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Momentary Assessment of Psychosocial Stressors, Context, and Asthma Symptoms in Hispanic Adolescents

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Abstract

Objective—The current study used a novel real-time data capture strategy, Ecological Momentary Assessment (EMA), to examine whether within-day variability in stress and context leads to exacerbations in asthma symptomatology in the everyday lives of ethnic minority adolescents.

Methods—Low-income, Hispanic adolescents ($N = 20$) (7th–12th grade) (54% male) with chronic asthma completed seven days of EMA on smartphones, with an average of five assessments per day during non-school time. EMA surveys queried about where (e.g., home, outdoors) and with whom (e.g., alone, with friends) participants were at the time of the prompt. EMA surveys also assessed over the past few hours whether participants had experienced specific stressors (e.g., being teased, arguing with anyone), asthma symptoms (e.g., wheezing, coughing), or used an asthma inhaler. Multilevel models tested the independent relations of specific stressors, and context to subsequent asthma symptoms adjusting for age, gender, and chronological day in the study.

Results—Being outdoors and experiencing disagreements with parents, teasing, or arguing were associated with more severe self-reported asthma symptoms in the next few hours (p 's < .05).

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Being alone and having too much to do were unrelated to the experience of subsequent self-reported asthma symptoms.

Conclusions—Using a novel real-time data capture strategy, results provide preliminary evidence that being outdoors and experiencing social stressors may induce asthma symptoms in low-income Hispanic children and adolescents with chronic asthma. The results of this preliminary study can serve as the basis for larger epidemiological and intervention studies.

Keywords

Chronic asthma; asthma symptoms; psychosocial stress; ecological momentary assessment; children; adolescents; experience sampling

Psychosocial stress and environmental exposures are associated with increased asthma morbidity in low-income and ethnic minority children and adolescents (Koenig, 1999; Nagata, Irie, & Mishima, 1999). Evidence from epidemiological studies suggests that chronic exposure to stressful experiences and perceived stress can exacerbate asthma onset and progression (Wisnivesky, Lorenzo, Feldman, Leventhal, & Halm, 2010). Differential exposures to stressful living conditions such as social and financial hardships, violence, lack of safety, difficult family situations, and early negative life events may explain disparities in asthma outcomes (Alves Gda, Santos, Feitosa, & Barreto, 2012; Beck et al., 2014; Fang et al., 2011; Hyland, Alkhalaf, & Whalley, 2013; Koinis-Mitchell et al., 2011; Scott, Smith, & Ellis, 2012; K. Shankardass et al., 2011; Tibosch, Verhaak, & Merkus, 2011; Vangeepuram, Galvez, Teitelbaum, Brenner, & Wolff, 2012). Children of mothers reporting higher levels of chronic stress had a higher lifetime prevalence of wheezing and asthma symptoms (de Marco et al., 2012; Sternthal, Coull, Chiu, Cohen, & Wright, 2011). Further, a growing body of work suggests that psychosocial stress may exacerbate the effects of exercise and air pollution on asthma outcomes. The association between traffic-related pollution near children's home and the onset of asthma was increased by parental stress levels (Ketan Shankardass et al., 2009). Hispanic children are disproportionately exposed to multiple environmental pollutants as well as social stressors (e.g., poverty, crime, discrimination), which may contribute to asthma disparities affecting Hispanics. Among children with asthma in Los Angeles, Hispanics were more likely than White-Caucasians to report a need for urgent medical services to treat asthma-related morbidities (Macartney, Bishaw, & Fontenot, 2013; OEHHA, 2014 ; Simon, Zeng, Wold, Haddock, & Fielding, 2003).

While epidemiological and intervention research indicates that *chronic* exposure to stress and outdoor air pollution may play a contributing role in asthma incidence and morbidity, less is known about the short-term (i.e., within-day) effects of *acute* stress and context on asthma symptomatology. Experimental studies have offered some evidence of acute stress-induced bronchial constriction. Psychosocial stress tasks such as free speech paradigms and mental arithmetic have led to changes in tidal volume, inspiratory flow, minute ventilation, tidal volume instability, and ribcage-abdominal asynchrony—with lengthening of inspiration, expiration, and the total respiratory cycle during stress significantly greater among participants with asthma as compared with healthy controls (T. Ritz, Simon, & Trueba, 2011). In another laboratory study, completing a frustrating computer task increased breathlessness in participants with asthma, some to excessive levels (Rietveld, van Beest, &

Everaerd, 1999). Yet, none of the participants developed airway obstruction, showed reduction in lung function, or experienced significant wheezing or coughing attacks. Among children, a related study found that viewing an emotional film that induced anxiety did not independently trigger airway obstruction and breathlessness. However, children reported feeling more breathless after an exercise task when they viewed the emotional film immediately before that exercise task (Rietveld & Prins, 1998). To date, little is known about whether children experience acute stress-induced asthma symptoms in free-living settings (i.e., outside of the laboratory). Equivocal results found in laboratory studies may be at least partially due to the limited ecological validity of the contrived situations and experimental manipulations. The extent to which experimentally-induced stressors replicate the types of stressful exposures that children experience in the real world is not entirely known.

Real-time data capture strategies such as Ecological Momentary Assessment (EMA) may better elucidate the acute (i.e., within-day) effects of psychosocial stress and contextual exposures on children's asthma morbidity in real-world settings (Bolger, Davis, & Rafaeli, 2003; Shiffman, Stone, & Hufford, 2008). There is emerging evidence that the measurement of health behaviors and symptoms is improved with approaches using mobile technologies for real-time data capture. EMA may reduce recall errors and biases that threaten retrospective self-report, and it may enhance ecological validity by measuring emotions, cognitions, behaviors, and symptoms in the settings where they naturally occur (Schwarz, 2007). This strategy makes it possible to examine many attributes of health behaviors and conditions, including severity and duration, patterns of variability, temporally-adjacent experiences, and concurrent exposures and events (Dunton, 2011; Dunton & Atienza, 2009). To date, a small but growing number of studies have applied EMA methodologies to measure asthma symptoms and adherence (Everhart, Smyth, Santuzzi, & Fiese, 2010; Juth, Smyth, & Santuzzi, 2008; MacDonell, Gibson-Scipio, Lam, Naar-King, & Chen, 2012; Mulvaney et al., 2013).

To address the identified research gaps, this study used EMA to measure specific psychosocial stressors, contextual exposures, and acute self-reported asthma symptoms in low-income Hispanic adolescents with chronic asthma. The first aim was to evaluate the feasibility, user compliance, and validity of the EMA procedures and measures in this population. The second aim was to describe the frequency of and variability in psychosocial stressors, inhaler use, and self-reported asthma symptoms experienced in the everyday lives of the low-income, Hispanic adolescents in this sample. The third aim was to examine whether specific stressors, and contextual exposures were related to exacerbations in subsequent self-reported asthma symptoms experienced over the next few hours.

Methods

Participants and Recruitment

Participants were low-income Hispanic adolescents (12–17 years old) ($N = 20$) living in the Los Angeles area who had been diagnosed with chronic asthma. Recruitment occurred through the Los Angeles County and University of Southern California Pediatric Asthma Disease Management Program (LAC+USC PADMAP) Breathmobile Program. This school-based disease management program uses fully equipped mobile clinics, which are staffed by

specialty trained asthma providers and clinicians. The program provides asthma case identification, community outreach, continuity of care, structured healthcare encounters, and patient tracking. Inclusion criteria consisted of the following: (1) age 12–17 years old, (2) diagnosed with asthma, (3) prescribed the use of a steroid inhaler, (3) able to comprehend written English, and (4) no other health problems that would prevent participation in physical exercise. Breathmobile providers referred potential participants with physician-verified asthma to research personnel. Screening for eligibility criteria, orientation, and consent were conducted by a bilingual project manager at a regularly scheduled Breathmobile appointment. This research was reviewed and approved by the Institutional Review Board at the University of Southern California. Parental consent and child assent were obtained.

Study Design

The current study used a cross-sectional, observational, case-crossover design (Maclure & Mittleman, 2000; Shiffman, 2009). In case-crossover designs, an individual serves as his/her own control to assess the within-day effects of immediate antecedents on a repeatedly-measured dependent variable (Maclure & Mittleman, 2000). Each child participated in 7 days of continuous assessment that included EMA and activity monitoring using a wearable, hip-worn accelerometer. Demographic characteristics and asthma history were assessed with a self-report paper questionnaire.

EMA Procedures

EMA data were collected using a Galaxy Y smartphone (Samsung, Inc.) with a custom Android OS software program installed that was modified for this study from an application used in other work (Dunton et al., 2014). Phones were loaned to participants for the duration of the study to ensure consistency across devices. Although the calling capabilities were disabled, the phones had active data plans, which enabled Internet connectivity. EMA occurred during children's non-school time between 3–9pm on weekdays and 7am–9pm on weekend days. Signal-contingent (i.e., randomly-prompted) and automatically initiated event-contingent sampling schemes were used (i.e., context-sensitive EMA) (Intille, 2007). One signal-contingent EMA survey was prompted at a random time within each of seven designated two-hour time intervals (7–9am, 9–11am, 11am–1pm, 1–3pm, 3–5pm, 5–7pm, 7–9pm). Event-contingent EMA surveys were automatically prompted approximately 5 minutes after each inhaler use. A Propeller sensor (Propeller Health, Madison, WI) was loaned to participants and attached to the top of participants' rescue (i.e., emergency inhalers used during acute asthma attacks) and control inhalers (i.e., maintenance inhalers used daily to prevent asthma symptoms). The sensor communicated via the Bluetooth radio to the mobile phone each time the inhaler was activated. The EMA application continuously monitored for all Propeller inhaler activation notifications. Upon receiving an activation notification, the EMA application waited approximately 5 minutes and then initiated an event-contingent EMA survey prompt. Upon hearing a notification chime from the phone (indicating either a signal- or event-contingent prompt), participants were instructed to stop their current activity and complete a short multiple-choice question sequence using the phone's touch screen display. Each EMA survey required 2–3 min to complete. Reminder chimes were sounded after 3 and 6 minutes if no response was recorded. After 10 minutes,

the survey became inaccessible until the next prompting period. If an EMA prompt occurred during an incompatible activity (e.g., sleeping, bathing), participants were instructed to ignore it. No EMA prompting occurred during school hours on weekdays (before 3pm). More information on the EMA methods and procedures is published elsewhere (Dzubur et al., 2015). Children were compensated \$100 for participating in the study.

Measures

EMA items—EMA question sequences measured specific psychosocial stressors, context, asthma symptoms, and type of inhaler used (i.e., rescue versus controller) as well as other behavioral variables not reported here. Figure 1 shows example screen shots from the EMA survey. Specific stressors occurring since the last survey or in the past four hours were measured using a four-item scale derived from the Hassles Scale for Children (HSC) (Parfenoff, 1989) (i.e., “has anyone teased you?,” “have you argued with anyone?,” “have you had a misunderstanding or a disagreement with parents?,” “have you had too many things to do?”) with five response options (i.e., “no,” “yes, but not at all stressful,” “yes, and caused a little stress, yes, and caused some stress,” “yes, and caused very much stress”) (see Figure 1). Responses were recoded into binary variables (1=the event occurred, 0=the event did not occur). Each specific stressor item was examined separately in statistical analyses. To limit the length of the EMA surveys, the specific stressor items each appeared in a randomly programmed 60% of the EMA prompts (i.e., each item group had a 60% chance of appearing on any given EMA survey).

The EMA question sequence also asked adolescents to indicate their current physical and social contexts. Participants indicated who they were with just before they were prompted. Responses to these items were used to create a summary variable for social context (*alone* versus *not alone*). Participants were also asked, “WHERE were you just before the phone went off?” with response options, “Home (Indoors),” “School,” “Outdoors,” “Restaurant,” “Store or mall,” “Someone else’s house (Indoors),” “In a car,” and “Other.” Responses to these items were used to create a summary item for physical context (*outdoors* versus *all else*). To limit the length of each EMA survey, questions about social and physical context were asked in only 60% of the EMA prompts using a programmed random selection procedure.

Asthma symptoms experienced since the last survey or in the past four hours if the prior survey was missed were assessed using a four-item scale derived from the Children’s Health Survey for Asthma (CHSA) (Asmussen, Olson, Grant, Fagan, & Weiss, 1999). The scale queried participants to determine whether they experienced coughing, wheezing, chest tightness, or shortness of breath with four response options. The mean severity of the four individual symptom items was used to assess total asthma symptomology. Type of asthma inhaler usage was differentiated with a single item during event-contingent prompts with three possible responses (see Figure 1). Self-reported asthma symptom severity and type of inhaler were assessed in every EMA survey.

Physical activity—The Actigraph, Inc. GT2M model (firmware version 7.5.0) activity monitors, worn on the hip, provided an objective measure of physical activity to test as a

potential covariate predicting self-reported asthma symptoms given the likelihood that children may experience exercise-induced bronchospasm. A 30-sec epoch was used. Moderate-to-vigorous physical activity (MVPA) was defined using age-specific thresholds generated from the Freedson prediction equation (4 Metabolic Equivalents) (METs) (Freedson, Pober, & Janz, 2005). Accelerometer non-wear was defined as 60 consecutive minutes of no activity counts, allowing for 2 min of minimal activity counts. Accelerometer data were linked to EMA survey responses using the electronic time stamps. Minutes of MVPA since the last completed EMA survey was calculated for each EMA prompt.

Demographic characteristics—Participants' age, sex, race/ethnicity, and socioeconomic status were assessed through a child self-report paper survey at the initial appointment. Socioeconomic status was measured by a single item querying whether or not the participant received free lunch.

Asthma history and severity—Participants' asthma history and severity were also assessed through the child self-report paper survey at the initial appointment. Asthma onset was measured by a self-reported first-use of inhalers for the treatment of asthma. Participants were asked how often they experienced attacks of symptoms (coughing, wheezing, chest tightness, or shortness of breath) over the past 12 months in general and during or after exercise. Additionally, participants were asked whether or not they were hospitalized due to attacks of asthma-related symptoms in the past 12 months.

Data Analyses

Prior to analyses, each day of observation was split into nine 2-hour windows between 5 AM and 11 PM. Three rules were applied to select or combine data if two or more answered EMA prompts occurred within the same window. First, whenever there was one or more answered event-contingent EMA prompt reporting rescue inhaler use, data from those answered event-contingent EMA survey were used, and data from any other answered EMA prompts falling into the same time window were not included in the analyses. Second, if two or more answered EMA prompts with identical contingencies (e.g., both signal-contingent, both event-contingent reporting rescue inhaler use) occurred within the same window, the means for all predictors and outcomes were calculated for that window, as well as a count of the number of times the inhaler was used. Event-contingent EMA prompts occurring during the overnight hours (between 11 pm and 5 am) ($n = 29$), event-contingent EMA prompts with participants reporting no inhaler use ($n=59$), and answered EMA prompts with incomplete data ($n=4$) were excluded. Finally, beyond these exclusions, windows with at least one answered EMA prompt were included in the analyses.

The data are multilevel in nature with time windows (Level 1) clustered within individuals (Level 2). Data were time-lagged to examine the acute directional effects of specific stressors and contexts on self-reported asthma symptoms because the hypothesized predictors and outcomes were originally measured during the same timeframe (i.e., just before the phone went off, since the last survey or the past four hours). Time-lagging is a data manipulation procedure that matches the outcome variables (i.e., self-reported asthma symptoms) measured during at any given time window t to predictor variables (i.e., specific

stressors, contexts) measured during the previous time window $t-1$. If data were missing in the previous time window, the closest window (i.e., $t-2$) not exceeding 4 hours of time was used for matching.

Multilevel logistic and linear regressions in Stata 13 were conducted. The variances for time-varying Level-1 binary predictors were partitioned into uncentered, within-person (WP) terms and between-person (BP) terms centered on the grand mean proportion (Curran & Bauer, 2011). To test the first aim of the study, multilevel logistic regressions conducted in Stata 13 (melogit) were run to determine whether level-1 time-varying (e.g., self-reported asthma symptoms and specific stressors in the previous time window $t-1$; time of day; day of week; and previous and concurrent MVPA) and level 2 time-invariant (e.g., asthma history and severity, demographics) variables are associated with EMA prompt compliance (0 = no response and 1 = response). To test the validity component of first aim, EMA-reported asthma symptom severity was compared between occasions of *rescue inhaler use* = 1 (from event-contingent prompts reporting rescue inhaler use) versus *no rescue inhaler use* = 0 (event-contingent prompts reporting controller inhaler use and signal contingent prompts reporting no inhaler use). Multilevel linear regressions examined differences in severity of self-reported asthma symptoms (outcome) reported for rescue versus no rescue inhaler use (entered as a binary predictor variable). All subsequent models combined data from signal- and event-contingent EMA prompts.

To test the second aim, multilevel logistic and linear regressions were used to examine the relationship between self-reported use of a control or rescue inhaler and chronological day in the study, time of day, age, gender, and MVPA during CS-EMA prompts. Multilevel linear regressions were also used to examine the relationship between self-reported asthma symptoms and time of day, day in the study, age, gender, and MVPA.

To test the third aim, multilevel linear regressions were used to examine the acute prospective associations of specific stressors, and context with the severity of subsequent self-reported asthma symptoms. A first-order autoregressive covariance structure was utilized. In order to examine directional relationships, self-reported asthma symptoms measured during at any given 2-hour time window t were linked to predictor variables (i.e., specific stressors, contexts) measured during the previous 2-hour time window $t-1$ within that same day. The same approach was taken for social and physical context variables. Models controlled for age, gender, and chronological day in the study. Each stress and context item was examined separately in statistical analyses. Time of day and minutes of MVPA since the last completed EMA survey were screened as potential covariates.

Results

Sample and EMA Prompt Characteristics

The study sample consisted of 11 boys and 9 girls, with a mean age of 14.6 (SD = 1.7) years, 100% Hispanic, and a reported 90% receiving free lunch or reduced priced lunch at school. Demographic and asthma characteristics for this sample are displayed in Table 1. Across the seven days of assessment, a total of 655 EMA surveys were prompted during non-school time between 3–9pm on weekdays and 7am–9pm on weekend days, of which 462 were

signal-contingent (i.e., random) and 193 were event-contingent. Of the answered event-contingent prompts, 57 reported control inhaler use, 25 reported rescue inhaler use in the past few minutes, and 111 had unknown or no inhaler use. Participants received a daily average of 3.5 (SD = 0.7, range = 2.0 – 4.6) signal-contingent and 2.0 (SD = 1.4, range = 1.0 – 5.8) event-contingent prompts. Adolescents received marginally more event-contingent prompts per hour of monitoring on weekend days ($M = 1.6$, $SD = 1.85$) as compared with weekdays ($M = 1.3$, $SD = 1.73$) ($z = -1.88$, $p = 0.06$). The number of event-contingent EMA prompts received did not differ by time of day ($F = 0.55$, $p = 0.46$).

Aim 1: Feasibility, Compliance, and Validity

Average EMA prompt compliance (i.e., completing all survey items in a given prompt or reminder prompt) rates ranged from 16% to 100% ($M = 50.1\%$, $SD = 20.5\%$), yielding 280 windows with at least one answered prompt ($M = 14.9$, $SD = 7.45$, range = 2–27 per participant). Accelerometers were not worn during 74 of the 2-hour windows with available EMA data, leaving a Level-1 sample size of 206 2-hour windows with linked EMA and accelerometer data. After taking into account planned EMA item skip patterns, up to 83 windows were available for each analysis. Between participants, average compliance to signal-contingent EMA prompts (mean of 54.6%) did not differ from event-contingent EMA prompts (mean of 47.9%) ($z = -0.28$, $p = 0.78$). However, within-participant analyses revealed that adolescents were 6.1 times (95% CI: 1.09 – 33.78) as likely to respond to a signal-contingent prompt compared to an event-contingent prompt ($z = 2.06$, $p < 0.05$). EMA compliance rates did not differ between adolescents by age, sex, asthma severity, or asthma history (see Table 2). Furthermore, the likelihood of responding to either a signal- or event-contingent EMA prompt during any given time window was not related to the time of day, day of the week, or MVPA since the last completed EMA survey. Within individuals, the likelihood of responding to either a signal- or event-contingent EMA prompt (at any given time t) was 2.90 times greater for each unit increase in the reported severity of self-reported asthma symptoms at the previous prompt (at time $t-1$).

To examine construct validity of EMA-reported asthma symptom severity, its relationship with type of inhaler use was tested. When one reported more severe self-reported asthma symptoms than one's average symptom severity levels (i.e., within-person; WP) in prior hours, adolescents were more likely to use a rescue inhaler as compared with no inhaler after adjusting for covariates ($est = 0.90$, $SE = 0.08$, $p < 0.001$). The positive WP effects were observed for severity of self-reported coughing ($est = 0.71$, $SE = 0.12$), chest tightness ($est = 0.78$, $SE = 0.10$), shortness of breath ($est = 1.05$, $SE = 0.12$), and wheezing ($est = 1.04$, $SE = 0.10$) (p 's < 0.001).

Aim 2: Frequency of and Variability in Stressors, Inhaler Use, and Self-Reported Asthma Symptoms

Descriptive statistics for specific stressors, inhaler use, and self-reported asthma symptoms for 2-hour windows with available data are presented in Table 3. The frequency of experiencing specific stressors in the past two hours was as follows: teasing (43.8%), parental disagreements (44.9%), arguments (46.0%), and having too much to do (52.9%). Adolescents reported being outdoors during 5.4% of the EMA prompts asking about current

physical context and being alone during 22.1% of the EMA prompts asking about current social context. On average, adolescents had performed 1.5 (SD = 4.85) minutes of MVPA since the last completed EMA survey.

Participants used a rescue inhaler in 7.4% (n=22) and a control inhaler in 11.7% (n=35) of the 2-hour windows with available data. The likelihood of using a controller or rescue inhaler was not related to chronological day in the study, age, or gender (p 's > 0.05). An individual was 4.6% and 3.6% less likely to use a rescue inhaler (95% CI: 0.92–0.99) or controller (95% CI: 0.93–0.99), respectively, at any given hour compared to the two hours before (p 's < 0.05)—indicating that inhaler use became less frequent as the day progressed. Within individuals, MVPA since the last completed EMA survey did not differ between prompts indicating the use of a rescue inhaler ($M = 5.44$, $SE = 1.57$) and those indicating no use of a rescue inhaler ($M = 10.15$, $SE = 5.04$) ($z = 0.94$, $p = 0.35$). Those reporting greater use of a rescue inhaler (between-person, BP) had, on average, 76.2 more minutes of MVPA ($SE = 19.77$) since the last completed EMA survey ($z = 0.35$, $p < 0.001$).

The average severity ratings on a four-point scale for asthma symptoms per two-hour windows with available data are presented in Table 3. Seven participants reported experiencing at least one type of asthma symptom during ten or more different occasions during the study. Two participants did not report any asthma symptoms. Severity of self-reported asthma symptoms was unrelated to time of day, age, or gender. Reported severity of total self-reported asthma symptoms was 0.05 lower, on average, ($SE = 0.02$) for each additional day enrolled in the study ($z = -3.39$, $p < 0.001$). The severity of self-reported asthma symptoms, both WP and BP, was unrelated to MVPA since the last completed EMA survey (p 's > 0.05). Thus, MVPA was not included as a covariate in further analyses.

Aim 3: Prospective Associations of Stress and Context with Subsequent Self-Reported Asthma Symptoms

The associations of specific stressors, social context, and physical context with subsequent self-reported asthma symptoms experienced in the next few hours are shown in Table 4. The WP terms indicate whether exposure to specific stressors or contexts at any given EMA prompt (time $t-1$) are prospectively associated with self-reported asthma symptoms experienced in the next few hours (time t). The between-person (BP) terms indicate whether those adolescents with greater frequency of exposure to the specific stressors and contexts, compared to others in the study, also reported greater asthma symptoms severity. Results demonstrated that when an adolescent experienced stress from arguing or teasing at any given EMA prompt (WP effect), he or she also reported more severe total self-reported asthma symptoms in the next few hours (p 's < .05). In particular, experiencing stress from teasing, arguing, and parental disagreements at any given EMA prompt was associated with increased shortness of breath over the next few hours as compared with not experiencing these specific stressors, respectively (p 's < .05). Experiencing stress from teasing and arguing was marginally prospectively associated with greater self-reported wheezing within-persons, relative to not experiencing stress from teasing or arguing, respectively (p 's < .10). However, those who experienced more frequent stress from teasing, arguing, or parental disagreements (BP effects) reported decreased severity shortness of breath and wheezing, on

average, relative to participants with less reported stress from teasing, arguing, or parental disagreements, respectively (p 's $< .05$). Also, those experiencing stress more frequently from teasing or arguing (BP effects) had marginally less severe total self-reported asthma symptoms, on average, relative to their peers with less frequent stress from teasing and arguing (p 's $< .10$).

Whether a child was alone (versus not alone) at any given EMA prompt was unrelated to the severity of self-reported asthma symptoms reported in the next few hours (i.e., within-person effect). However, those who reported being alone more frequently, compared to others in the study (BP effect), reported marginally greater average severity of coughing, chest tightness, and total asthma symptoms (p 's $< .10$). When a child was outdoors (versus any other physical/environmental contexts) during any given EMA prompt (WP effect), the child reported greater severity of coughing, shortness of breath, chest tightness, and total asthma symptoms in the next few hours (p 's $< .05$). However, those who spent more time outdoors did not differ with respect to asthma symptom severity, relative to their peers who spent less time outdoors (BP effect).

Discussion

The current study used EMA, an innovative real-time data capture strategy, to examine the acute within-daily effects of psychosocial stress and contextual exposures on self-reported asthma symptoms in low-income, Hispanic adolescents with chronic asthma. Although epidemiological studies have shown that chronic stress may play a contributing role in asthma severity, less is known about the short-term (i.e., within-day) effects of acute stress on asthma morbidity (Alves Gda et al., 2012; Fang et al., 2011; Hyland et al., 2013; Koinis-Mitchell et al., 2011; Scott et al., 2012; Tibosch et al., 2011; Vangeepuram et al., 2012). EMA methods can measure exposure to specific stressors and contexts, and self-reported asthma symptoms as they naturally occur during the course of participants' everyday lives (Kaplan & Stone, 2013; Stone AA, 1994). The current study is, to our knowledge, one of the first studies to employ automatically-initiated event-contingent (i.e., context-sensitive) EMA sampling to trigger smartphone surveys immediately after the deployment of an asthma inhaler is automatically detected (Intille, 2007). Thus, it has the potential to capture the events and exposures leading up to asthma exacerbations to help researchers and clinicians to identify high-risk situations for disadvantaged children and adolescents with severe asthma.

This study showed that when adolescents experienced stress from teasing, arguing, or parental disagreements; they reported more asthma symptoms in the next few hours. Results build upon and extend limited evidence offered from experimental laboratory studies suggesting that acute stressful exposures may trigger the onset of airway constriction and breathing difficulties among those with asthma (Rietveld & Prins, 1998; Rietveld et al., 1999; T. Ritz et al., 2011). In these previous studies, the types of stressful stimuli (e.g., speech tasks, mental arithmetic, and emotional films) may not resemble stressful exposures that adolescents encounter in their everyday lives. A methodological advantage of the current study is that the EMA items measure naturally-occurring social stressors such as teasing, arguing, and disagreements. It is important to note, however, having too many things

to do was unrelated to asthma symptom severity. This type of stressor was selected for inclusion on the EMA survey because it was thought to represent a common source of daily stress encountered by adolescents (Parfenoff, 1989). It is possible that other unmeasured daily stressors (e.g., academic pressures, romantic turmoil) may exacerbate or trigger asthma symptoms. Future research should explore the effects of a wider range of acute stressors on asthma severity.

Results from the current study also indicate that contextual exposures may exacerbate asthma symptoms among low-income, Hispanic adolescents with chronic asthma. In particular, adolescents reported more severe asthma symptoms when they were outdoors as compared with other physical contexts. Being outdoors may increase exposure to respiratory irritants such as PM 2.5 and ozone, particularly among this sample of low-income adolescents living in urban Los Angeles, which has some of the most polluted air in the United States (Alexis et al., 2014; Jerrett et al., 2005). Adolescents and other children in disadvantaged minority and low-income groups are disproportionately exposed to multiple environmental chemicals in California. Recent efforts to summarize the cumulative environmental burden illustrate these inequities, with the Hispanic population carrying the greatest burden of environmental exposures by far (OEHHA, 2014). An interesting finding was that the severity of self-reported asthma symptoms did not differ depending on whether the child was alone as compared to with other people at any particular EMA prompt, even though experiencing social stressors appeared to exacerbate self-reported asthma symptoms. It is possible that the effects of positive (e.g., support, companionship) and negative (e.g., arguments, teasing) social interactions on asthma symptom severity cancel each other out.

Another notable finding from the study was that in some cases, the within- and between-person effects of stress on self-reported asthma symptoms had opposite signs. The positive within-person effects suggest that *when* adolescents experienced stress from teasing, arguing, and parental disagreements; they reported more asthma symptoms in the next few hours. However, the negative, between-person effects suggest that adolescents *who* reported more frequent stress from these types of social encounters than other participants in the sample also tended to report fewer asthma symptoms on average. It may be that children who frequently experience stress from social encounters are less sensitive to these types of asthma triggers; however, this explanation warrants further research. The emergence of these contrasting results underscores the importance of differentiating between within- and between-sources of variation in phenomena that are measured in a repeated manner (Curran & Bauer, 2011). It should be noted that the observed between-person effects represent average levels of acute stressors (e.g., daily teasing), which may differ from between-person effects due to sources of chronic stress (e.g., poverty, discrimination, illness, neighborhood crime). Evidence suggests that chronic versus acute stress may have differing effects on Hypothalamic-Pituitary-Axis (HPA) and other immune responses (Gu, Tang, & Yang, 2012).

Results from the current study suggest that the EMA procedures for measuring stress, contexts, and asthma symptoms are feasible and acceptable among low-income, Hispanic youth with asthma. Smartphone device loss and breakage were minimal. EMA compliance rates did not differ between individuals based on age, sex, asthma severity, or asthma history. Also, experiencing stress in the past few hours was unrelated to the likelihood of responding

to an EMA prompt. However, the adolescents were less likely to respond to EMA prompts that were linked to the use of their asthma inhaler (i.e., event-contingent) than EMA prompts that occurred at random. This pattern could have occurred because the adolescents were continuing to experience asthma symptoms at the time of the prompt that prohibited completing an EMA survey. Alternatively, some event-contingent prompting could have occurred when adolescents had recently completed an EMA survey prompt and were not expecting another prompt so soon.

Strengths of this study include use of context-sensitive, real-time data capture to reduce recall biases and increase ecological validity, and time-lagged data manipulation procedures to test directional associations (and reduce concerns about reverse causation). However, there are a few limitations. Measures consisting of only a small number of items are often necessary in EMA research to limit the length of time required to respond to each electronic survey to only a few minutes in order to reduce participant burden. Additionally, these measures are derived from longer scales and have not been validated on their own. Seven days of assessment may not be sufficient to represent participants' usual behavior. Yet, longer monitoring periods at the current rate of survey prompting could impose an unacceptable participant burden and reduce compliance. Also, this study only captured adolescents' leisure-time physical activity. Stressful exposures and asthma-related events taking place at school are not represented. While the study used objective detection of inhaler usage, there was no objective measure of asthma symptomology. Moreover, it may be possible that when participants are exposed to stress, their perception of asthma symptoms may become hypersensitive (Feldman, Siddique, Thompson, & Lehrer, 2009; Lavoie et al., 2005; Thomas Ritz, Rosenfield, Meuret, Bobb, & Steptoe, 2008). Child asthma history was also self-reported without parent or physician verification. This study was conducted in Los Angeles, a geographical area with elevated air pollution levels and childhood asthma rates. Results of the study may not generalize to other urban or rural areas with lower levels of air pollution. Likewise, the study is limited in generalizability by a small (N=20) and homogeneous (Hispanic) sample. Lastly, observed associations may be confounded by variables such as personality traits or concurrent activities that were not measured.

Overall, this study used EMA to examine the acute directional effects of psychosocial stress on asthma severity in adolescents. Results indicated that being outdoors or experiencing stress from disagreements with parents, teasing, or arguing were associated with more severe self-reported asthma symptoms in the next few hours. These preliminary findings provide evidence that social stress may exacerbate asthma, but only for those individuals under acute stress. Future research might combine EMA with real-time neural and immune measures of the stress response to more clearly delineate the pathways linking acute stress and asthma exacerbation (Haczku & Panettieri, 2010; Wright et al., 2004). Furthermore, studies may seek to replicate the results using EMA procedures in a larger, more demographically diverse sample (i.e., with younger children, in less polluted areas, and with other ethnic groups).

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Figure 1.
Example screenshots of mobile ecological momentary assessment survey items. This figure shows an example of items querying specific stressors, context, inhaler use, and asthma symptoms.

Table 1

Descriptive Statistics for Sample Demographics and Asthma History (N = 20)

	%	N
Age (Mean, SD)	14.55	1.73
Gender		
Male	55	11
Female	45	9
Ethnicity		
Hispanic	100	20
Free Lunch at School		
Yes	90	18
No	5	1
Unknown	5	1
First Diagnosis of Asthma		
2–4 years old	45	9
5–7 years old	25	5
11–13 years old	25	5
14–16 years old	5	1
Hospitalization Due to Asthma (12 mo.)		
Yes	35	7
No	65	13
General Asthma Symptoms (12 mo.)		
Less than once each month	30	6
About once each month	15	3
About twice each month	40	8
About once each week	5	1
About 2–6 times each week	10	2
Exercise-Induced Asthma Symptoms (12 mo.)		
Sometimes	65	13
Most of the time	30	6
All of the time	5	1
Self-Reported Rescue Inhaler Use (12 mo.)		
Less than once each month	20	4
About once each month	10	2
About twice each month	20	4
About once each week	20	4
About 2–6 times each week	15	3
About once a day	5	1
Several times per day	10	2

Table 2

Ecological Momentary Assessment (EMA) Prompt Response Rates: Associations with Person- and Prompt-Level Characteristics

Person-Level (n = 20)	B	SE	P
Age	0.001	0.03	0.97
Gender (1=Female, 0=Male)	-0.04	0.10	0.67
Age of first asthma inhaler use	0.02	0.04	0.50
Hospitalized due to asthma (past 12 mo.)	0.07	0.10	0.49
General asthma symptoms (past 12 mo.)	-0.03	0.04	0.48
Exercise-induced asthma symptoms (past 12 mo.)	0.04	0.08	0.64
Self-reported rescue inhaler use (past 12 mo.)	-0.02	0.03	0.56
Prompt-Level (n = 655)	OR	SE	P
Day of Week	1.01	0.04	0.70
Time of Day	1.00	<0.001	0.49
MVPA 60 minutes before prompt	1.01	0.01	0.56
Total asthma symptoms ^a	0.39	0.29	0.39
Teasing ^{a,b}	1.21	0.16	0.16
Parental disagreement ^{a,b}	1.15	0.15	0.27
Arguing ^{a,b}	1.03	0.13	0.82
Having too much to do ^{a,b}	1.21	0.14	0.12
Physical context ^{a,c}	0.13	0.69	0.85
Social context ^{a,d}	-0.46	0.40	0.25

Note. Analyses were conducted at the person- and prompt- level with linear regressions and multilevel logistical regressions, respectively, using Stata 13. For the person-level analyses, the outcome was the rate of EMA response. For the prompt-level analyses, the outcome was binary: 1 = response to EMA prompt, 0 = no response to EMA prompt. MVPA = moderate-to-vigorous intensity physical activity.

^a Measured at the previous EMA prompt (time t-1).

^b Binary predictor variable: 1=the event occurred, 0=the event did not occur since the last survey or in the past four hours.

^c Binary predictor variable: 0 = not outdoors and 1 = outdoors.

^d Binary predictor variable: 0 = not alone and 1 = alone.

Table 3

Descriptive Statistics for Stressors, Inhaler Use, and Self-Reported Asthma Symptoms for 2-hour Windows with Available Data

		Percent (%)	N
Stressors			
Teasing	Yes	43.8	121
	No	56.2	155
Parental Disagreement	Yes	44.9	124
	No	55.1	152
Arguing	Yes	46.0	127
	No	54.0	149
Having too much to do	Yes	52.9	146
	No	47.1	130
Inhaler Use			
	Rescue	7.4	22
	Control	11.7	35
	None (Random prompt)	80.9	222
		Mean	SD
Severity of Asthma Symptoms ^b			
	Total	1.27	0.43
	Coughing	1.33	0.56
	Wheezing	1.23	0.53
	Tightness of Chest	1.19	0.46
	Shortness of Breath	1.31	0.61

Note.

^a Binary variable: 1=the event occurred, 0=the event did not occur since the last survey or in the past four hours.

^b Likert response scale ranging from 1= Not at all to 4 = Very much

Results of Multilevel Regressions Predicting Self-Reported Asthma Symptoms as a Function of Specific Stressors and Context Experienced Over the Past Few Hours

Table 4

	Total Asthma Symptoms			Coughing			Wheezing			Chest Tightness			Shortness of Breath		
	WP	BP	SE	WP	BP	SE	WP	BP	SE	WP	BP	SE	WP	BP	SE
	β	β	SE	β	β	SE	β	β	SE	β	β	SE	β	β	SE
Teasing ^a	0.50 [*]	-0.70 [*]	0.32	0.01	0.02	0.42	0.73 ^{***}	-0.88 ^{***}	0.34	0.34	-0.54	0.35	1.13 ^{***}	-1.34 ^{***}	0.42
Arguing ^a	0.45 [*]	-0.69 [*]	0.30	0.22	-0.25	0.40	0.57 ^{***}	-0.97 ^{***}	0.30	0.22	-0.41	0.33	0.85 ^{***}	-1.09 ^{***}	0.41
Parental Disagreements ^a	0.34	-0.52 [^]	0.29	-0.15	0.31	0.14	0.47 [^]	-0.80 ^{***}	0.29	0.22	-0.39	0.33	0.78 [*]	-0.95 [*]	0.40
Having too Much to Do ^a	0.05	-0.17	0.24	-0.17	0.21	0.08	0.15	-0.38	0.25	-0.03	0.19	0.26	0.35	-0.30	0.37
Social Context (Alone vs. Other)	-0.09	0.14	0.62 [^]	0.04	0.26	0.49	0.05	0.63 [^]	0.33	-0.16	0.15	0.36	-0.27	0.19	0.50
Physical Context (Outdoors vs. Other)	0.57 ^{***}	-0.66	0.73	0.67 [*]	-0.86	1.10	0.36	-0.31	0.96	0.58 [*]	0.26	0.79	0.67 [*]	-1.17	1.13

Note. WP = within-person. BP = between-person.

^a Binary variable: 1=the event occurred, 0=the event did not occur since the last survey or in the past four hours. Models controlled for age, gender, and time (chronological day in study). Each column group and row represents a different model.

[^] p<0.10

* p<0.05

** p<0.01

*** p<0.001