2014

The impact of severe housing stress on child asthma control and pediatric asthma caregiver quality of life (PACQOL)

BOSTON UNIVERSITY

SCHOOL OF MEDICINE

Thesis

THE IMPACT OF SEVERE HOUSING STRESS ON CHILD ASTHMA CONTROL AND PEDIATRIC ASTHMA CAREGIVER QUALITY OF LIFE (PACQOL)

by

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Submitted in partial fulfillment of the

requirements for the degree of

Master of Science

2014

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ACKNOWLEDGMENTS

I would like to thank Dr. Megan Sandel for giving me a wonderful opportunity to learn more about the effects of poor housing quality on health and for teaching and inspiring me along the way. I would also like to thank Dr. Sandel and my other readers, Dr. Robyn Cohen and Dr. Theresa Davies; this work would not have been possible without their help and guidance. I am grateful to Dr. Howard Cabral, who helped me with the analytical design and deeply appreciative of Johnna Murphy and Emily Suther, who collected the data for this study and patiently answered my questions.

THE IMPACT OF SEVERE HOUSING STRESS ON CHILD ASTHMA CONTROL AND PEDIATRIC ASTHMA CAREGIVER QUALITY OF LIFE (PACQOL)

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ABSTRACT

Background: Asthma is a chronic inflammatory disease of the airways that disproportionately affects low-income and minority children in the United States. Some studies have found a clear link between poor housing quality and exposure to allergen triggers associated with increased risk of asthma. Other studies have evaluated the relationship between stressful circumstances due to chronic illness, premature birth or violence on asthma outcomes. Psychological stress is thought to weaken the immune and neuroendocrine response making the body more vulnerable to environmental allergens. Studies have been done to assess the impact of psychological stress due to violence or the care of long term-critically ill children on increased asthma morbidity. However, asthma morbidity is not equal in all low-income and minority communities. It is possible that a form of stress – housing stress – which results from living in substandard housing conditions, may in fact provide more insight into the pathways linking indoor home exposures and stress in a way that leads to greater asthma susceptibility. Few studies have been done to assess the impact of stress due to substandard housing conditions.

Objective: To determine the impact of severe housing stress due to dilapidation, mold and a lack of housing control on child asthma control and on caregiver asthma-related quality of life.

Methods: A total of 143 children with asthma living in Boston, Massachusetts and between the ages of 4 and 18 were enrolled in the *Boston Allergen Sampling Study* between 2008 and 2011. Home visits were conducted to measure the levels of common allergens in the home and assess child asthma control, housing stress, perceived stress, and caregiver asthma-related quality of life. Housing stress was assessed based on resident perceptions of dilapidation, mold, and a lack of housing control; perceived stress for the caregiver was assessed using the Perceived-Stress Scale (PSS); child asthma control was assessed using Asthma Control Test (ACT) scores; and caregiver asthma-related quality of life was assessed using the Pediatric Asthma Caregiver Quality of Life (PACQOL) questionnaires.

Results: In a multivariate logistic regression severe housing stress was associated with 7.5 times increased odds of poor asthma control (OR = 7.51, 95%CI 2.7 to 20.79, $p<0.0001$) for the child and 3.0 times increased odds of poor caregiver asthma-related quality of life (OR = 3.02, 95%CI 1.37 to 6.63, $p<0.006$). This association was significant after adjusting for potential confounders.

Conclusions: Independent of allergen exposure, the association between severe housing stress and asthma health outcomes for both the child and caregiver indicate that there is an emotional stress-based pathway directly tied to poor housing quality that poses increased risk for worse asthma health outcomes.

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LIST OF ABBREVIATIONS

ACT ..... Asthma Control Test

BMC ..... Boston Medical Center

ELISA ..... Enzyme Linked Immunosorbent Assay

MARIA ..... Multiplex Array for Indoor Allergens

MLP ..... Medical-Legal Partnership

PACQOL ..... Pediatric Asthma Caregiver Quality of Life

PSS ..... Perceived Stress Scale

RAST ..... Radioallergosorbent Test

INTRODUCTION

Asthma is a Chronic Disease and the Causes of Asthma Remain Largely Unknown

Asthma is a chronic inflammatory condition of the airways, which can be fatal, and is characterized by multidimensional qualities including symptoms like coughing shortness of breath and wheezing, changes in pulmonary function, and effects on a person's quality of life and functional ability (Watts 2010, Schatz 2006). It is the most common chronic condition affecting 9.1% of all children in the United States and its prevalence is increasing globally with approximately 300 million people currently affected (Sunshine 2011, CDC, Asthma Fast Facts). Despite many years of research in this field, the causes of asthma are not well understood; it is thought that interactions between genetic, environmental and lifestyle factors play a role in asthma and asthma related mortality (Rosas-Salazar 2012). There is no cure for asthma and as a result, asthma control is the primary goal for those who suffer from asthma. Poor asthma control leads to an increased number of hospitalizations, emergency room visits and deaths (Wood 2010, CDC Health Disparities and Inequalities Report). Asthma is a problem not only from a medical standpoint, but also from an economic and social standpoint because it increases medical expenses and often leads to absenteeism from school and work (Rosas-Salazar 2012, Canino 2009).

Asthma Disparities Exist and the Reasons Are Also Unknown

While asthma affects people of all races, ethnic groups and ages, studies have shown that asthma disproportionately affects children, minorities and the poor, with 9.1% of American children currently living with the disease compared to 7.3% of adults; 10.2% of African Americans compared to 7.6% of White Americans; and 11.2% of the poor compared to 7% of the non-poor (Wood 2010, CDC Asthma Fast Facts, CDC Health Disparities and Inequalities Report)**.** Minority children and poor children have a higher prevalence of asthma and experience more severe asthma attacks. Moorman et al. (2007) found that African American children are 4.8% more likely to have asthma as compared to white children (Moorman 2007, Wood 2010, Davidson 2010). Even more concerning is the fact that the asthma related mortality is four times greater in African American children than White American children (Wood 2010).

Studies have described how children of low-income families and African American children are disproportionally affected with higher rates of asthma and more severe disease, but the mechanism for why this disparity exists is not entirely clear. Several other studies have attempted to understand the underlying causes of the disparities in asthma. Canino et al. (2009) suggest that the challenge is complex, involving consideration of the health care system, provider and clinician level factors, social factors, environmental factors, individual factors, and family level factors (Canino 2009). Physical factors like substandard housing quality, which leads to increased exposure to asthma allergens, and emotional factors including

psychological stress are two theories that have been used to explain asthma disparities.

Housing Quality, the Indoor Environment and Asthma

One explanation for the disparity of asthma outcomes is the influence of indoor allergen exposure and physical housing quality. Several studies have found a link between exposure to allergens in the home like those of dust mites, cockroaches, rodents, molds, and pet dander to allergen sensitization and asthma (Kreiger 2010, Rosenstreich 1997, Morgan 2004, Sporik 1999, Zock 2002, Phipatanakul 2002, Salo 2009). Other indoor exposures that have been associated with asthma exacerbation include tobacco smoke, combustion products like nitrogen oxides, formaldehyde, and volatile organic compounds (Kreiger 2010, Butz 2011, Dannemiller 2013).

Studies have shown that among those living in substandard housing there is a higher risk of exposure to potential allergens and triggers for asthma (Kreiger 2010, Northridge 2010). Substandard housing conditions include excessive moisture from water leaks, dampness, mold odor, inadequate heating systems, below average housekeeping, crowding, pest infestations, and structural defects like holes in the walls, which have all been associated with the presence of elevated allergens from cockroaches, dust mites, and rodents (Kreiger 2010, Murphy 2011, Frank 2006, Lambertino 2009, Keall 2012, Kitch 2000, Rauh 2002, Wilson 2010). A study of children living in New York City found that child living in public housing

had higher odds of asthma than children living in private homes even after adjusting for individual and community level socio-economic and demographic factors; they attributed this to the increased prevalence of home asthma triggers like cockroaches and rats among those living in public housing (Northridge 2010). According to some, 40% of the excess asthma risk in non-white children may be attributable to home allergen exposure (Kreiger 2010, Lanphear 2001). As a result, children living in low-income, substandard housing are often exposed to more asthma triggers including cockroaches, rodents, and mold (Murphy 2011, Lambertino 2009).

Stress and Asthma

Living in poor housing conditions not only exacerbates asthma symptoms, but also is thought to put significant stress on both the child with asthma and the caregiver. Social and psychological factors like emotional stress exacerbate allergy flares and worsen asthma symptoms and serve as another explanation for the disproportionate effect that asthma has on low-income and minority children (Patterson 2014, Wright 2011). The psychosocial stress model provides an explanation for how psychological stress compromises the body's immune system and makes it more vulnerable to environmental pollutants (Wright 2011). Studies have shown that stress influences the neuroendocrine, autonomic, and immune inflammatory processes involved in pulmonary and airway function (Wright 2011, Ritz 2014, Marshall 2004).

Recent studies have shown that increased perceived stress is associated with

poor asthma control and more allergy flares (Patterson 2014, Lu 2014). Patterson et al. (2014) found that persistent emotional stress as measured by both blood cortisol levels and self-reported questionnaire on the perceived stress scale was associated with more allergy flares (Patterson 2014). Lu et al. (2014) found that adolescents with increased perceived stress and neuroticism were more likely to have poor asthma control and that among adolescents with asthma there were more known comorbidities for both asthma and psychologically depressive factors including a history of smoking, a higher body mass index, and a lower housing status, all of which are known to be associated with asthma and psychological comorbidities (Lu 2014). Other studies have shown that adolescents with asthma were at greater risk of depression than their healthy peers and that frequent mental distress is commonly noted among those with asthma and other chronic conditions (Lu 2014, Al-Nsour 2013).

While several recent studies have considered the mental and emotional state of the child with asthma, there is a longer history of research into the stress that caregivers experience and how this also is associated with worse asthma exacerbations among their children (Kopel 2014, Cousino 2013). Caregivers of children with chronic illnesses like asthma frequently report greater parenting stress than caregivers of healthy children (Canino 2013). This is often due to the fact that they feel a greater parenting stress from the burden of managing the treatment of their child, making time for frequent clinic visits, and general worry for a child's health. Research shows that parenting stress not only affects the parent, but also

affects the child. Caregiver stress has been shown to affect depression among children with diabetes; it has also been shown to affect the health outcomes for a child, particularly when stress interferes with the management of a child's chronic condition (Cousino 2013, Mullins 2004). As a result, there is a bi-directional relationship between child asthma severity and caregiver quality of life, in which both influence one another. Stress experienced either directly through life circumstances or through the indirect stress of a close caregiver can impact a child's emotional health, influence how they manage their disease, and further exacerbate a cycle in which stress affects an immune response and vulnerability of a child to more severe illness (Sandel 2006).

Stress in the Home and Asthma

Research suggests that both exposure to environmental toxins from substandard housing as well as stress-related factors of the child and caregiver can exacerbate vulnerabilities among children with asthma. However, few studies have explored the effect of stress directly due to substandard housing on a child's asthma control and caregiver quality of life. Living in substandard housing causes both physical discomfort and psychological stress, which in combination affects the health and quality of life of those suffering in poverty. Differences in housing quality and health outcomes cannot be explained simply by differences in socioeconomic factors. Children living in the Bronx in New York City were found to have higher asthma morbidity than other children living in U.S. inner-city areas when controlling

for demographic factors (Warman 2009).

Researchers found that children in the Bronx were more likely to be exposed to household allergens, to live in poor housing conditions and to have higher levels of psychological stress than other inner city children with asthma (Warman 2009). This finding is not unusual, substandard housing conditions have been linked to negative mental health among children and their caregivers (Sandel 2006). Furthermore, larger household size, the presence of pests, and dampness have been all of which are characteristics of substandard housing have been associated with psychological distress, poor mental health, worse health status, and poor caregiver quality of life (Sandel 2006, Levy 2004). Ultimately, deprivation in the physical environment affects the psychological wellbeing of residents, which can further impact their health and quality of life (Sandel 2006).

Suglia et al. (2010) noted that physical environmental factors like housing disarray and stress due to intimate partner violence were associated with increased risk of children in these homes developing asthma in their early childhood. Kopel et al. (2014) found that a caregiver's perception of a lack of neighborhood safety was also associated with greater childhood asthma morbidity among inner-city children (Kopel 2014). The study also revealed that among children whose caregivers perceived the neighborhood to be unsafe there was a greater exposure to violence, lower socioeconomic status, less access to health care services, and greater caregiver stress which are comorbidities for asthma. As a result, the role that poor

housing quality and caregiver stress plays on reducing a child's asthma control or increasing their susceptibility to asthma is important to understand (Suglia 2010). Sandel et al. (2006) proposed a conceptual model for housing stress linking housing quality, housing stress, and asthma risk and described the interplay of physical and emotional factors on housing stress (Figure 1). Housing hardships that cause psychological distress lead to housing stress. Housing stress is a likely explanation for the disproportionate burden of asthma morbidity among some urban inner-city children. Poor housing quality as well as a perceived inability to cope with the situation can lead to both the physical and emotional constructs that comprise housing stress.

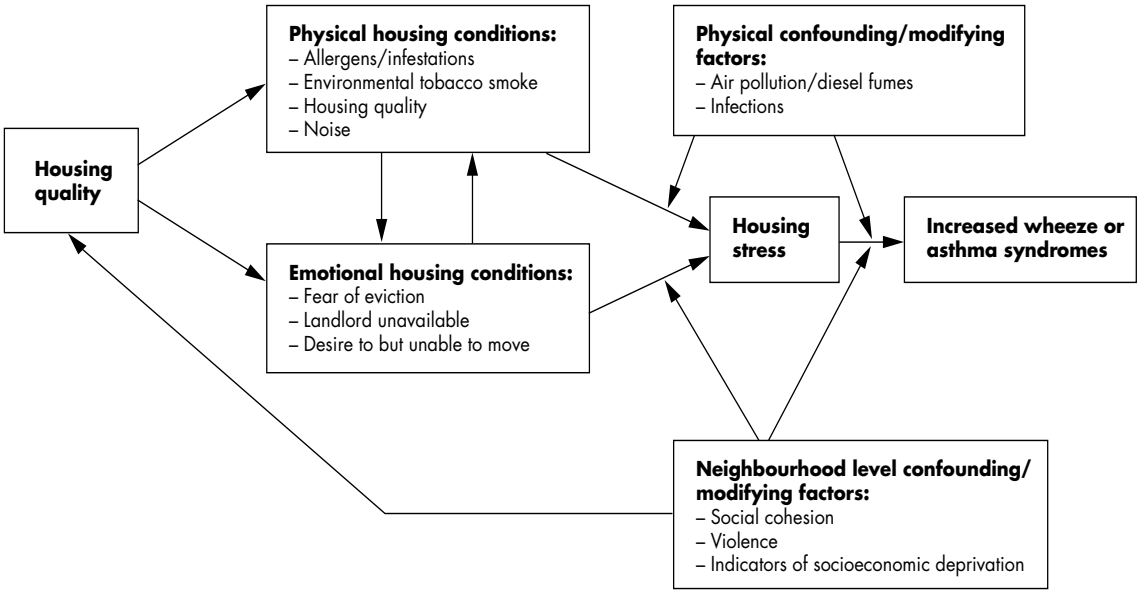

Figure 1. A Framework for the Relationship Between Housing Quality, Housing Stress and Asthma Symptoms. In this model both the physical housing conditions and the emotional housing conditions impact one another and lead to an increase in housing stress, which in turn increases asthma symptoms (Sandel 2006).

As a result, housing stress has two domains comprise of the physical and emotional factors. But those domains can be further described in three distinct constructs including signs of dilapidation, mold, and a lack of housing control. Dilapidation is recognized as signs of physical damage to the home including cracks in the walls or holes in the floor, pests and vermin and a lack of heat. Mold includes signs of mold as well as conditions where there is dampness or signs of water leaks indicating that mold would thrive. A lack of control is evidenced by the emotional state of the respondent in which the desire to move, feeling of crowding, and the challenges of contacting the landlord to fix the problems persist.

SPECIFIC AIMS

Studies have tied poor housing quality and conditions within the home to worsening asthma symptoms. In addition, some studies have described how stress in general or due to living with a chronic condition, may mediate the relationship between environmental and socio economic factors and their effect on the biological immune system. Thus, while several studies have recognized the fact that the physical and psychological demands of living in a disadvantaged environment may potentiate an individual's susceptibility to environmental exposures and lead to increased asthma exacerbation, whether this is due to stress from poor housing conditions is not well understood.

The primary objective of this paper is to describe the impact of severe housing stress, which is defined by a presence of dilapidation, mold, and a lack of control over housing, on the asthma health outcomes of 143 asthmatic children living in Boston, Massachusetts and their caregivers. Asthma Control Test (ACT) scores will be used as a measure of child asthma control and scores from the Pediatric Asthma Caregiver Quality of Life (PACQOL) will be used to assess caregiver asthma-related quality of life.

There are three secondary objectives in this paper. The first is to describe the association between elevated allergen levels in the home and stress due to both severe housing stress as well as the perceived stress of the caregiver (as measured from the 4-item Perceived Stress Scale). The second objective is to consider the role

that perceived stress has in asthma health outcomes for both the child and caregiver. The third objective is to determine if there is an association between perceived stress and severe housing stress.

METHODS

Study Population and Eligibility

In order to determine the role that housing stress plays in predicting child asthma control, we used data collected from Boston Allergen Sampling Study. This study was a cross-sectional study conducted through Boston Medical Center (BMC) from 2008 to 2011. This study was approved by the Boston University Institutional Review Board and designed to analyze the home allergen exposures of subjects with asthma living in Boston, Massachusetts.

Subjects who were over the age of four, had been diagnosed with asthma, and had lived in their home for more than six months were eligible to participate. Eligible subjects were recruited from Boston Medical Center and/or referred by primary care physician. Subjects were excluded from the study if they did not speak either English or Spanish, had any coexisting chronic diseases like sickle cell anemia, and if they were living in temporary housing or homeless shelters. Two hundred and one subjects with asthma were enrolled in the study in which they answered several questionnaires and consented to participate in a home visit so that researchers could assess their homes for potential allergens.

During these visits, researchers also collected surface dust samples from the kitchen, living room and bedroom areas to assess for the levels of dust allergens, pet allergens, and pest allergens in the home. The subjects and caregivers of subjects were also asked to complete questionnaires to assess housing stress, perceived

stress, asthma control, asthma symptom recall, quality of life assessment (for those subjects over 8 years of age), and caregiver asthma-related quality of life (if the subject was a child under 18 years of age).

Of the 201 subjects, 165 were children under the age of 18. Of these 165 children, 22 subjects were found to have incomplete data and they were eliminated from this study analysis. This study specifically analyzed the data from 143 of the children enrolled in the Boston Allergen Sampling Study where the information gathered was complete.

Housing Stress

Housing stress was determined based on answers to 14 questions that asked about three domains of physical and emotional stress including: dilapidation, mold, and perceived housing control. Dr. Megan Sandel, an Associate Professor of Pediatrics at Boston University Medical School and Boston Medical Center, developed this questionnaire. The precision of its use as a measurement tool has been validated in a study that has not yet been published. Questions related to dilapidation involved questions about the physical structure of the house and whether there were cracks or holes in the walls, a lack of heating, or pests. Questions regarding mold, related to whether there were indications of mold, dampness, water leaks or other signs that the physical structure supported the growth of mold. Perceived housing control was determined based on questions regarding the overcrowding, an inability to cope with the problems, and the desire

to move. Severe housing stress was defined as having positive indications of all three housing stress constructs. Thus severe housing stress was defined as least 1 positive response to the dilapidation construct, at least 1 positive response to the mold construct, and at least two positive responses to housing control construct of housing stress. This variable was noted as a dichotomous variable in this response.

Child Asthma Control and Asthma Recall

Asthma control is assessed on a multifactorial scale that includes symptoms, pulmonary function, and quality of life, which may not consistently correlate well with each other and provide independent information about an individual's clinical status without providing comprehensive information about asthma control. As a result, the Asthma Control Test (ACT), a 5-item, patient administered survey for assessing asthma control was developed to assess the multidimensional nature of asthma control and has been found to be both a valid, reliable, and responsive assessment tool appropriately changing with changes in asthma control over time (Schatz 2006).

Asthma control for the child in this study was determined by responses to the Asthma Control Test (ACT) with questions on a Likert scale for determining a child's asthma control (Schatz 2006). The ACT was administered to children between ages 12 and 18. If subjects were over the age of 12 and at home during the visit, then they were asked to complete the ACT questionnaire. If the subject was under the age of 12 or not at home during the study visit, then the caregiver

completed the ACT on behalf of the child. The scores were evaluated on the same scale used in previously published papers where scores equal to or less than 19 indicate poor asthma control, while scores that are greater than 19 indicate that subjects have well-controlled asthma (Schatz 2006). ACT was evaluated as both a continuous and dichotomous variable in statistical analyses.

In addition to completing the ACT and evaluating the subject's asthma control, other measures were also assessed through self-reported questionnaires which asked subjects and their caregivers to recall the number of times in the past two weeks when the subject had experienced wheezing, slow play, or lost sleep as indicators of asthma symptoms. We used this data to assess the consistency of the ACT scores. Subjects were also asked to identify how many days of school they had missed in the past two weeks; how many times they had been admitted to the hospital for an overnight stay in the past two months; and the number of unscheduled clinic appointments and emergency room visits they had made which may not have resulted in an overnight stay in the same two month period. These other measures of asthma control were evaluated as continuous variables.

Allergen Sensitivity

Data on allergen sensitivity was collected for 65 patients who were patients at BMC and who consented to a medical chart review. Among this group of patients, data was assessed if they had a radioallergosorbent test (RAST) or skin prick test or both to assess for their sensitivity to common home allergens. Any positive

indication of allergen sensitivity was noted in comparison to negative allergy sensitivity. Missing data was coded as such.

Caregiver Perceived Stress and Caregiver Asthma-Related Quality of Life

The Perceived Stress Scale (PSS) is a validated instrument developed by Sheldon Cohen (Cohen 1988). PSS is a measure of the degree to which people find situations in their life to be stressful and the perceived degree to which environmental demands exceed their ability to cope (Cohen 1988). Since psychological stress is assumed to increase the risk of disease and several studies found that stress may mediate the interaction between environmental exposures and asthma (Suglia 2010, Wright 2011), we used the validated four-item abbreviated PSS to determine the level of the caregiver's perceived stress. The questions in the PSS ask about feelings and thoughts during the past month and respondents are asked to how often they felt a certain way with answer choices as graded responses listed on a Likert scale. PSS scores are obtained by reversing response to the two positively stated items and summing across all scale items to determine a total score.

The Pediatric Asthma Caregiver Quality of Life (PACQOL) was used to determine the influence that the child's asthma had on the caregiver's quality of life. Scores were determined by answers to 13 self-reported questions on Likert scale with seven options. This is a validated and reliable questionnaire developed by Elizabeth Juniper that seeks to understand whether the caregiver's activity and

emotional function has been affected by their child's asthma (Juniper 1996). The sum of the scores for the 13 questions were averaged to determine the final caregiver quality of life score, in keeping with how the measure has been used in other published studies (Juniper 1996). The scores from the perceived stress scale and the PACQOL were analyzed as both continuous variables and dichotomous variables. To analyze them as dichotomous variables scores received a binary code depending on whether the value was above or below the median value.

Measured Allergen Exposure in the Home

Samples of dust from surfaces in the living room, kitchen, and bedroom were collected by trained researchers and sent to an outside lab for further analysis of seven possible allergens including: tests for dust mites (Der f 1, Der p1), cat allergens (Fel d), dog allergens (Can f 1), cockroach allergens (Bla g 2), rat allergens (Rat n1), and mouse allergens (Mus m1). MARIA (Multiplex Array for Indoor Allergens) tests were performed on each sample collected. For the purposes of this study, we only analyzed the measured allergen levels collected from the bedroom of each subject's home. The bedroom is likely to be a better reflection of true allergen exposure since there is often less foot traffic and potential contamination in this area. Samples were considered to be "bedroom" samples if they were taken from the location identified by the child and caregiver as the place where child regularly slept each night. Consistent with the literature, dust mite, cat and dog allergens were considered to be elevated if they were >2 $\mu g/g$; mouse allergens were considered to

be elevated if they were above 0.5 $\mu g/g$; cockroach allergens were elevated if they were above 1 $\mu g/g$; and any detectable rat allergen was considered elevated (Wilson 2010, Suther 2010). Bedrooms of subjects that had any elevated allergen levels on any of the MARIA tests were classified as having elevated allergen exposure. In order to analyze the measured allergen exposure level for each subject, the allergens were grouped by type of allergen. In this way, dust allergens included all of the dust mite allergen exposures; pet allergens included both cat and dog allergen exposures; and pest allergens included mouse, rat, and cockroach allergens. The highest measured dust mite allergen level in the bedroom of the subject was recorded as the subject's dust allergen exposure. Similarly, the highest measure pet allergen and pest allergen level in the subject's bedroom were noted as the subject's pet and pest allergen exposure respectively.

Statistical Analysis

The data was calculated and statistically analyzed using SAS 9.3® Software. Univariate descriptive statistics for the variables used in the analysis and including demographic information about the study population with information on age, gender, and race were also included.

Descriptive information on the primary variables of interest was also stratified by the presence or absence of severe housing stress.

ACT scores and PACQOL scores were the main outcome measures and severe housing stress was the primary predictor variable. Perceived stress and measured

elevated allergen level of dust, pet, and pests were also evaluated in a secondary analysis for their effect on the outcomes of interest. Bivariate, unadjusted analyses were done to assess the relationships between the variables. For variables with a continuous outcome, two-sided independent t-test were performed and $p<0.05$ was considered statistically significant. For variables with a dichotomous outcome, χ^2 tests and simple logistic regressions were performed and odds ratio measures and a 95% confidence interval that did not include the null value were considered statistically significant.

Lastly, multivariate logistic regression was used to examine the associations between severe housing stress and 1) child asthma control and 2) caregiver quality of life, after adjusting for potential confounders (age and gender).

RESULTS

Description of the Variables in the Study Population

The 143 children with asthma analyzed in this study consisted of 79 boys and 64 girls between the ages of 3 and 18 with a mean age of 9 years. Only 4% of subjects identified as White and not Hispanic, while 96% of the study participants classified themselves as non-white racial minorities. Among the study population, 54% identified as African American, 24% identified as Hispanic/Latino, 8% identified as either Caribbean, African, or Cape Verdean, 1% identified as Native American, and 10% identified as Other. Table 1 displays the descriptive data for the study variables. All of the subjects had lived in their homes in Boston, Massachusetts for at least six months when the home visits were conducted.

Exposure to Elevated Allergens

An analysis of the allergen exposures in these home including bedroom, kitchen, and living room revealed that 115 (81%) subjects were exposed to elevated allergens in their home. A specific analysis of allergens in the subject's bedroom revealed that 92 (64%) subjects had an elevated level of dust mite, pet or pest allergen with 18% of these subjects living with more than one type of elevated allergen. In addition, 62 (43%) subjects had 5 times the elevated allergen level in their bedrooms. When assessed by specific allergen type, 7.7% of subjects had elevated dust mite allergens in their bedrooms, 28.7% had elevated levels of pet

allergens from dogs or cats, 39.9% had elevated levels of pest allergens mostly due to mice.

Allergen Sensitivity

Among the 65 subjects for whom allergy sensitivity data was available, all had had either a radioallogergosorbent test (RAST) or skin prick test or both and 54 (83%) had a positive indication of sensitivity to at least one allergen.

Table 1: Descriptive Statistics for the Study Population. The mean and standard deviation are used for continuous variables that are normally distributed. Median and interquartile range vales are provided for continuous variables that do not follow a normal distribution. The frequency and percent are used to describe dichotomous variables in this study. Some variables were classified as both continuous and dichotomous for use in different types of analyses.

Variable	Mean (N=143)	SD	Median	IQR	Frequency	Percent (%)
Age	9.07	3.61				
ACT score	18.04	5.11				
PSS Score	6.25	3.95				
Caregiver QOL	5.21	1.35				
Asthma Symptoms Days in Past 2 weeks			3	10		
Missed Days of School in Past 2 weeks			0	2		
Hospital Admissions in Past 2 months	0.08	0.34				
Unscheduled Clinic and ER visits in Past 2 months	0.19	0.45				
Gender						
Male					79	55.24
Female					64	44.76
Severe Housing Stress						
No					106	73.43
Yes					38	26.57
Housing Stress Constructs						
Dilapidation					127	88.11
Mold					74	52.11
Lack of Housing Control					64	47.06
ACT categories						
Poorly Controlled (Scores <19)					82	57.34
Controlled (Scores >19)					61	42.66

Variable	Mean (N=143)	SD	Median	IQR	Frequency	Percent (%)
Perceived Stress Categories						
Low Stress (scores ≤6)					75	52.45
High Stress (scores >6)					68	47.55
Caregiver Quality of Life Categories						
Low Caregiver QOL(scores ≤5.4)					70	48.95
High Caregiver QOL (scores >5.4)					73	51.01
Elevated Level of Any Measured Allergens in the Bedroom						
No					51	35.66
Yes					92	64.34
Elevated Dust Allergens in the Bedroom						
No					132	92.31
Yes					11	7.69
Elevated Pest Allergens in the Bedroom						
No					86	60.14
Yes					57	39.86
Elevated Pet Allergens in the Bedroom						
No					102	71.33
Yes					41	28.67

Severe Housing Stress

Housing stress contains three constructs that relate to both the physical environment as well as the emotional perceptions of the responder. A positive indicator of dilapidation, mold, or the resident's perception of a lack of housing control constitutes the presence of housing stress. Table 2 describes the subject responses to each question on the housing stress questionnaire. More than 50% of the respondents indicated one of more of the following: had difficulty heating their homes; had pests including rats, mice and cockroaches in their homes; and/or had a strong desire to move from the area. In this study, 134 subjects (94%) suffered from at least one housing stress construct.

Severe housing stress was classified based on at least one positive response to housing constructs of dilapidation and mold, and at least positive responses to the housing construct regarding control a lack of housing control. In this way, severe housing stress was an indicator of dilapidation, mold and a perceived lack of housing control. A total of 47% of respondents indicated that they believed they had a lack of control over their housing situation while 88% and 52% found that dilapidation and mold were both housing concerns respectively. Overall, a total of 38 subjects (27%) were identified as suffering from severe housing stress.

Table 2: Housing Stress Constructs. The three housing stress constructs of dilapidation, mold, and housing control are defined based on specific questions from the housing stress questionnaire. The number of positive responses for each question and the percentage of the study population are represented alongside each question.

	N (143)	Percentage (%)
Housing Dilapidation *(One or more of the following)*		
Open cracks in walls	55	39.8
Peeling paint	28	19.7
Holes in floors	8	5.6
Home is hard to heat	77	54.6
Last winter, house cold for 24 hours	47	33.6
Rats, mice, cockroaches	78	54.5
Mold *(One of more of the following)*		
Water leaked in from outdoors	26	18.3
Water leaks from inside building	29	20.4
Water leaks	39	27.3
Mold growing	44	30.8
Lack of Housing Control *(Two or more of the following)*		
Crowded living conditions	47	33.6
Desire to move from area	79	56.0
Difficulty contacting landlord	21	15.6
Hard to get landlord to fix things	51	37.8

Perceived Stress

Perceived stress of the caregiver was determined by caregiver responses when scores fell in a range between 0 and 14, with a median value of 6. High scores with values greater than 6 were considered to be an indication of a high level of perceived stress. Sixty-eight (48%) caregiver responses had perceived stress scores above the median and were identified as having high perceived stressed, while those scores that were at or below the median were considered to have a low level of perceived stress (52%).

Pediatric Asthma Caregiver Quality of Life (PACQOL)

Caregiver quality of life was determined by the PACQOL test, which had a range of scores from 1.2 to 7.0 and a mean score of 5.2 (median of 5.4). Scores above the median value of 5.4 were considered to be an indication of better caregiver quality of life. As many as 49% of subjects had PACQOL scores that indicated they had a poor quality of life.

Asthma Control Test and Other Measures of Asthma Control

Child asthma control from ACT scores fell in a range from 4 to 28 with a mean score of 18 (and a median of 19). Eighty-two (57%) children had ACT scores that were 19 or less, which was considered to be indicative of poorly controlled asthma. Sixty-one subjects (43%) had scores that were greater than 19 and were

considered to have asthma that was controlled. As another aspect of child asthma control, the mean number of asthma symptom days and missed days of school in a two-week period were 5 days and 1 day respectively.

There was consistency between different measures for asthma control. Asthma Control Test scores were found to have a statistically significant association with other asthma control measures. Child asthma control measured from high ACT scores was inversely associated with the number of asthma symptom days ($p < 0.0001$, 95% CI -0.70, -0.41), the number of missed school days ($p<0.0001$ 95%CI -0.25, -0.13), and the number of unscheduled and emergency room visits in the past two months ($p=0.02$ 95%CI -0.03, -0.003).

Associations Between Child Asthma Control (ACT Scores) and Caregiver Asthma-Related Quality of Life (PACQOL Scores)

As another assessment of consistency in the data, ACT scores denoting child asthma control were significantly associated with caregiver asthma-related quality of life ($p<0.0001$, 95% CI 0.09, 0.17). Increased PACQOL scores were strongly associated with an increase in ACT scores and vice versa, indicating that asthma control for the child and caregiver quality of life are linked together and influence each other bi-directionally.

Description of Variables Stratified by Severe Housing Stress

When elevated allergen exposures were assessed based on the presence or absence of severe housing stress, there is no noticeable increase in the presence of elevated allergens for subjects who experience severe housing stress compared to those who do not experience severe housing stress despite the fact that the perception of allergens like rats, mice, and cockroaches in the home is a quality assessed within the dilapidation construct of housing stress (Table 3). In situations where subjects experienced severe stress, the perceived stress scores of the caregiver were elevated; ACT scores of the child and PACQOL scores of the caregiver were decreased. In addition, there were more indications of asthma symptoms, missed days of school and unscheduled clinic and emergency room visits.

Table 3: Stratified Summary Statistics By Severe Housing Stress. Each continuous variable is defined by the mean and standard deviation, while dichotomous variables are defined by the percent and frequency for each category of severe housing stress. Two-sided independent t-tests were used for continuous outcome measures and χ^2 tests were used for dichotomous outcome measures to determine significance of the difference in the association depending on the presence of severe housing stress and p-values <0.05 are considered significant at $\alpha = 0.05$.

	Severe Housing Stress Absent N=105		**Severe Housing Stress Present N=38**		**p-value**
	Mean (Sd)	***% (N)***	***Mean (Sd)***	***% (N)***	
Age	9.09 (3.60)		9.05(3.68)		0.96
ACT Score	19.17 (4.91)		14.92 (4.36)		<0.0001 ***
PACQOL Caregiver Quality of Life	5.40 (1.33)		4.69 (1.30)		0.005**
Asthma Symptoms in 2 week period	4.40 (5.08)		6.50 (5.59)		0.05*
Missed Days of School in 2 week period	0.87 (1.43)		1.97(3.01)		0.04*
Hospital Admissions in 2 month period	0.09 (0.34)		0.05(0.32)		0.59
Unscheduled Clinic Visits and ER Visits in 2 month period	0.18 (0.45)		0.24(0.43)		0.51
Perceived Stress Score	5.93 (3.98)		7.13 (3.76)		0.11

	Severe Housing Stress Absent N=105		Severe Housing Stress Present N=38		p-value
	Mean (Sd)	***% (N)***	***Mean (Sd)***	***% (N)***	
Gender					
Male		56.19% (59)		52.63% (20)	0.71
Female		43.81% (46)		47.37% (18)	
Perceived Stress Category					
Low Perceived Stress		57.14%(60)		39.47% (15)	0.06
High Perceived Stress		42.86% (45)		60.53% (23)	
Caregiver Quality of Life					
Lower QOL		41.90%(44)		68.42% (26)	
Higher QOL		58.10% (61)		31.58% (12)	0.005 **
Any Measured Level of Elevated Allergen in the Bedroom					
No		34.29% (36)		39.47% (15)	0.20
Yes		65.71%(69)		60.52% (23)	
Elevated Dust Allergen in the Bedroom					
No		94.29%(99)		86.84%(33)	0.14
Yes		5.71%(6)		13.16% (5)	

	Severe Housing Stress Absent N=105		Severe Housing Stress Present N=38		p-value
	Mean (Sd)	*% (N)*	*Mean (Sd)*	*% (N)*	
Elevated Pet Allergen in the Bedroom					
No		68.57%(72)		78.95 &(30)	0.22
Yes		31.43% (33)		21.05% (8)	
Elevated Pest Allergen in the Bedroom					
No		58.10%(61)		65.79% (25)	0.41
Yes		41.90 (44)		34.21% (13)	

* significant at p<0.05
** significant at p <0.01
*** significant at p<0.000

The Primary Analysis: Severe Housing Stress and Asthma Health Outcomes

We found that severe housing stress had a statistically significant relationship with asthma control test (ACT) scores and caregiver quality of life (PACQOL) scores.

Severe Housing Stress and Child Asthma Control (ACT)

The presence of severe housing stress in a home had a statistically significant association with decreased ACT scores, which were used as a measure of child asthma control ($p<0.0001$ 95%CI 4.27, 5.40). As a result, severe housing stress was associated with 7.5 times greater odds of poor asthma control (i.e. low ACT scores) (OR =7.5, 95% CI 2.73 to 20.82, $p<0.0001$) than living without severe housing stress.

Since the relationship between severe housing stress and asthma control was strongly associated in the unadjusted analysis. We conducted a multivariate logistic regression to adjust for possible confounders with the association. We included the child's age and gender as possible confounders. After adjusting for age and gender, severe housing stress was still significantly associated with child asthma control ($p<0.0001$). For those living with severe housing stress, we found that there were 7.52 times greater odds (OR = 7.51, 95%CI 2.7 to 20.79, $p<0.0001$) that a child with asthma will have poor asthma control compared to a child living in a home in which the caregiver experienced severe housing stress.

Severe Housing Stress and Caregiver Asthma-Related Quality of Life (PACQOL)

The presence of severe housing stress in a home also had a statistically significant association with decreased caregiver quality of life as measured by the PSCAQOL (p=0.005, 95%CI 1.18, 1.49). Severe housing stress was associated with 3 times greater odds of having poor caregiver quality of life (OR =3.0, 1.36, 6.59, p = 0.005) that living without severe housing stress.

Similarly to the relationship between severe housing stress and child asthma control, the relationship between severe housing stress and caregiver asthma-related quality of life was strongly associated in the unadjusted analysis. We conducted a multivariate logistic regression to adjust for possible confounders with the association. We included the child's age and gender as possible confounders. After adjusting for age and gender, severe housing stress was still significantly associated with caregiver asthma-related quality of life (p=0.006). For those living with severe housing stress, we found that there were 3.02 times greater odds (OR = 3.02, 95%CI 1.37 to 6.63, p<0.006) that a caregiver of a child with asthma would have reduced quality of life compared to a caregiver who did not experience severe housing stress.

The Secondary Analysis: Elevated Allergens and Stress

Elevated Allergen Levels, Housing Stress and Perceived Stress

Overall, levels of elevated allergen exposure in the bedroom were not significantly associated with caregiver perceived stress or severe housing stress. Individual analyses were done to determine if there was an association between a specific type of elevated allergen (i.e. either dust mite, pet, or pest allergen) and each of the two measures of stress. No statistically significant associations were found.

We also assessed the association between overall elevated allergen levels in the bedroom as well as elevated dust mite, pet, and pest allergens specifically with child asthma control and caregiver quality of life measures and found no significant associations despite previous studies regarding this association (Wilson 2010, Suther 2010). In addition, allergen exposures in the bedroom that were elevated-five-fold did not have any significant association with asthma health outcome measures.

Lastly, there was no significant association between the small subset of subjects for whom data on allergen sensitivity was available and elevated allergen levels, severe housing stress, caregiver perceived stress, caregiver quality of life or child asthma control scores.

The Secondary Analysis: Perceived Stress and Asthma Health Outcomes

Perceived Stress and Child Asthma Control (ACT)

Perceived stress of the caregiver, which was determined from the 4-item Perceived Stress Scale (PSS), was not associated with asthma control in the child.

Perceived Stress and Caregiver Quality of Life (PACQOL)

The perceived stress score of the caregiver was found to be associated with caregiver quality of life as measured on a continuous scale from responses to the PACQOL (p=0.03 95% CI 1.19, 1.51). However, an analysis with dichotomized variables revealed that there were 1.36 times greater odds of having decreased caregiver quality of life scores when there is heightened perceived stress (OR = 1.36, 95%CI 0.70 to 2.62 p =0.36). The associations with perceived stress were not statistically significant since the confidence interval included the null value and p> 0.05

The Secondary Analysis: Severe Housing Stress and Perceived Stress

Severe housing stress was closely associated with heightened perceived caregiver stress where those subjects who were living with severe housing stress had two times greater odds of having high levels of perceived stress (OR = 2.04, 95%CI: 0.95, 4.35, p=0.06) than those who were living without severe housing stress. The association between severe housing stress and perceived stress were

not statistically significant since the confidence interval included the null value and $p > 0.05$

DISCUSSION

The effect of perceived stress has been evaluated in several studies as a way to understand asthma disparities. However, few studies have evaluated the effect of severe housing stress, (where the stress is due to living in substandard housing conditions), and how this type of stress affects health outcomes. The purpose of this analysis was to understand the impact that severe housing stress has on both a child's asthma control and on a caregiver's quality of life.

Severe Housing Stress and its Effect on Asthma Control and Caregiver Asthma-Related Quality of Life

Based on the results of this study it is clear that severe housing stress, characterized by the presence of dilapidation, mold and a lack of housing control, is associated with a decreased ACT score for the child and with a decreased PACQOL score for the caregivers. The fact that there was such a strong association between severe housing stress and ACT scores, where those experiencing severe housing stress has 7.5 times the increased odds of having poor asthma control, highlights a the impact of substandard housing quality. When ACT scores are low this is a sign of poor asthma control and more severe asthma exacerbation for the child. There was a strong correlation in our data between poor asthma control and worse asthma symptoms, more missed days of school, and an increase in the number of unscheduled clinic and emergency room visits, which is similar to what other

studies have found describing the burden of severe asthma (Rosas-Salazar 2012).

Similarly, the fact that severe housing stress was also associated with 3 times the increased odds of a caregiver experiencing worse asthma-related quality of life measures, reminds us that substandard housing quality and the severe housing stress that can arise from experiencing these conditions has a broad impact. When the indoor exposures to environmental triggers are high and there are signs of dilapidation and mold, and an individual also suffers from the lack of control about their housing choices, this can lead to difficulty coping with the situation, depression and increased stress. Studies have highlighted the fact that issues like housing disarray and housing instability are linked to maternal depression and generalized anxiety disorder (Suglia 2011). While other studies have explored the connection between the mental and emotional health of the caregiver and the impact that caregiver distress can have on the health of their children (Wright 2010, Ritz 2014, Mullins 2004).

As a result, the findings of the primary analysis reveal that asthmatic children experience greater risk of poor health outcomes and are consistent in this context. Children with asthma are not only directly affected by the housing conditions they live in, but they are also affected by the distress their caregivers experience.
The findings of this paper shed additional light on a possible pathway for how the psychological demands and stress specifically due to living in a disadvantaged environment (where one is struggling to cope with the challenges faced), may only

serve to increase susceptibility to environmental exposures, impacting the child's asthma control and the caregiver's asthma-related quality of life.

Limitations of Elevated Allergen Measurements

Severe housing stress was not significantly associated with the measured dust, pet, or pest allergen levels in the home. The relationship between measured allergens in the home and housing stress was not significant in this study. Considering the many research studies that have carefully described these associations and the fact that the housing stress constructs are designed upon questions specifically tied to housing quality concerns, we considered this to be a limitation in the study.

One possible reason for the lack of association of the measured allergens with any of the other variables of interest in this study could have been the use of MARIA tests for home allergen levels instead of ELISA tests to analyze the presence of allergen levels. ELISA tests are more specific for each allergen and previous studies assessing allergen exposures and risk of asthma using ELISA tests have had positive correlations (Wilson 2010).

Secondly, it is possible that we did not find an association with measured allergen levels and severe housing stress because over 80% of the homes had elevated measured levels of allergens in either the kitchen, living room or bedroom and over 60% of subjects had elevated levels of allergens specifically in their bedrooms. This lack of variability in the data may have made it hard to distinguish

the association between elevated allergens exposure and severe housing stress.

However, the non-significant associations between elevated home allergen levels and asthma health outcomes has indicated that the severe housing stress described and analyzed in this study is likely due to the effect of the emotional pathway of housing stress (Figure 2). Housing stress as described by Sandel et al. (2006) stems from the interplay of both emotional components as well as physical components. Emotional factors can include wishing to move and being unable to do so as well as the perception that one has no of control over their housing challenges. Physical factors can include allergens in the home and exposure to tobacco and smoking in the home (Figure 1). These issues influence one another, however, since there was no direct association between the elevated allergen levels and the asthma health outcomes of the child and caregiver, it would appear that the severe housing stress experienced is likely due to the emotional component of housing stress (Figure 2). More studies will have to be done to understand the interplay between the physical and emotional factors that lead to severe housing stress.

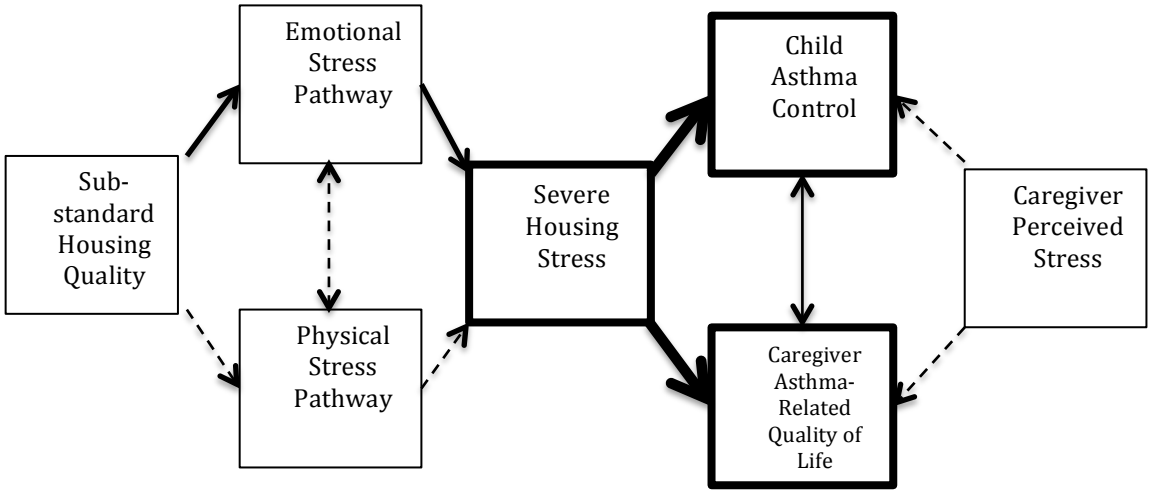

Figure 2. A Proposed Model for the Emotional Pathway for Severe Housing Stress and Asthma Health Outcomes. This figure describes the proposed relationship in the variables assessed in this study and is based on the Housing Stress model described by Sandel et al. (2006). The dark lines describe the path for the proposed emotional pathway based in part on the findings in this paper. The relationship between severe housing stress and child asthma control as well as that of severe housing stress and caregiver quality of life were found to be statistically significant in this study. The dashed lines represent relationships that have been described in the literature, but which were not seen in this study. Based on the model, poor quality housing is associated with severe housing stress, which in turn leads to worse asthma health outcomes for the child and caregiver.

Limitations of Perceived Stress

Another limitation of this study lies in the fact that the perceived stress scale (PSS) questions, which were answered by adult caregivers, are rather subjective. As a result, for caregivers experiencing long term, chronic stress, the PSS score may not be able to distinguish between less stress for one person, and insensitivity to stress due to ongoing life circumstances for another. While perceived stress was increased among those who were experiencing severe housing stress, the associations between perceived stress and severe housing stress and with perceived stress and caregiver quality of life were weak were not statistically significant. Since many studies have found the opposite results when they considered perceived stress and asthma health outcomes, it is possible that the PSS scores in this study population did not have enough variability to see a clear association. Another aspect to consider is the fact that few studies have tried to assess both housing stress and perceived stress. Where housing stress assessments allow a respondent to identify a clear source of his/her concern, the perceived stress questions are less specific, which could explain the slight, but not statistically significant association between severe housing stress and perceived stress.

Implications for Future Research

In this analysis, since the relationship between elevated levels of measured home allergen exposure and perceived caregiver stress with the primary outcome variables in the analysis were weak at best; this allowed us to examine the effect of

severe housing stress in a new dynamic. Housing stress is comprised of three domains two of which may relate to direct allergen exposures in the home and the third domain, which is tied to a perceived lack of control and emotional state. The fact that allergen exposures were not significantly associated with either child asthma control or caregiver quality of life indicates that there is an additional pathway tied to housing stress that is affecting both the child and caregiver. It would be interesting to examine the association between the third housing stress construct, a lack of housing control, and perceived stress to determine if this is the link between these different forms of stress.

Additional studies should consider how different types of stress due to different underlying concerns could be distinguished from one another in other analyses. It is important to understand the underlying issues causing the stress of the caregiver and child. Since studies have shown that not all children who live in inner city homes experience the same level of elevated asthma risk, the presence of stress plays an important role in exacerbating health outcomes (Warman 2009). Furthermore, since the health of the child and the psychological health of the parent or caregiver are linked together, when one factor like severe housing stress impacts both of these outcome measures, recognizing the underlying cause of that stress can provide insight into the appropriate types of interventions (Wood 2010, Suglia 2010, Mullins 2004, Wright 2010). By remedying housing stress concerns it may be possible to alleviate the bi-directional and cyclical worsening of health outcomes among children and parents.

One way to address this issue is through the medical-legal partnership (MLP) model. Interventions designed to address the construction and condition of rental properties could impact those living in low-income, substandard housing conditions and improve their health outcomes. The MLP model is designed to use legal tools to help vulnerable people in cases where hardships related to hunger, housing, and energy access can have a direct impact on health (Lawton 2014, Murphy 2011). The use of MLPs in medical practice has been associated with an increase in patient wellbeing and a reduction in perceived stress, while direct housing interventions including home modifications have been shown to improve child health (Ryan 2012, Sandel 2004). Recognizing that the findings of this study describe a unique stress pathway in the housing stress paradigm, where the perception of a lack of control may have a key role in the perception of stress, interventions that are designed to empower residents should have a positive impact on the asthma control of the child and the quality of life of the caregiver.

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