never	104 (45.6)	108 (46.8)
<6 months	93 (40.8)	84 (36.4)
≥6 months	31 (13.6)	39 (16.9)
At least one positive IgE to allergens (atopy)[a]	109 (52.9)	145 (71.8)**
Residential distance from a major roadway (meters)	398 (305)	329 (272)**
Heard a gunshot (lifetime)		
Never	72 (30.8)	48 (20.7)**
Once	40 (17.1)	28 (12.1)**
More than once	122 (52.1)	156 (67.2)**
Afraid to leave home because of violence	47 (20.1)	63 (27.3)

Definition of abbreviation: ETS = Environmental tobacco smoke.
P value for comparison between cases and controls: *<0.05, **<0.01.
[a] Shown as percentage of the cases (n = 206) and control subjects (n = 202) with available measurements for IgE to allergens.
[b] Values are shown as No. (%) for binary variables or mean (standard deviation) for continuous variables.

Table 2 Analysis of the relation between hearing gunshots and asthma in Puerto Rican children.

Covariate	Odds ratio (95% confidence interval), P value	
Unadjusted analysis		
Hearing a gunshot more than once	1.9 (1.3–2.7), <0.01	
Afraid to leave home due to violence	1.5 (1.0–2.3), 0.07	
Multivariate analysis[a]	Model 1	Model 2
Hearing a gunshot more than once	1.8 (1.1–2.7), 0.01	1.7 (1.1–2.7), 0.01
Afraid to leave home due to violence	–	1.4 (0.9–2.3), 0.19
Household income ≥$15,000/year	1.1 (0.7–1.7), 0.74	1.1 (0.7–1.7), 0.73
Parental (paternal or maternal) history of asthma	4.2 (2.8–6.4), <0.01	4.3 (2.8–6.6), <0.01
Prematurity	2.4 (1.1–5.4), 0.04	2.4 (1.0–5.4), 0.04
Current environmental tobacco smoke	1.2 (0.8–2.0), 0.37	1.2 (0.8–1.9), 0.38
Residential distance from a major roadway (per every 100 m)[b]	1.1 (1.0–1.2), 0.04	1.1 (1.0–1.2), 0.04

[a] All multivariate models were adjusted for age and gender, in addition to the covariates listed in each column.
[b] Per every 100 m closer to a major roadway, the odds of asthma increase by ~10%.

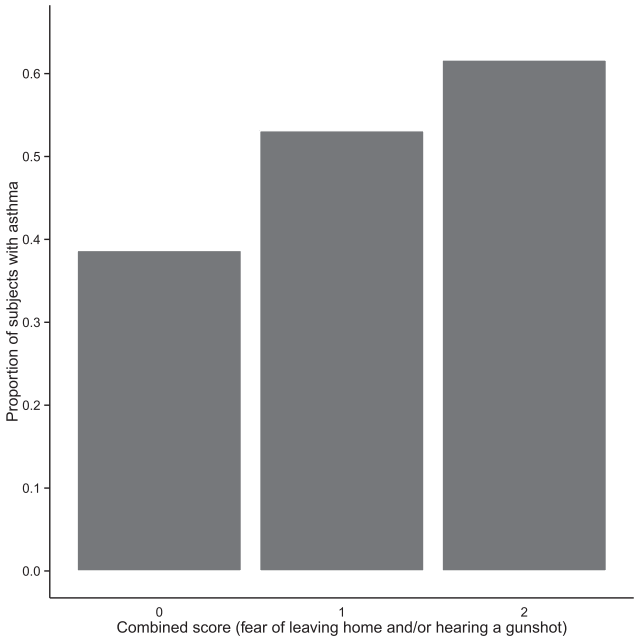

Figure 1 Proportion of subjects with asthma in each of three groups of children: 0) heard a gunshot not more than once and is not afraid to leave home because of violence, 1) either heard a gunshot more than once or is afraid to leave home because of violence, and 2) heard a gunshot more than once and is afraid to leaving home because of violence.

least one positive IgE to allergens (atopic asthma, $P < 0.01$). In contrast, there was no significant association between the composite score and asthma without at least one positive IgE to allergens (non-atopic asthma).

Discussion

Exposure to community violence has been previously associated with adverse psychological effects in children, such as depression and anxiety [22—24]. We previously showed that physical or sexual abuse in the previous year (a highly traumatic event) is associated with asthma and morbidity from asthma in a separate cohort of Puerto Rican children ages 6—16 years [8]. Those findings were subsequently replicated in a longitudinal study showing that physical abuse during childhood is associated with incident asthma in African American women [25].

More recently, we reported that exposure to violence (assessed as a continuous scale and incorporating answers to eight questions on domestic and community violence) is associated with childhood asthma in Puerto Ricans [5]. In this report, we show that exposure to gun violence (hearing a gunshot more than once) is associated with asthma in Puerto Rican children, even after adjustment for indicators of socioeconomic status, parental asthma, ETS, prematurity and residential proximity to a major road. To our knowledge, this is the first report of a link between exposure to gun violence and asthma.

In the U.S., poverty, racial discrimination and violence are more often experienced by ethnic minority groups who are also disproportionately affected by childhood asthma (e.g. African Americans and Puerto Ricans). Growing evidence strongly suggests that exposure to violence influences the pathogenesis of asthma and asthma morbidity through increased psychosocial stress [26]. In this context, the impact of violence on a child's perceived stress is influenced or modified by the severity and frequency of violent events, and the availability of coping mechanisms (e.g. familial or social support). Ultimately, children with highest perceived stress would thus be at greater risk of asthma. Our results are consistent with this theory, as they suggest synergistic effects of exposure to gun violence and concurrent fear to leave the home as a result (a marker of the impact of violence on the child's daily life).

The mechanisms underlying the link between violence-related stress and asthma are incompletely understood but likely include detrimental effects on the regulation of the hypothalamic-pituitary-adrenocortical (HPA) axis and immune responses [27]. Our finding that exposure to gun violence is associated with atopic asthma (but not with non-atopic asthma) should be interpreted with caution because of the exploratory nature of this analysis. However, this result is interesting and consistent with findings from experimental models and observational human studies which suggest that chronic pre- or post-natal stress enhance Th2 (allergic) immune responses [27—30].

We recognize several limitations of our results. First, ours is a cross-sectional study, and thus temporal

Table 3 Analysis of a composite score (for hearing gunshots and fear of leaving the home because of violence) and asthma.

Covariate	Odds ratio (95% confidence interval), P value	
	Unadjusted	Adjusted[a]
Hearing a gunshot more than once and being afraid to leave home because of violence[b]	1.7 (1.3—2.2),<0.01	1.6 (1.1—2.2), <0.01
Household income $15,000/year		1.1 (0.7—1.7), 0.78
Parental (paternal or maternal) history of asthma[c]		4.4 (2.9—6.7), <0.01
Prematurity		2.3 (1.0, 5.3), 0.04
Current environmental tobacco smoke		1.3 (0.8—2.0), 0.37
Residential distance from a major roadway (per every 100 m)[b]		1.1 (1.0—1.2), 0.047

[a] The multivariate model was adjusted for age and gender, in addition to the variables listed in the table.
[b] Results shown as odds of asthma per 1-point increment in the combined score of hearing a gunshot more than once and being afraid of leaving home because of violence (0 = neither event, 1 = either event, 2 = both events). Thus a child with a score of 2 would have, on average, 3.2 greater odds of having asthma than a child with a score of 0.
[c] Per every 100 m closer to a major roadway, the odds of asthma increase by ~10%.

Table 4 Analysis of a composite score (for hearing a gunshot more than once and fear of leaving the home because of violence) and asthma, stratified by atopy (at least one positive IgE to allergens). [a]

Covariate	Asthma and ≥1 positive IgE to allergens		Asthma and no positive IgE to allergens	
	Odds ratio (95% CI), P value			
	Unadjusted	Adjusted[b]	Unadjusted	Adjusted[b]
Hearing a gunshot more than once and/or afraid to leave home because of violence[c]	1.8 (1.2–2.6), <0.01	1.9 (1.2–3.0),<0.01	1.3 (0.8–2.2), 0.28	0.8 (0.4–1.6), 0.56
Household income <$15,000/year		1.4 (0.8–2.7), 0.27		0.7 (0.3–1.6), 0.37
Parental (paternal of maternal) history of asthma		4.5 (2.5–8.1), <0.01		5.0 (2.3–11.1), <0.01
Prematurity		7.1 (1.9, 27.2), <0.01		0.4 (0.1, 2.1), 0.26
Current environmental tobacco smoke		1.3 (0.7–2.3), 0.47		1.9 (0.8–4.3), 0.12
Residential distance from a major roadway (per every 100 m)[d]		1.1 (0.9–1.2), 0.14		1.1 (0.9–1.2), 0.28

[a] 408 (87.6%) of the study participants (206 cases and 202 control subjects) had available measurements for IgEs to allergens, and are thus included in this analysis.
[b] The multivariate models were adjusted for age and gender, in addition to the variables listed in the table.
[c] Results shown as odds of asthma per 1-point increment in the combined score of hearing a gunshot more than once and being afraid of leaving home because of violence (0 = neither event, 1 = either event, 2 = both events).
[d] Per every 100 m closer to a major roadway, the odds of asthma increase by ~10%.

relationships cannot be established. For example, we cannot separate potential effects of prenatal exposure to gun violence from those in early childhood or at school age. Second, selection bias is possible in any observational study such as ours. However, selection bias is an unlikely explanation for our results, both because of a probabilistic sampling study design and a high participation rate (~87%), with nonstatistically significant differences in key characteristics between children who did and did not agree to participate. Third, we cannot exclude confounding by variables not measured in this study, such as physical or sexual abuse. However, abuse was relatively uncommon in a prior study [8], and our results were unchanged after accounting for potential confounders such as indicators of socioeconomic status, ETS, prematurity and residential proximity to a major roadway (which is strongly correlated with traffic-related air pollution). Moreover, we found nearly identical results in a confirmatory analysis adjusting for the average income of the child's neighborhood (derived from census data) instead of the child's household income (data not shown). Fourth, recall bias is possible in a cross-sectional study such as ours. Although the main study question may not differentiate well between those who never heard a gunshot and those who heard a gunshot only once, it is very likely that children who heard a gunshot at least twice have been more frequently exposed to gun violence. Since misclassification of the first two categories of exposure (never vs. once) is likely non-differential (and thus would bias our results toward the null hypothesis), recall bias is an unlikely explanation for our findings. Finally, our results may not be generalizable to non-Puerto Rican children. However, our findings are relevant to underserved children who are disproportionately exposed to gun violence.

Firearm violence is an important public health and safety issue in the U.S [9,31]. Our findings merit replication in longitudinal studies of Puerto Rican children and in children from other disadvantaged groups in whom exposure to violence from firearms and asthma are common (e.g., African Americans).

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Conflicts of interest

The authors have no conflicts of interest to disclose.

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Appendix A. Supplementary data

Supplementary data related to this article can be found at http://dx.doi.org/10.1016/j.rmed.2015.05.011.

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