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A randomized trial of a one-time pest intervention: impact on childhood asthma outcomes

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ABSTRACT

Objectives: To evaluate the effects of a one-time, apartment-level Integrated Pest Management (IPM) intervention on healthcare utilization and asthma symptoms among children with persistent asthma living in households with a pest infestation.

Study design: In a randomized controlled trial of 384 children aged 5–12 years with persistent asthma, we assigned 183 to receive IPM and 197 to usual care (UC). The primary outcome was healthcare utilization from hospital and Medicaid claims records. Secondary outcomes included caregiver-reported asthma symptoms, pest infestation levels, missed days of school due to asthma, and rescue medication use.

Results: The entire cohort improved over the study period, with significant but equivalent declines in mean healthcare utilization in both groups. IPM group had fewer days with reduced activity due to asthma ($p=0.04$) and larger declines that fell short of statistical significance in asthma symptom days ($p=0.22$), severe symptoms ($p=0.16$), missed school ($p=0.27$) and rescue medication use ($p=0.27$). Both roach ($p=0.001$) and mice ($p=0.11$) infestations decreased much more in the IPM group than the UC group.

Conclusions: After a one-time, apartment-level IPM intervention, we found no difference in health care utilization, but fewer days of reduced activity and consistent suggestive evidence of clinically meaningful improvements relative to usual care across other secondary outcomes. Coupled with the established effectiveness of IPM in reducing allergens and scientific consensus on pest-related allergens as asthma triggers, these findings support adding home pest control to traditional medical management of children with severe asthma.

Abbreviations: IPM: Integrated Pest Management; UC: Usual Care; NYC: New York City; DOHMH: Department of Health and Mental Hygiene; PMP: Pest Management Professional

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Introduction

Asthma disproportionately affects poor urban children of color nationwide (1), and both income- and race-based inequities are seen in asthma prevalence and severity among New York City (NYC) neighborhoods (2–4). Disparities in asthma outcomes are driven partly by differences in household-level asthma triggers, such as pests—cockroaches and mice—which are more common in low-income, deteriorating housing (5–8). Children with asthma who live in households with pests have worse health outcomes, ranging from more asthma symptom days to increased healthcare utilization (9–11).

Addressing pests as a household trigger requires not only eliminating current infestation, but also preventing its recurrence. Integrated pest management (IPM) is a prevention-focused method that effectively reduces both pests and allergens (12). A NYC public housing study found sustained allergen reduction at 6- and 9-months for a building-wide IPM intervention (13). Several multifaceted asthma management interventions with pest control have improved asthma outcomes for children (14–17). However, such interventions are resource-intensive and frequently require delivery by trained community health workers. IPM could be effectively delivered by the pest control

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Portions of the study were presented at the Pediatric Academic Societies annual meeting May 6–9, 2017, San Francisco, California, and the Interdisciplinary Association for Population Health Science Conference, October 5, 2018, Washington, District of Columbia.

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industry for lower cost per household as a complement to existing clinical interventions. Recent national and state Medicaid reform has opened new pathways for reimbursement of nontraditional medical interventions; however, the medical sector can only intervene at the household level. To our knowledge, only two studies have tested the direct impact of an apartment-level pest control interventions on children's asthma outcomes with conflicting results (8,18).

Our primary study objective was to evaluate a one-time, apartment-level IPM intervention on healthcare utilization and asthma symptoms among children with persistent asthma living in households with a pest infestation.

Methods

Study design and oversight

The NYC Department of Health and Mental Hygiene (DOHMH) and the Montefiore Medical Center (MMC) conducted a 2-year prospective, waitlisted, randomized controlled trial (RCT) of children with persistent asthma from the Bronx and Manhattan, NYC, between May 2014 and June 2016 (ClinicalTrials.gov: NCT02700542). The institutional review boards at both institutions approved the study protocol.

Participants

Children aged 5–12 years with asthma diagnosis were identified from MMC's patient database and member databases of two Medicaid managed care organizations, Healthfirst and Affinity Health Plan (AHP). Trained interviewers contacted families by phone for eligibility screening and informed consent, including assent for children aged 7–12. Inclusion criteria were persistent asthma per national guidelines (19), caregiver report of ≥ 1 past-year asthma-related ED visit or hospitalization, caregiver-reported home cockroach or mouse infestation, living in the Bronx or Northern Manhattan, spending ≥ 4 nights per week in the intervention home, and having no plans to move within 3 months of recruitment. Children living in foster care or shelters were excluded.

Study procedures

We randomized study participant identification numbers 1–400 into the two study groups (one-time, apartment-level IPM or usual care (UC)) before beginning recruitment using the SAS SURVEYSELECT

procedure. After consent, new participants were entered into the study database and assigned the next participant ID with its pre-selected study group using an automated procedure. The UC group was offered IPM after their 12-month assessment. Interviewers conducted structured baseline, 6-month and 12-month telephone interviews with caregivers about the child's asthma symptoms, current medications, and demographic information, including child's gender, date of birth, and race/ethnicity; caregiver's level of education and employment; and household characteristics, such as pest infestation. We assessed caregivers' well-being using the Pediatric Asthma Caregiver Quality of Life (QoL) Emotional Scale (20). Caregivers received \$20 for each completed interview. We obtained electronic medical record data on healthcare utilization from MMC for participant patients and Medicaid claims data from AHP and Healthfirst for participant members.

Integrated pest management intervention

The intervention was delivered in 2 home visits by a contracted pest management professional (PMP). The work followed the DOHMH IPM Intervention for Children with Asthma Protocol [available upon request], developed based on literature review (13,21–24) and in consultation with PMPs. On the first (assessment) visit, the PMP inspected and documented observed evidence of cockroaches or mice and conditions conducive to pests, including access, and potential pest food, water and shelter. The protocol required kitchen and bathroom inspection, but pest activity observed anywhere was recorded. The PMP brought any conditions requiring repair or sanitation measures outside the protocol's scope of work to the family's attention. The PMP also placed pest monitoring devices (sticky traps) in pest-prone areas, and educated the family on pest management, sanitation best practices and preparation for the treatment visit (e.g. removing items from cabinets).

The second (treatment) visit—scheduled on average 15 days (range: 0–189) after the first—included: documenting, removing and replacing sticky traps; intensive cleaning and removal of pests and pest evidence; removal of pest harborage areas; and sealing of cracks, crevices, gaps in cabinetry, and access points with pest-resistant materials to prevent future infestations. Subsequently, the PMP used reduced-risk pesticides in areas inaccessible to children or pets to control any remaining cockroaches. Homes with severe infestations ($N=13$) received an additional visit to bring

conditions to a level consistent with scope. The PMP also reviewed completed work and steps to prevent re-infestation with the family.

Outcomes

Mean asthma healthcare utilization was defined as the number of ED visits or hospitalizations with a primary diagnosis of asthma [International Classification of Diseases 9 (493) or 10 (J45)]. Mean asthma symptom days was defined as the maximum days from 3 questions about daytime symptoms, nighttime symptoms, and reduced activities due to asthma in the past 14 days, as in similar studies (14,16). Other secondary outcome measures included percent of severe symptoms, defined as ≥ 8 symptom days in the past 14 days; mean daytime and nighttime symptom days; mean days of reduced activity due to asthma; mean days with use of rescue medication in the past 14 days; and mean missed school days due to asthma in the past 30 days. We measured pest infestation with reported mean daily number of cockroaches and percent reporting signs of mice in the past 3 months, as well as percent professional pest control (other than intervention) in the past 3 months.

Statistical analysis

Study power calculations indicated that a sample size of 126–241 per group would be sufficient to detect a 15–20% difference at 80% power and $\alpha = 0.05$ between groups in the change over time in mean healthcare utilization. We assessed differences in caregiver, child and household characteristics between IPM and UC groups at baseline using Chi-square tests for categorical variables and T-tests for continuous variables.

We examined differences in outcome variables between IPM and UC groups at each time-point, as well as the change in the IPM-UC difference over time. For symptom day analyses, we employed multiple imputation methods (11 iterations) (25) under the missing-at-random assumption to impute daytime and nighttime symptom days and days of reduced activity, from which we calculated asthma symptom days and severity for participants with at least 1 completed assessment but missing symptom data at any time-point. For count variables, we employed a negative binomial regression model with log-link function to account for between subject heterogeneity. We used generalized linear model with a logit link function for dichotomous outcomes. Generalized estimating

equations (GEE) method accounted for the within-family correlation given siblings in 23 participating families, as well as the within-subject correlation for multiple assessments of subjects (26). Model predictors included: group (IPM vs. UC), 6- and 12-month time indicators (vs. baseline), group-by-time interaction term, and characteristics differing by group at baseline: caregiver QoL, employment, and having controller medication. For asthma outcomes, we also adjusted for asthma seasonality (local severity by time of year) with smoothed syndromic surveillance counts of asthma ED visits for Bronx children aged 5–12. For pest outcomes, we controlled for season of assessment as proxy for infestation seasonal variation (27,28).

For all models, we reported regression coefficients of group-by-time interaction terms and corresponding 95% confidence intervals (CI) with Type 3 p values obtained from the joint test of intervention effects for both time points. The interaction regression coefficient is the logarithm of the IPM:UC group ratio of rate ratios for count variables and of odds ratios for dichotomous variables, showing the “difference in differences” magnitude of the IPM intervention effect. We also presented the mean differences at each follow-up point based on raw data to aid in interpretation of findings. For outcomes that reflect deterioration of health such as symptom days and healthcare utilization, a negative regression coefficient indicates a larger decline in the IPM than UC group. We used the intention-to-treat principle for all outcomes. All analyses were completed using SAS 9.1, and we considered a 2-tailed p values < 0.05 as statistically significant.

Results

From a pool of 2,030 potential participants, we conducted the eligibility screen for 1,128 children, of whom 490 were eligible (Figure 1). We consented and randomized 393 children (80.2% of those eligible) and 384 children (360 families) completed the study (97.7% of those randomized). Caregivers of 377 participants completed at least 1 assessment, 300 (78.1%) completed all 3 assessments, and we obtained health utilization data for 383 participants. Of the 179 IPM group families, 140 (78%) received the intervention before their final assessment.

The children were primarily Hispanic (61.1%) or non-Hispanic black (35.5%) with a mean age of 8.0 years. The majority (86.0%) had government health insurance, and 10.1% were uninsured sometime during the past year. Two thirds (67.3%) of participants

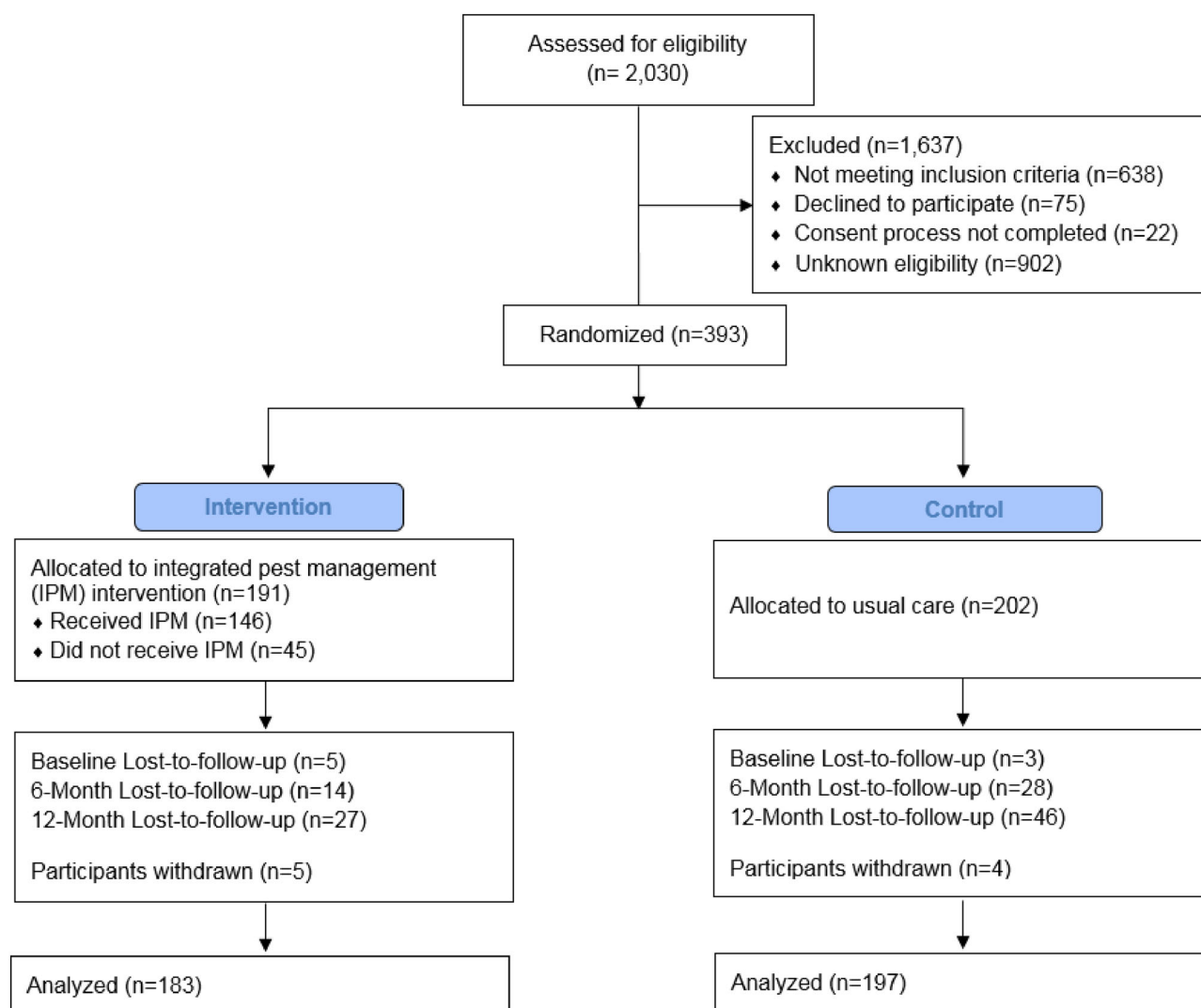


Figure 1. Consort diagram: New York City Asthma and Pest Control Study.

lived with at least one employed caregiver, and 54.5% lived in households with incomes below the federal poverty level. Participants had a mean of 0.8 asthma ED visits and hospitalizations during their baseline year. Although all caregivers reported past-year asthma healthcare utilization at eligibility, 117 (31%) participants had no visits in medical records during the baseline year—evenly distributed between the study groups. Participants had a mean of 5.8 asthma symptom days in the past 14 days, with 29.4% having severe symptoms, and they missed an average 1.9 days of school due to asthma in the past month. Most (83%) had asthma controller medications at home. Nearly 9 in 10 lived in households (89.2%) with cockroach infestations and 70.2% with mice. [Table 1](#) presents baseline study population characteristics by group. Differences were found between groups for only three characteristics. Both caregiver QoL ($p=0.02$) and living with an employed caregiver

($p=0.01$) were lower in UC than IPM group, while the UC group was more likely to have controller medication than the IPM group ($p=0.09$).

Despite overall improvements in mean asthma healthcare utilization, IPM and UC groups had no difference in magnitude of decline ([Table 2](#)). Unadjusted asthma symptom days declined by nearly 1 day more in the IPM than the UC group (2.3 vs. 1.4 day decline) at 12 months ([Figure 2](#)), but adjusted model results fell short of statistical significance ($p=0.22$). We found a greater reduction in the proportion of participants with severe asthma symptoms in the IPM than the UC group at 6 months (beta = 0.64, 95% CI = -0.12, 1.40), but the difference by group attenuated through 12 months. The IPM group had a greater reduction in days with reduced activity due to asthma ($p=0.04$), but we found no differences between groups in daytime or nighttime symptoms. While both groups also improved in missed school days and

Table 1. Baseline characteristics by study group.

	Usual care		Intervention (IPM)		Difference: P-value**
	N*	% or mean	N	% or mean	
Child					
Female	97	49.0	81	43.5	0.29
Mean age	195	7.9	182	8.1	0.45
Race/ethnicity					0.93
Black, non-Hispanic	69	35.8	64	35.2	
Hispanic	118	61.1	111	61.0	
Other	6	3.1	7	3.8	
Government health insurance (Medicaid/Child Health Plus)	157	86.3	151	85.8	0.90
Uninsured current or past 12 months	21	10.8	17	9.4	0.67
Asthma					
Mean asthma symptom days	195	6.0	181	5.6	0.43
Mean daytime symptom days	194	4.6	181	4.2	0.36
Mean nighttime symptoms days	194	3.1	180	2.8	0.48
Mean days with reduced activity due to asthma	189	4.2	178	4	0.72
Severe asthma symptoms	62	31.3	51	27.4	0.40
Mean asthma emergency department visits and hospitalizations (annual rate)	159	0.8	150	0.8	0.87
Current rescue med	194	99.5	181	100	–
Current controller med	168	86.2	144	79.6	0.09
Current ICS	145	74.4	123	68	0.17
Mean days of missed school due to asthma (past month)	183	1.8	177	2	0.62
Pests					
Cockroach infestation	170	89.5	161	89.0	0.87
Mouse infestation	134	69.8	127	70.6	0.87
Both cockroaches and mice	114	59.4	108	60.0	0.90
Professional pest control (past 3 months)	60	31.9	69	39.0	0.16
Caregiver/household					
Household income below federal poverty level	88	57.1	81	51.9	0.36
Less than high-school education	39	20.7	44	24.4	0.17
Single caregiver in home	81	41.5	65	35.9	0.14
Employed caregiver in home	118	61.5	133	73.5	0.01
Live in public housing	29	14.6	35	18.8	0.27
Mean Quality of Life (1 = severe impairment; 5 = no impairment)	187	3.5	179	3.7	0.02

*377 participants completed at least 1 assessment. Presented N excludes missing data for variable.

**T-test for continuous variables; Chi-square test for categorical variables.

rescue medication use, IPM group declines at 12 months were 40% greater for absences and more than double for rescue medication use, but not statistically significant ($p=0.27$ for both). The IPM intervention resulted in a significantly higher and sustained decline in mean daily cockroaches for IPM versus UC group ($p=0.001$). Similarly the percent observing signs of mice declined more than twice as much for the IPM group at 12 months (beta = -0.47 , 95% CI = -1.12 , 0.18). We also found increasing rates of professional pest control in the UC group compared with a decline in IPM group ($p < 0.001$).

Discussion

A one-time, apartment-level IPM intervention resulted in no difference in healthcare utilization improvements but a greater decline in days that children had to slow down or stop activities because of asthma, and findings were suggestive of a greater reduction in severe asthma symptoms at 6 months than usual care. The IPM group declined nearly 1 day more than the UC group in overall symptom days in a two-week period, an improvement found to be clinically

meaningful when observed in other asthma intervention studies (14,29). Similarly, we saw suggestive, though insignificant, evidence of greater reductions in missed school days and rescue medication use in IPM relative to UC group, showing consistency in findings across outcomes.

Most research evaluating in-home interventions for asthma involved multiple visits with pest intervention, coupled with extensive asthma case management (15,16,30). In contrast, our study examined the effectiveness of a stand-alone IPM intervention adjunct to routine medical management. We found only two published studies that have independently calculated the impact attributable specifically to in-home pest control. One study of bait-only cockroach control found fewer symptom days and unscheduled healthcare visits for children in intervention homes (18), although they did not find differences in change over time between study groups. In contrast, our IPM intervention used a prevention-based approach to reduce both cockroaches and mice with measurable impacts on children's symptoms over time. An RCT to examine the effects of IPM targeting mice found no difference in asthma outcomes of children with a

Table 2. Asthma symptom, caregiver impact, and pest outcomes: Unadjusted difference from baseline at each follow-up by study group and model-adjusted differences between study groups in change over time.

Outcome	Usual care difference from baseline		Intervention (IPM) difference from baseline		Difference between study groups in change from baseline*		
	6 months	12 months	6 months	12 months	6-month beta** (95% CI)	12-month beta** (95% CI)	Type 3 P-value
Mean asthma symptom days	−0.8	−1.4	−1.5	−2.3	−0.17 (−0.41, 0.07)	−0.22 (−0.50, 0.06)	0.22
Mean daytime symptom days	−0.7	−1.3	−1.0	−1.7	−0.07 (−0.36, 0.21)	−0.15 (−0.47, 0.16)	0.63
Mean nighttime symptoms days	−0.6	−0.5	−0.6	−0.6	−0.09 (−0.44, 0.27)	0.04 (−0.36, 0.44)	0.82
Mean days with reduced activity due to asthma	−0.4	−0.6	−1.3	−1.6	−0.34 (−0.65, −0.04)	−0.37 (−0.73, −0.01)	0.04
Proportion with severe asthma symptoms (8 or more days in the past 14)	−8.4	−14.9	−14.0	−17.2	0.64 (−0.12, 1.40)	0.43 (−0.43, 1.28)	0.16
Mean asthma emergency department visits and hospitalizations (annual rate)	−0.3	−0.4	−0.2	−0.3	0.13 (−0.56, 0.83)	0.23 (−0.51, 0.96)	0.71
Mean days of missed school due to asthma (past month)	0.0	−0.5	−0.4	−0.8	−0.36 (−0.84, 0.11)	−0.20 (−0.69, 0.29)	0.27
Percent used rescue meds in past 14 days	−7.7	−7.1	−5.5	−15.9	0.12 (−0.60, 0.85)	−0.40 (−1.13, 0.33)	0.27
Mean daily roaches	−1.4	−2.1	−7.6	−7.0	−0.88 (−1.50, −0.26)	−0.81 (−1.45, −0.16)	0.001
Any mice past 3 months	−5.7	−9.8	−17.7	−20.6	−0.51 (−1.14, 0.13)	−0.47 (−1.12, 0.18)	0.11
Non-study professional pest control in past 3 months	6.2	11.7	−2.2	−8.7	−0.68 (−1.31, −0.04)	−1.21 (−1.87, −0.54)	<0.001

CI = Confidence Interval.

*Models control for caregiver quality of life, caregiver employment at baseline, any controller medication for all outcomes, as well as asthma seasonality for non-pest outcomes and season of assessment for pest outcomes.

**Represents log of the ratio of intervention group change from baseline over control group change from baseline.

mouse allergy between those receiving the intervention versus those with education alone, as well as little difference in measured mouse allergens in the homes of both groups (8). We measured pest infestation over time based on caregiver report and saw significant differences, as well as possible evidence of compensatory behavior in the UC group with alternative pest control, which may partially explain unanticipated improvement across all asthma outcomes for the entire study sample.

While asthma healthcare utilization declined for all participants, there was no measurable difference between study groups. We powered our study to measure differences in a high asthma severity population with past-year healthcare utilization. However, despite a consistently delivered eligibility process with caregivers, healthcare records showed that nearly 1 in 3 participants had no ED visit or hospitalization during the baseline year. The intervention's impact on healthcare use in a population with less severe asthma may have been below the level this study was designed to detect. We also examined secular trends in asthma utilization and found that both asthma ED visits and hospitalizations in the Bronx changed from steadily increasing in 2013 and 2014 to abruptly declining in 2015 and 2016 (31,32), potentially

masking intervention impacts for our study participants. Finally, while an important, costly outcome for the healthcare system, ED visits—the most frequent utilization type—are influenced by factors like access to alternative healthcare services (33) and caregiver education (34), making it challenging to impact through environmental intervention. Study group differences in reported pest severity indicated the IPM intervention reduced pest infestations for IPM group participants, while continued alternative pest control over the study period in the UC group suggested possible cross-contamination. This could lead to a smaller IPM effect than would otherwise have been observed.

Our study used a rigorous RCT design but had several limitations. The conclusions from this research with a sample of urban, ethnic minority children cannot be generalized to other communities. Participants were not blinded to group assignment, and we used caregiver self-report to identify days with symptoms, introducing possible response bias. In addition, while recall bias is a potential limitation, we asked about the past 14 days, which is a short period for caregivers to remember and report and used in other studies (14,16). However, the differing results on past-year asthma healthcare utilization between caregiver-report at eligibility screening and in baseline

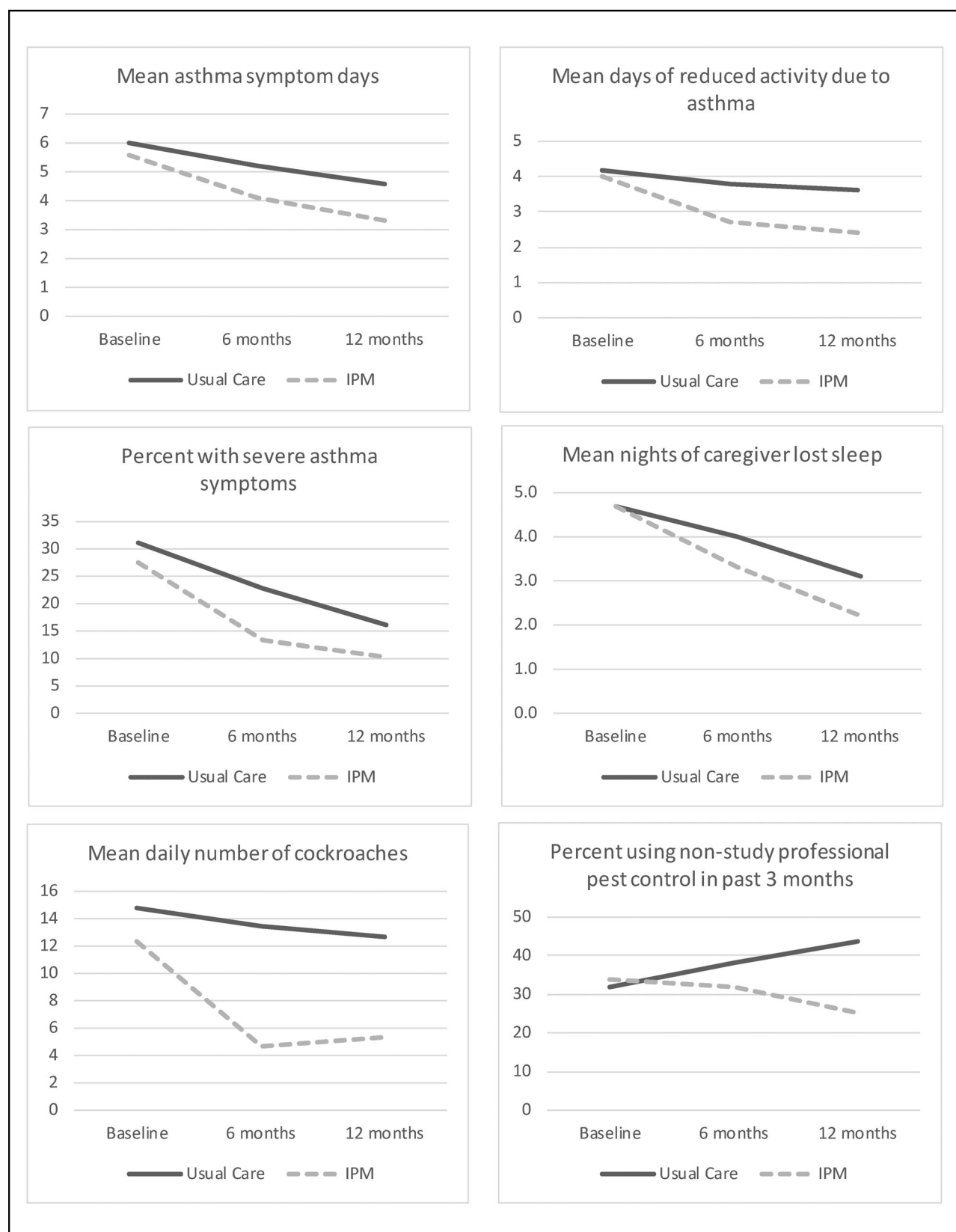


Figure 2. Unadjusted outcomes by time and study group.

utilization records demonstrate caregiver fallibility in recall over longer periods. We used a secular measure of asthma seasonality to account for our rolling

recruitment period of 10 months. Finally, while not measured in our study, future research on IPM effects should consider including mental health outcomes,

since previous research has demonstrated associations between household disrepair and mental health in families (35).

Conclusions and implications

While asthma healthcare utilization improved irrespective of intervention, we found consistent, suggestive evidence of clinically meaningful improvements across several secondary measures of children's asthma after an IPM intervention relative to usual care, despite decreased symptoms in both groups. Coupled with the established effectiveness of IPM in reducing allergens and scientific consensus on pest-related allergens as asthma triggers, our findings support adding home pest control to traditional medical management of children with severe asthma. Ongoing DOHMH initiatives are using this study's protocol to provide industry-delivered IPM at the apartment level via clinical partnerships that couple the environmental intervention with clinical care and case management for families and children. We recommend comprehensive initiatives focused on populations with the most severe outcomes to improve asthma treatment and control that harness the existing pest control industry for "treatment". While our results do not directly calculate into economic returns, they demonstrate potential savings for policymakers and health sector payers considering reimbursement schemes for low-cost pest management interventions when clinically indicated. Such innovative approaches focused beyond the traditional medical model can move the needle in eliminating inequities across urban neighborhoods with high prevalence of asthma.

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Declaration of interest

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