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Stress, coping, self-efficacy and asthma control:

clinic, diary and laboratory studies

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Abstract

Asthma has not declined in morbidity and mortality despite significant advances in medical treatment. A literature review was conducted and a program of research was devised with the goal of improving understanding of why many appropriately treated and educated asthmatics are unable to gain adequate control of their asthma. A review of the literature found that psychological stress was a poorly understood trigger for asthmatic symptoms and a possible factor in poor asthma control. A clinic visit study of adult asthmatics found: 1) life event stress was associated with asthma quality of life but not ventilatory function, 2) asthma self-efficacy was strongly related to asthma quality of life and ventilatory function, 3) style of coping with stress appeared to buffer the effects of stress on asthma, and 4) evidence for a stress-responsive asthmatic subgroup. A subsequent longitudinal daily diary study found: 1) concurrent stress and daily asthma symptoms were strongly associated, 2) daily bronchodilator use appeared to be determined by pre-diary beliefs about disease severity and controllability, 3) stress could precede (within one day) increases in asthma symptoms and decreases in airflow, and 4) clinically significant decreases in peak flow were often preceded by large increases in perceived stress. A laboratory study found: 1) exposure of asthmatics to specific passive and asthma-related stressors resulted in decreased airflow and that these decreases are associated with a concurrent increase in vagal (parasympathetic) tone, 2) an active stressor that resulted in increased sympathetic arousal did not result in decreased airflow, 3) relaxation resulted in parasympathetic arousal and decreased airflow, and 4) asthma self-efficacy was associated with parasympathetic reactivity. In sum, the program of research has generated findings that help explain how stress, coping and

self-efficacy contribute to asthma control led to concrete suggestions to improve current asthma care and suggested new directions for basic research in asthma psychophysiology.

Résumé

Les nombres des morbidités et des mortalités dû à l'asthme n'ont pas baissé malgré le progrès considérable en traitements médicaux. Une documentation extensive a été conduit et une programme de recherche a été conçue pour améliorer la compréhension de pourquoi un si grand nombre d'asthmatiques qui ont reçu un traitement et une instruction approprié sont incapable de gagner le contrôle adéquat de leur asthme. Une révision de la documentation a trouvé que le stress psychologique était une cause mal comprise pour les symptômes de l'asthme et était un facteur possible de la mauvaise gestion personnelle. Une étude des visites en clinique des asthmatiques adultes a trouvé que: 1) il y avait une corrélation entre les événements stressants et la qualité de la vie avec l'asthme, mais non entre les événements stressants et la fonction ventilatoire; 2) il y avait une forte corrélation entre l'auto-efficacité avec l'asthme, la qualité de la vie avec l'asthme, et la fonction ventilatoire; 3) le style de coping avec le stress semblait améliorer les effets du stress sur les symptômes de l'asthme; et 4) évidence pour une sous-groupe des asthmatiques responsive au stress. Une étude subséquente et longitudinale des journaux quotidiens a trouvé que: 1) il y avait une forte corrélation entre le stress concurrent aux symptômes quotidiens de l'asthme; 2) l'utilisation quotidien d'un bronchodilatateur semblait d'être déterminé par les opinions concernants la sévérité et le contrôllabilité des maladies établies avant de garder les journaux; 3) le stress pourrait précéder (par un jour) des augmentations des symptômes de l'asthme et des diminutions de la circulation de l'air, et; 4) des diminutions de la circulation optimum considérables cliniquement étaient souvent précédés par des grosses augmentations du stress perçu. Une étude finale en laboratoire a trouvé que:

1) l'exposition contrôlé expérimentalement des asthmatiques aux spécifiques stresseurs passifs et liés à l'asthme a abouti à une diminution de la circulation de l'air, et ces diminutions sont associés avec une augmentation concurrente avec un ton parasympathique; 2) un stresseur actif auquel le résultat était une éveillement sympathique augmenté n'avait pas comme résultat une circulation de l'air diminueé; 3) la relaxation avait comme résultat l'éveillement parasympathique et une circulation de l'air diminuée; 4) auto-efficacité avec l'asthme était associé avec réactivité parasympathique observée. En sommaire, la programme de recherche a donné des conclusions qui aident à expliquer comment le stress, le coping, et l'auto-efficacité apporte à la contrôle de l'asthme et a mené aux suggestions concrètes de comment améliorer les traitements actuels de l'asthme et a suscité des nouvelles directions pour la recherche fondamentale de la pathophysiologie de l'asthme.

Statement of Original Contributions

Asthma is a growing problem. Each of the studies in this research program comprise original attempts to explore links between psychological variables and asthma control. This program of research makes a number of important advances and contributes findings that help account for problems in asthma control, further understanding of asthma psychophysiology and have important implications for asthma management. First, a hospital clinic-based study was conducted to assess the role of life event stress, coping style, and asthma self-efficacy in subjective asthma quality of life and pulmonary function. Both subjective and objective indices of asthma status were used and all subjects were carefully screened for airway hyperreactivity. Coping was found to buffer the effect of stress on asthma, while self-efficacy appeared to effect asthma status directly. Evidence for a stress-responsive asthmatic subgroup was found. Next, I conducted a prospective daily diary study to assess perceived stress, asthma symptom perception, peak flow (an objective indicator of airway limitation) and beta-agonist bronchodilator ("rescue") medication use. The association between concurrent daily stress and daily symptom reporting was high, and evidence that minor decreases in airflow could be preceded by increases in stress was generated. Further evidence for a stress-responsive asthma subgroup was found. Daily rescue medication use was better predicted by pre-diary asthma quality of life, self-efficacy and emotion-coping than by diary measures of symptom severity or airflow.

In the final study, I conducted a laboratory experiment testing the effects of different kinds of stressors on asthmatics' airflow and other physiological variables. A variety of stressors and one relaxation condition

were introduced and important indices of sympathetic and parasympathetic nervous system function were assessed. Measuring sympathetic nervous system activity (skin conductance) and parasympathetic activity (vagal tone) had not previously been done while monitoring airway reactivity to different types of stress and relaxation in asthmatics. This study demonstrated that certain kinds of stressors (passive and asthma-related) and relaxation can trigger increases in parasympathetic tone and in decreases in airflow in asthmatics. An active stressor was associated with increased sympathetic arousal and no decrease in airflow. These results suggest that certain kinds of stressors can lead to reduced airflow in asthmatics and that this reduction may be mediated by parasympathetic arousal. Furthermore, asthma self-efficacy was associated with parasympathetic reactivity.

Taken together, the program of research makes important theoretical and methodological advances. The findings improve understanding of asthma psychophysiology and have implications for asthma treatment and education.

Preliminary data from these studies have been presented at the 1997 Canadian Psychological Association's Annual Convention, the 1997 Canadian Network for Asthma Care Conference on Asthma and Education, the 1998 American Thoracic Society/American Lung Association International Conference, and the 1999 American Psychosomatic Society's Annual Conference and will be presented at the 2000 American Thoracic Society/American Lung Association International Conference. Some material has been published in brief report or abstract form in the peer-reviewed scientific journals: Chest, the American Journal of Respiratory and Critical Care Medicine, Canadian Psychology, and Psychosomatic Medicine and in

article form in the publications: Canadian Health Psychologist and Modern Medicine:

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INTRODUCTION: LITERATURE REVIEW AND PROGRAM RATIONALE

I begin this review with a description of the problem and nature of asthma. Recent advances in the understanding of the pathophysiology of asthma and of how psychological and emotional reactions to stress lead to neuroendocrine, immunological and health behaviour changes are described, suggesting plausible mechanisms by which stress can affect asthma. Empirical research on the link between stress and asthma research is then presented. It is argued that individual differences in coping with stress and asthma self-efficacy may explain observed differences in response to stress among asthmatics. Lastly, general objectives and specific predictions for a program of research comprising clinic-based, longitudinal diary, and experimental laboratory studies of stress, coping and asthma are described.

Asthma: Prevalence and Pathophysiology

Asthma is a becoming a greater burden on society, with alarming increases in prevalence over the past 20 years in most parts of the world (Partridge, 1997; Sears, 1997, 1996), affecting up to 10% of the population of most developed countries (O'Byrne & Postma, 1999; Sears, 1997). In North America, the prevalence of asthma has more than doubled in the last decade (National Heart, Lung & Blood Institute, 1998). This increase has occurred despite significant advances in available medical treatment and the improvement of air quality in many areas where prevalence has increased the most (Lieberman & Kane, 1997; Sears, 1997). The reasons for this increase in asthma prevalence are unclear, but the increases are not simply related to changes in disease coding (FitzGerald & Macklem, 1996).

Morbidity is also increasing as asthma symptoms and functional limitations caused by asthma worsen and persist longer (Sears, 1997). Despite

many significant medical advances, hospital admissions due to asthma have increased 40% since 1980 (McCaig, 1994). More poorly controlled asthma results in lower quality of life, decreased productivity and greater health care costs. In Canada, the total yearly cost of asthma is estimated to be between $504 million and $648 million, with direct costs (resulting from inpatient care, emergency services, medications, etc.) totaling $306 million (Krahn, Berka, Langlois, & Detsky, 1996) with these costs expected to rise with increasing prevalence and morbidity.

Deaths from asthma are also on the rise in many parts of the world (O'Byrne & Postma, 1999; Sears, 1997,). It is possible that with the rising prevalence of asthma, a small shift in severity among a cohort of asthma subjects may be causing significant increases in asthma mortality (Sears, 1997). These alarming prevalence, morbidity and mortality trends are perplexing given recent advances in understanding of the pathophysiology of asthma, the development of highly effective new medications and increased availability of asthma patient education.

The Nature of Asthma

Asthma is a chronic respiratory illness characterized by variable airflow limitation resulting in a complex of recurring symptoms such as wheezing, coughing, shortness of breath and chest tightness (Ernst, FitzGerald, & Spier, 1996). Severe activity limitation and death from acute airway obstruction may occur. The hallmarks of asthma are: 1) airway obstruction that is usually intermittent and reversible, either spontaneously or with treatment, 2) airway inflammation, and 3) increased airway responsiveness to a variety of stimuli (Lemanske & Busse, 1997). Given reversibility in airflow limitation, an asthmatic may appear healthy between attacks.

Difficulty getting air into and out of the lungs has been likened to suffocation, and the raspy, harsh noise of the wheezing and coughing can make asthma attacks very vivid and frightening. The exertion caused by the difficult breathing can also be exhausting. Acute asthma symptoms may last an hour or less or may continue for several hours or even days. Between attacks it is possible that no abnormal signs are detectable when the individual breathes normally, however forced heavy expiration may allow asthmatic wheezing to be detected.

Asthmatic airways are abnormally reactive. Reduced airflow may result from exposure to stimuli that would not affect non-asthmatics (Clark & Rees, 1998). Diagnostically, asthmatic variability in airflow can be demonstrated by a 10-15% (or greater) drop in expiratory airflow volume after inhalation of small amounts of an airborne irritant. Increased responsiveness of the trachea, major bronchi and peripheral bronchioles to various stimuli may result in extensive narrowing of the airways which causes impairment of air exchange and subsequent symptoms. Airways may narrow because of: 1) contraction or spasm of smooth muscle which surrounds the airways, 2) congestion of immune substances associated with the inflammatory response that cause the walls of the airways to expand and interfere with airflow, 3) structural changes of the airways - a thickening of the airway walls over time (Hegele & Hogg, 1996), 4) increased mucus secretion and mucus plugging of the airways, and 5) collapse of the posterior walls of the trachea and bronchi during certain types of forced expiration (Lemanske & Busse, 1997; O'Byrne and Postma, 1999; Purcell & Weiss, 1970).

The effects of the different sources of airflow limitation are often combined. Asthma symptoms can emerge suddenly or develop slowly over

time. While asthma is a chronic illness, its course is highly variable, involving both acute attacks and gradually worsening symptoms that result from increasing airway inflammation. Acute bronchoconstriction, the sudden tightening of the muscles that surround the airways, may be extremely dangerous where airway limitation is already present due to inflammation and structural changes.

Asthma may result from allergies as cells in the respiratory tract may become especially reactive to one or more substances (e.g., pollen, dust, molds, cigarette smoke). It may also be brought about by infections (such as acute bronchitis) which may potentiate a highly reactive respiratory system. While allergic precipitating factors are present in some patients, research suggests that allergic causes of asthma are present only in a minority of patients (Clark & Rees, 1998). Asthmatics can be broadly categorized as either intrinsic (non-allergic) or extrinsic (allergic). For extrinsic asthmatics, specific environmental allergens (e.g., airborne irritants) trigger symptoms. Intrinsic asthmatics, by contrast, do not develop symptoms or attacks in response to specific airborne allergens but may respond to internal triggers that are not well understood. These intrinsic, non-allergic, asthmatics have a worse prognosis compared to extrinsic asthmatics in terms of mortality and yearly loss of lung function (Ulrik, Backer, & Dirksen, 1992). Asthma is now viewed not as a simple allergic response, but as a more complex and heterogeneous syndrome characterized by an abnormality in ability to maintain normal airway tone.

Controlled, or stable asthma can be defined as having no clinically significant variations in ventilatory functioning (e.g., decreases in peak expiratory airflow volume (PEFR) that are not greater than 20%). Well-controlled asthma can also be indicated by the absence of symptoms that

impair quality of life and having no asthma-related health crises (e.g., life threatening asthma attacks) that would require hospital admissions or emergency room visits.

As asthma is a chronic condition with risk of sudden deterioration, appropriate ongoing self-management is extremely important. This management is geared toward maintaining respiratory state as normal as possible and reducing the severity of acute attacks. Asthma is typically treated by a combination of medications: bronchodilators ("rescue" medications) and anti-inflammatory inhaled corticosteroids ("preventer" medications). Effective asthma management involves taking medications appropriately, avoiding known triggers, monitoring changes in airway limitation, and following an asthma action plan (to follow when airway limitation increases). Given the effectiveness of asthma medication to control airway limitation, much of asthma's current morbidity and mortality is considered needless (Osman, 1997). Yet, among appropriately treated asthmatics, some have good control over their asthma while others do not. It is estimated that only one-third of adult asthmatics achieve adequate control over their symptoms, despite the fact that effective medication exists for the vast majority of asthmatics (Vianna & Martin, 1998).

Asthma patients exhibit several forms of variability in their reactions to airway irritants or other triggers. Some asthmatics respond to a large number of stimuli, and others to only a few. These stimuli include viral infections, cold air, exercise, allergens, hyperventilation and emotion. Asthmatics vary in the degree to which they respond to a stimulus (from mild to severe). In all, the etiology and course of asthma may be influenced by a wide variety factors such

as genetics, environment, and stress (Busse, Kiecolt-Glaser, Coe, Martin, Weiss, & Parker, 1995).

Focus on traditional environmental risk factors has not fully explained the rising trends in the severity of asthma observed worldwide (Wright, Rodriguez, & Cohen, 1998). Clearly, other factors must be involved. Whatever the origin, a lowered threshold of reactivity to many stimuli (which provoke inflammation or bronchospasm) is the basic "error" in airway homeostasis found in asthma. This increasing inability to maintain normal airway tone is thought to be caused by underlying immunological and autonomic dysfunction. Recently explored interactions among behavioral, neural, endocrine, and immune processes suggest how psychosocial factors may impact on the development and expression of diseases such as asthma (Ader, Cohen, & Felten, 1995).

Autonomic Function and Asthma

The autonomic nervous system can affect airway caliber and ventilatory function via effects on airway smooth muscle, bronchial vessels and production of mucus. Airflow limitation and asthma symptoms can result from an imbalance of bronchoconstricting and bronchodilating mechanisms triggered by the autonomic nervous system (Clark & Rees, 1998). Both the sympathetic (SNS) and parasympathetic nervous system (PNS) have direct effects on the lung. Increased parasympathetic tone (via the vagus nerve) results in increased tone in the smooth muscles of the lung and subsequent bronchoconstriction. Normal airway tone exists when beta-sympathetic (involved in bronchodilation) and alpha-sympathetic and parasympathetic (involved in bronchoconstriction) autonomic forces are balanced.

Bronchomotor tone is largely determined by cholinergic influences arising from parasympathetic vagal activity. Electrical stimulation of vagal efferents to the lungs results in the release of acetylcholine and immediate bronchoconstriction (Lemanske & Kaliner, 1990; Wright et al., 1998). This rapid onset of bronchoconstriction after vagal stimulation suggests that it is caused by smooth muscle contraction. The vagus also participates in a variety of neural reflexes that result in bronchoconstriction. Airway caliber is dependent upon both cholinergic and adrenergic mechanisms (Lemanske & Busse, 1997). Cholinergic effects (triggered by increased parasympathetic tone) are one of the causes of asthmatic symptoms. Many asthma treatments attempt to shift autonomic balance from cholinergic toward adrenergic activity, thereby reducing airflow limitation and symptoms.

Activation of beta receptors results in smooth muscle relaxation, while alpha receptors contract the muscles. The parasympathetic nervous system innervates the airways via efferent fibers from the vagus nerve and synapse in ganglia in the airway wall with short post synaptic fibers directly supplying the airway smooth muscle and submucosal glands (Barnes, 1995). The parasympathetic nerves release acetylcholine, which binds to (M3) muscarine inhibitors, causing contraction of the muscle and airway narrowing. The release of acetylcholine is also controlled by an inhibitory (M2) muscarinic neural receptor, thus creating a negative feedback mechanism for the control of acetylcholine release (Lemanske & Busse, 1997). Thus, the dominant autonomic control of the airways appears to be provided by the parasympathetic nervous system. Lemanske and Kaliner (1990) suggest that asthmatics have three specific autonomic abnormalities: 1) alpha-sympathetic hyperresponsiveness, 2) cholinergic hyperresponsiveness; and 3) beta-

sympathetic hyporesponsiveness. It is possible that there is some dysfunction of the parasympathetic nerves in asthma.

Stress and Asthma

Although asthmatics often report that stress and emotional factors can worsen asthma, research to corroborate this claim and explain the connection is still in its infancy. However, recent research has suggested a number of ways in which stress can impact on asthma (e.g., Busse et al., 1995; Lehrer, Isenberg, & Hochron, 1993; Weiss, 1999; Wright et al., 1998). 1) Acute stress may trigger autonomic responses that result in bronchoconstriction (Lehrer et al., 1993; Lemanske & Kaliner, 1990). 2) Distress may increase respiratory drive which may lead to hyperventilation, panic and subsequent exacerbation of asthma symptoms and greater risk of attacks (Carr, Lehrer, Hochron, & Jackson, 1996; Klein, 1993). 3) Stress may decrease the likelihood of appropriate health behavior (Noeker, 1996). 4) Stress may activate specific immune system activity such as cytokine production, which results in airway hypersensitivity and subsequent inflammation (Weiss, 1999). 5) Stress may alter susceptibility to respiratory infections that impact heavily on asthma (Cohen et al., 1998). 6) Stress during early infection may trigger development of asthma (Busse et al., 1995).

There is a long history of clinical cases linking emotional stress and asthma. For example, in 1868, an allergic/asthmatic reaction was triggered after a physician presented an allergic subject with an artificial rose (Mackenzie, 1868, in Kotses, 1998). In addition to such cases illustrating what could be termed conditioned asthma (asthma symptoms appearing when allergic trigger expected), many cases where strictly distressing material was found to reliably trigger asthma attacks have been reported. These range from

Maimonides (1190/1963), who wrote about a patient who was unable to breathe normally when emotionally upset, to Eysenck (1965) who described a case in which a man's asthma attacks could be reliably triggered whenever a picture of his mother-in-law was turned toward him.

Historically, emotional factors were linked to asthma to such a convincing extent that they likely slowed advances into the understanding of the disease's pathophysiology. In the 19th century, Osler (1892) described asthma as a "neurotic affection" and concluded that emotional factors triggered asthmatic symptoms such as coughing and wheezing. At that time, asthma was considered to be of entirely psychogenic origin and was even referred to as asthma nervosa. Later, psychoanalysts such as Alexander, who saw asthma symptoms as a symbolic expression of unconscious conflicts, began to perform experiments which linked conflict triggers to asthma symptoms (reviewed in Alexander, 1968).

Asthma morbidity has been historically linked to psychological morbidity. Before the physical pathology of asthma was well understood, asthma had been historically linked to psychiatric problems, especially anxiety. However, a large scale epidemiological study recently found no evidence that patients with bronchial asthma were more anxious or depressed than those without asthma (Janson, Bjornsson, Hetta, & Boman, 1994). In addition, Rocco, Barboni and Balestrieri (1998) found that anxiety, depression, and personality characteristics do not distinguish asthmatics from healthy controls or asthmatics who experienced near-fatal asthma from better controlled asthmatics (see also, Sommaruga, Spanevello, Migliori, Satta, & Neri, 1995). In sum, there is no evidence that asthmatics have clinically significant levels of psychopathology or general emotionality (see also Kotses, 1998).

Certain constellations of personality traits, such as neuroticism, were long thought to be linked to asthma, based on studies comparing asthma patients with healthy controls (Hambley, Brazil, Furrow, & Chua, 1989; Herbert, 1965 Knapp & Nemetz, 1957). However, because similar personality profiles characterize patients with chronic illnesses, it is possible that increased neuroticism of asthmatics may be a function of having a chronic illness, as neuroticism scores become higher the longer someone has lived with an illness (Kelly & Zeller, 1969). Psychopathology or personality questionnaires used in past research may lack the specificity to predict the acute or chronic neuroendocrine changes directly associated with asthma symptoms. It was only with the development of the modern concept of stress that connections between external events, psychophysiological reactivity, and asthma could be explored.

Stress may be a more likely and testable factor in asthma exacerbation than general emotionality. Seyle's (1950) general adaptation syndrome model of stress characterized stress as a systemic psychophysiological reaction to external demands that involved autonomic nervous system and physical responses. A current widely accepted definition of stress is "external or internal demands that are appraised as taxing or exceeding the resources of the person" (Folkman & Lazarus, 1988). In the Folkman and Lazarus model, both degree of threat posed by the environmental demands and available resources are appraised. If the demands are found to be threatening and if resources are viewed as insufficient, stress is perceived. An integrated network of regulatory processes is required to maintain the stability of internal physiology when subjected to continually changing environmental conditions and demands. Stressors may be seen as any significant event that challenges internal

homeostasis by presenting demands that may exceed perceived resources. Stress experienced may then result in negative emotional states and autonomic and neuroimmunological changes that can affect asthma. Neuroendocrine response to emotional or cognitive demands are often similar to the response elicited by tissue damage or early infection (Coe, 1994).

Models of the connections between psychological stressors and health have been put forward (e.g., Herbert & Cohen, 1993). Emotional and behavioral changes that accompany efforts to adapt to environmental situations are accompanied by complex patterns of neuroendocrine and immunological changes (Herbert & Cohen, 1993). The body's physiological reaction to psychological stimuli appears to take advantage of response systems that evolved earlier to facilitate adaptation to physical stressors (Coe, 1994). In the case of stress and asthma, these may be autonomic and immune responses that result in bronchoconstriction or inflammation.

Stress and psychological factors have been associated with modulation of many of the hormones, neurotransmitters and neuropeptides involved in autonomic control and inflammation of the airways. Advances in psychoneuroimmunology (PNI) research provide evidence of connections between psychological stress, the nervous system and alterations in immune and endocrine function. These connections suggest plausible mechanisms by which stress could impact on asthma. As described above, airway smooth muscle contraction is one way that stress-triggered autonomic reactivity can affect asthma. Stress induced vagal reactivity as a mediator for emotion or stress-induced bronchoconstriction has been suggested (e.g., Lehrer et al., 1993).

Psychological stressors have been linked to the activation of the sympathetic and adrenomedullary system and the hypothalamic-pituitary adrenocortical (HPA) axis. Negative emotional responses disturb the regulation of the HPA system. Chronic stress may trigger a state of hyporesponsiveness of the HPA axis whereby cortisol secretion is attenuated, leading to increased secretion of inflammatory cytokines typically counterregulated by cortisol. A hyporesponsive HPA axis may explain stress-induced exacerbations of asthma in certain subgroups of asthmatics and increased association of asthma with particular psychological states (see Wright et al., 1998). Hormones and neuropeptides released into the circulation when stress is experienced may also be involved in regulating inflammatory and airway responses.

In exploring the complex processes of stress and asthma, a paradox emerges. Normally, acute and chronic stress create increases in cortisol and epinephrine which should reduce rather than exacerbate asthma symptoms. These hormones result in what has been described as the "fight or flight" response: accelerated heart rate, faster respiration and bronchodilation (just as when asthmatics take an epinephrine based "rescue" inhaler). In non-asthmatics, exposure to an acute stressor requiring an active response may result in increased sympathetic nervous system activity, increased blood pressure, heart rate and bronchodilation. Why might asthmatics respond to acute stress with bronchoconstriction instead of bronchodilation? Studies dating back to those of Hahn (1966) and Mathe and Knapp (1971) have suggested that asthmatics may have an unusual profile of autonomic response to stress. When exposed to acute stress, asthmatics' heart rate and blood pressure increase as do those of control subjects. However, the airway

conductance and respiratory rate of asthmatics appear to go in the opposite direction as those of non-asthmatic controls (Hahn, 1966; Mathe & Knapp, 1971). More recent researchers have suggested how this might occur, proposing mechanisms including exaggerated PNS reactivity in asthmatics.

SNS response to stress results in release of mediators with a beta-agonist effect. However, it is possible that once the acute stress has passed, levels of adrenaline and noradrenaline return to normal or below normal (Dimsdale & Moss, 1980). Exaggerated parasympathetic rebound may then result in bronchoconstriction. The relative strength of sympathetic versus parasympathetic control in response to certain forms of stress varies from individual to individual, with some having a largely parasympathetic response (Lehrer et al., 1993). Asthmatics with this pattern of response may be especially vulnerable to stress induced bronchoconstriction

Porges (1995) and Isenberg, Lehrer and Hochron (1992) describe a hypothesis based on vagal mediation. Rather than exhibiting the "fight or flight" response to stress, which includes bronchodilation, asthmatics may have a more parasympathetic adaptive response to stress -- a "shutting down" rather than "powering up" -- which results in bronchoconstriction rather than bronchodilation. Here, increased vagal activity to the bronchi in asthma is seen as the manifestation of generally increased parasympathetic neural activity (Porges, 1995). This hypothesis is supported by evidence that asthmatics have increased vagal nervous tone compared to healthy controls (Sargunaraj, Lehrer, Hochron, Rausch, Edelberg, & Porges, 1996).

Exaggerated PNS rebound in asthma has also been suggested (e.g., Busse, 1988). After the "fight or flight" reaction to the acute stressor, the opponent process to restore homeostasis may be exaggerated in asthmatics,

leading to subsequent bronchoconstriction (van Aalderen, Meijer, Oosterhoff & Bron, 1993). Offering another explanation, Bramley, Thomson, Roberts, and Schellenberg (1994) suggest that bronchoconstriction in asthmatics may be due to decreased airway elastance. Bramley et al. (1994) contend that airway inflammation in asthma may alter connective tissue matrix elements within airway walls leading to decreased elastance and excessive smooth muscle shortening. Thus, according to this explanation, after years of inflammation the bronchial muscles cannot dilate anymore. PNS rebound after an acute stressor may then result in net effect of bronchoconstriction as the SNS response can no longer trigger bronchodilation.

It is also possible that prolonged increases in catecholamines caused by chronic stress may contribute to asthma severity. Furthermore, daily use of beta-agonist bronchodilators by asthmatics with a genetic predisposition may increase asthma severity by downregulating beta-adrenergic receptors (Drazen et al., 1996). Stress may then have increased bronchoconstrictive effects. Autonomic response to stress may also impact asthma via central nervous system (CNS) effects on immune function.

Stress, the CNS, Immunity and Asthma

Anatomical, pharmacological, and physiological studies support the hypothesis that virtually all aspects of airway inflammation may be influenced by autonomic and/or afferent neurons (American Thoracic Society, 1999). The immune system has been likened to a sensory organ because it appears to help detect internal or external demands (e.g., stressors) via bi-directional feedback to the central nervous system and endocrine system (Maier, Watkins, & Fleishner, 1994). Psychological stressors can greatly influence the interactions

between the central nervous system (CNS) and the immune system (Ader & Cohen, 1993; Adler & Mathews, 1994; Maier, Watkins, & Fleshner, 1994).

Stress may increase asthma-related immune function. Exposure to acute psychological stressors can alter components of immune response rapidly, sometimes within 5 minutes of stressor exposure (Manuck et al., 1991). These include: production of immunoglobulin E (IgE), cytokines (Persoons, Berkenbosch, Schornagel, Thepan, & Kraal, 1995), eosinophils (Wardlaw, 1994), and the cells that make cytokines (Busse, 1999). Stress can also rapidly change behaviour of alveolar macrophages, which play an important role in the regulation of the local immune response in the lungs (Persoons, et al., 1995). Cytokines involved in the regulation of many normal homeostatic functions may serve an especially significant role in mediating the acute response to physical and psychological disturbance. Kang, Coe, McCarthy, Jarjour, Kelly, Rodriguez and Busse (1997) found that a stressful life event (exam period) altered the pattern of cytokine release in asthmatic individuals. When exposed to multiple acute laboratory stressors over time, some people exhibit stress-triggered alterations in immunity while others do not (e.g., Marsland et al., 1995).

How someone psychologically responds to stress may affect autonomic and immune reactions. There may be a feedback loop between airway neuronal activity and immune-initiated inflammation (Riccio, Myers, & Unden, 1996). Individual differences in autonomic nervous system activity and reactivity may interact with stressors to produce different patterns of immunologic and endocrinologic changes. Individual differences in immunologic responsivity to stressful situations may be predicted by interindividual variability in stress-induced sympathoadrenal activation (Busse

et al., 1995). Hormones (such as epinephrine) are part of the control mechanisms through which the CNS interacts with the immune system. People who exhibit large blood pressure and plasma catecholamines reactions to acute stressors experience the biggest changes in cellular immune function in response to the same stressor. Furthermore, increases in epinephrine and norepinephrine extend CNS arousal during acute stress and may lead to long term elevations of catecholamine responses during chronic stress (Baum, Cohen, & Hall, 1993).

Behavioural Research on Stress and Asthma Research

Studying stress and asthma may be much more fruitful than past attempts to correlate general emotionality or personality traits with asthma. Studies exploring links between stress and asthma have increased in number since the late 1980s. The following review of adult stress and asthma research suggests a number of crucial, unanswered questions. For example, while an association between life stress and asthma (symptoms or ventilatory function) among a subgroup of asthmatics is suggested, the nature of the relationship and the factors that identify the subgroup remain unknown.

Psychological stress has been found to be associated with asthma symptoms, bronchoconstriction and reductions in objectively assessed ventilatory function. In a longitudinal retrospective self-report study, Kleeman (1967) interviewed twenty-six adult asthmatic patients monthly over an eighteen-month period. According to the patients' reports, 69% of their attacks began with an episode of emotional disturbance. However, retrospective self-reports may not be able to separate the temporal cause from the effect of the event (Dawes, 1994) - the emotional disturbance may well have resulted from the asthma attack and the patients may have simply confused the order.

Experiments conducted in the 1970s suggest that asthmatics have greater airway reactivity to various stressors (e.g., watching a gory film, being angered) than do non-asthmatics (Levenson, 1979; Mathe & Knapp, 1971; Miklich et al., 1973; Thorn & Fisher, 1978). Stressful experiences studied have included mental arithmetic (Miklich et al., 1973), watching emotionally difficult material, and listening to stressful interactions. While asthmatic subjects in these studies may not have been well screened, these findings suggest that stressful situations can trigger reduced airflow in asthma.

Global life event stress has been linked to serious asthma exacerbations. In a retrospective self-report study, Northup and Weiner (1984) found that reported life stresses appear to cluster prior to rehospitalization for asthma. However, the stressors indicated by subjects (inability to complete daily tasks, worries about health) may have been directly related to the asthma itself. The occurrence of other non-asthmatic stressors was not related to hospitalization in this sample. Due to reliance on retrospective self-report and the likely confound between illness limitation and stress reporting, this study may add little to the understanding of stress and asthma.

Negative mood and asthma symptoms over time have been studied. In a small-scale home self-monitoring study of adult asthmatics, Steptoe and Holmes (1985) found that scores on a visual analog mood scale were associated with peak expiratory airflow volume (PEFR) in three of seven asthmatics they studied. Negative mood was associated with lower PEFR scores (reduced airflow). Daily fluctuations in negative mood may be strongly linked to stressful events and perceived stress. Here again, however, the negative emotions may be simply a consequence of the reduced airflow rather than a cause. An early review of these stress and asthma studies by Weiner

(1987) concluded that asthma symptoms and stress reporting appear to be positively correlated over time within individuals. However, what cannot be inferred from these correlational studies is whether the asthma resulted from the stress, caused it, or whether other variables were involved.

Type of stress experienced may be important. Kotses, Westlund and Creer (1987) studied changes in airflow in normal subjects under varying degrees of stress. Subjects were randomly assigned to a high stress (difficult math problems) or low stress (simple math problems) group. Individuals assigned to the difficult arithmetic task showed a significant increase in laboratory measured respiratory resistance while performing the task. In this case, it is possible that sympathetic activation triggered by the actions required by the "active" math stressor may have resulted in the increased respiratory resistance. Other types of stressors, for example "passive" stressors that require no action to be taken (e.g., discomfort that cannot be escaped) may have resulted in bronchoconstriction, mediated by parasympathetic reactivity.

Measures of daily stressful events have been used to explore the connection between environmental stressors and asthma. Goreczny, Brantley, Buss, and Waters (1988) asked a mixed sample of adult asthma and chronic obstructive pulmonary disease (COPD) patients to record daily stress and asthma symptoms over a 21-day period. During high stress periods, subjects averaged more coughing, wheezing and activity limitation than low stress periods. Peak flow (PEFR), a measure of airway caliber, was negatively associated with life event distress in a subgroup of the sample. However, as the sample contained COPD patients, the results cannot be generalized to asthmatics. Nathan, Brantley, Goreczny, and Jones (1988) conducted within-subject analysis of minor stress and asthma symptoms in 39 asthmatics and

COPD patients across a 21-day period. They found that scores for daily stressful events were associated with asthma symptoms, but not with PEFR. This result is interesting, in that it suggests that daily stressful events and ventilatory functioning may not be associated. The association between asthma symptoms and stress reporting could be due to shared method variance or subjects confounding stress effects with symptoms or vice versa.

In a more recent diary study, Tetzlaff, Leplow, Staud, Dahme, and Richter, (1994) had 35 asthmatics keep daily records of their shortness of breath and subjective stress for 8 weeks. They found few links between shortness of breath and mental stress/stressors concurrently or with a one-day time lag. However, they did find a significant association between stress and overall quality of life. Subjective stressors were found to be negatively correlated with quality of life. It is possible that other asthma symptoms (e.g., chest tightness, wheezing, coughing) other than the shortness of breath reported by their subjects contributed to both the subjective stress and the quality of life scores or that a third factor (e.g., neuroticism, poor coping) accounted for both. In this study, stress and symptom ratings were both rated subjectively and may have been confounded due to the likelihood that people who report higher stress also tend to report more physical symptoms.

If stress is linked in some way to asthma, it seems reasonable that interventions to reduce experienced stress, such as relaxation training, may have a beneficial impact on asthmatics. However, relaxation studies of asthma have yielded mixed results. Maes and Schlosser (1988) found a small positive effect for relaxation training on asthma outcome over time. Lehrer et al. (1997), however, found that the immediate effect of generalized relaxation instructions is a parasympathetic response which results in

bronchoconstriction. Lehrer (1999) does suggest that while relaxation may have a short-term negative effect on airflow, it is possible that it could have a beneficial long-term effect. It is interesting to note that Freedburg et al. (1987) found that progressive muscle relaxation (PMR) sessions resulted in reduced anxiety and increased PEFR after the sessions only for a subgroup of asthmatics with moderate or high panic/fear. It is possible that only a subgroup of asthmatics have reductions in airflow that are triggered by stress.

Psychological Subgroups, Stress and Asthma

As reviewed above, part attempts to demonstrate a clear link between stress and asthma symptoms have yielded inconclusive or mixed results. As Brantley and Jones (1993) suggest, this may be because there is only a subset of asthmatics whose symptoms are highly response to stressful or upsetting situations.

In an early study, Dekker and Groen (1956) found that asthma attacks could be triggered in 25% of an adult asthmatic sample when they were presented with a picture of environmental conditions that the asthmatic had stated were triggers. This suggests that asthmatics respond differently to representations of triggers. In the 1970s, the studies that obtained evidence of reduced air flow in asthmatics during laboratory-induced emotional scenarios (e.g., Levenson, 1979; Thorn & Fisher, 1978) also found that some asthmatics had significantly more reduced airflow than others, suggesting a greater airway response to stress among some asthmatics.

While stress and symptom reporting have been linked, the connection between stress and ventilatory function is less clear. Most asthmatics report high perceived stress during periods when their symptoms are severe. In such anecdotal reports, it is unclear whether the stress caused, arose independently,

or resulted from worsening symptoms. Reporting that symptoms are bad during periods of high stress does not tell us whether the stress is a cause or an effect of the asthma symptoms. To find this out, prospective studies of stress and asthma symptoms are required. A few studies have looked at daily asthma symptoms and daily stress. However, most studies conducted thus far have not overcome a second methodological problem, namely confounding stress with the measure of asthma symptoms.

A close examination of past asthma research reveals that usually only a subgroup of asthmatic study participants exhibited a strong association between stress and asthma. Steptoe and Holmes (1985) found that mood scale ratings were negatively associated with PEFR in just three of the seven asthmatic subjects. In a separate (but equally small sample study) Hyland (1990) examined mood and PEFR in 10 adult asthmatics who monitored their PEFR and mood twice a day. He found a significant correlation between negative mood ratings and evening PEFR readings for six of the ten asthmatics. Hyland also noted that these six subjects showed the greatest variability between morning and evening PEFR readings and suggested that this was caused by stressors that the asthmatics encountered during the day. In Goreczny's (1989) study of 39 asthma and COPD patients, the stress-asthma relationship described in the full sample was accounted for by 15 of his 39 subjects, whom he described as "stress responders." Though limited by small sample sizes (and in the Goreczny study, a partly non-asthmatic sample) these studies suggest that only some asthmatics show airflow variability during stress.

Suggestion also appears to affect ventilatory function in only a subgroup of asthmatics. Neild and Cameron (1985) found that in 10 of 25

asthmatics, bronchoconstriction (reduced FEV1) could be produced by a saline substance when it was accompanied by the suggestion that it might impair breathing. In an earlier study, Luperello, McFadden, Lyons and Bleecker (1971) found that fourteen out of forty asthmatics showed significant airway obstruction, and twelve had full-fledged attacks, after being informed that they were inhaling successively larger concentrations of a known irritant. More recently, Isenberg, Lehrer and Hochron (1992) also demonstrated that some asthmatics respond to suggested bronchoconstriction with significant reductions in expiratory airflow volume. It is possible that the same individual difference variables that explain why some asthmatics respond to suggestion with reduced airflow and others do not, also explains why some asthmatics respond to stress and others do not.

Type of asthma could be one such factor. There may be significant differences in the response to stress between non-allergic and allergic asthmatics. It is possible that for the intrinsic asthmatics, emotional stress may be both the acute trigger and the factor which causes the airway hyperresponsiveness. For the extrinsic asthmatics, emotional stress may trigger airway hyperresponsiveness; inflammation and bronchoconstriction only when exposed to specific allergic triggers. Ulrik, Backer and Dirksen (1992) found that intrinsic asthmatics have greater mortality and greater decline in lung function than extrinsic asthmatics. Intrinsic asthmatics may therefore have lower asthma quality of life and poorer sense of control over their illness than extrinsic asthmatics. Walker (1993) suggests that there may be fundamental immunological differences between intrinsic (non-allergic) and extrinsic (allergic) asthma. Intrinsic asthmatics have different patterns of T cell activation and cytokine production than extrinsic asthmatics. It may be that

these intrinsic asthmatics comprise a subgroup of asthmatics who respond to stress with bronchoconstriction and excessive cytokine production.

Patterns of response to stress may also be an important factor in determining effect on asthma. Lehrer et al. (1993) report that some people respond stereotypically to a variety of events and stressors in a particular physiological way, e.g., responding to psychological stressors with increased autonomic reactivity. Each time these asthmatics are presented with stressful stimuli (whether from internal or external sources); this characteristic pattern of autonomic reactivity may exacerbate their asthma, with high levels of parasympathetic reactivity resulting in bronchoconstriction.

Taken together, the above research suggests that the relationship between psychological stress and asthma requires further study. The ability to identify the characteristics of the apparent asthmatic subgroup who exhibit connections between stress and asthma appears particularly important. Examining individual differences in factors related to stress reactivity (e.g., coping style, autonomic reactivity) may be extremely valuable.

Stress, Coping, Self-Efficacy and Asthma

Individual differences in how asthmatics cope with stress may account for varied response to stress among subgroups of asthmatics. It is possible that individual differences in style of coping with stressful situations account for the stress-asthma relationship found in some asthmatics, but not in others. In particular, those who tend to use more passive coping strategies may be more likely to react to stress in ways that could trigger or exacerbate asthma symptoms. Nouwen, Freeston, Cournoyer, Deschesnes, and Boulet (1994) found that some asthmatics mistake distress for actual bronchial closing. Differences in coping ability may increase perceived distress and increase the

likelihood that distress and physical symptoms may be confused. Isenberg, Lehrer, and Hochron (1997) found that some asthmatics were very inaccurate when estimating the size of an applied inspiratory airway restriction. These asthmatics rated even the mildest restrictions as extremely unpleasant. The authors suggest that a defensive coping style may explain why these asthmatics had difficulty coping with even mild increases in airway resistance. Ability to cope with asthma-related stressful events is likely an important factor in maintaining asthma control.

As noted above, accurately sensing airflow limitation is an important factor in determining appropriate asthma self-management. It is possible that during stressful situations, asthmatics whose attention is taken up with other processes (e.g., regulating their emotional responses) may not be able to accurately assess worsening airflow obstruction and respond appropriately to asthma-related crises. Furthermore, if they spend most of their energy dealing with their emotional reactions, they may not have the resources to deal appropriately with the stressor. The experience of the stressful situation could then be protracted leading to the autonomic and immunological reactions that exacerbate asthma. While little research has been published relating asthma to coping style, there is a sound rationale for pursuing such a course.

Coping is defined as "the process of managing demands (external or internal) that are appraised as taxing or exceeding the resources of the person" (Lazarus and Folkman, 1984b). Noeker (1996) has suggested a feedback loop incorporating stress, coping, health behaviour and disease severity. In this description, severe asthma creates a broad array of somatic and psychosocial stressors (causes or consequences of asthma) which intensify experiences of threat and helplessness. The feelings of threat make emotion regulation (as

opposed to problem solving) more likely to occur during exacerbations of asthma. This could then result in greater risks of attacks and worsening symptoms. According to this model, the symptoms then feed back into the loop creating more stress and decreasing the chance of effective coping. While the feedback model has yet to be demonstrated empirically, there appears to be sound theoretical basis to assert that coping style may be an individual difference variable that identifies asthmatics who respond to stress with reduced airflow.

Methodologically sound measures of how people characteristically cope with stressful situations have been developed (Endler & Parker, 1990; Folkman & Lazarus, 1988). Current coping style taxonomies break coping down into three separately assessed styles: emotion, avoidant and task/problem-focused. It would not be unreasonable to predict that an individual with a tendency to cope ineffectively with stress (i.e., low task-coping and high emotion or avoidant coping) would be more likely to have a more extreme psycho-physiological reaction to a stressor, be less likely to take effective action to reduce the impact of the stressor, and experience negative (emotional/ physiological) effects of the stressor for a longer duration. Greater perceived stress over a longer period of time may then directly result in reduced airflow or decreased self-management behaviour.

A person's characteristic pattern of coping responses in stressful situations may predict stress reactivity. In particular, the Coping Inventory for Stressful Situations (CISS), which has been shown to predict reactions to stressful situations reliably and with demonstrable validity (Endler & Parker, 1994), may be especially well-suited to the study of asthma. As described above, acute stress may be a trigger for asthma attacks, and chronic stress may

heighten airway sensitivity to allergens. How asthmatics cope may determine the impact that events have on subsequent health behaviour, symptom reports and respiratory functioning.

There may be different neuroendocrine response patterns associated with specific cognitive assessments of stressful situations (Frankenhauser, 1978, 1991). It is possible that an asthmatic with an ineffective (e.g., primarily emotion or avoidant-oriented) coping style may have a physiological reaction to stressors that worsens their asthma symptoms directly. Overreacting, both emotionally and physiologically, to a minor stressor may result in neuroendocrine and immunological changes that exacerbate or provoke asthma symptoms. It is also possible that asthmatics who cope ineffectively with stress are less likely to engage in appropriate health behaviours, such as medication usage and seeking medical help when necessary, than those who cope more effectively. Thus, on a theoretical level, there are many plausible mechanisms by which coping style may mediate, moderate or buffer the effect of stress on asthma.

Self-Efficacy and Asthma Control

Another individual difference variable that may identify asthmatics with the greatest psychophysiological reactivity to stress is self-efficacy. The experience of positive consequences following task performance leads to self-efficacy, a belief in personal capability of achieving a desired outcome (Bandura, 1978, 1986). Self-efficacy is generally predictive of health outcomes (Holden, 1991; Schwarzer, 1995). Self-efficacy expectancy refers to beliefs in one's capabilities to execute a recommended course of action successfully. Self-efficacy may then play a role in determining how hard someone tries and how long they persist in a health behaviour. While asthma

knowledge is found to be a necessary factor in both self-treatment and self-management, self-efficacy expectancies appear to be a more important determinant of response when patients experience a real asthma exacerbation.

Self-efficacy may influence the quality and nature of decisions related to medical recommendations (Schwarzer, 1995; van der Palen et al., 1997). If belief in capability of successfully achieving the desired outcome (e.g., asthma control) is low, it is unlikely that prescribed actions will be adopted. An individual may believe that early treatment of exacerbations of asthma may reduce the duration and severity of the attack (i.e., a high outcome expectancy) but may not believe that s/he is capable of recognizing the early signs or being personally able to enact an action plan to stop the deterioration. It is possible that a long-standing pattern of ineffective coping could result in continued deficits in asthma self-management and a lack of asthma self-efficacy. Low asthma self-efficacy could then reduce treatment motivation and adherence (Tobin, Wigal, Holroyd, & Creer, 1987). As noted above, improving knowledge is necessary to improve asthma self-management, but is not sufficient by itself to lead to improved health behaviour and outcome. Risk perceptions and outcome expectancies likely effect decisions about whether to engage in a health behaviour. Believing or expecting that your actions can achieve the desired result is an important determinant of whether the actions will be started or maintained (Schwarzer, 1995). Applied to asthma, having confidence that self-management strategies can control asthma symptoms or attacks may explain why some asthmatics exhibit appropriate self-management and others do not.

Self-efficacy may also play an important role in determining the direct effect of stressful events on asthma symptoms. Noeker (1996) suggests that

asthma can be associated with helplessness, which can be seen as the lowest levels of self-efficacy, because of its potential for sudden, unpredictable deterioration. Low asthma self-efficacy may be associated with increased helplessness, greater levels of stress experienced and possibly greater psychological and physiological reactivity to stress which could directly result in neuroendocrine changes that cause reduced airflow.

Performance-based biofeedback from adaptive coping with threatening situations (asthma-related or otherwise) may reinforce self-efficacy appraisals and positive outcome expectations, which, in turn, increase the likelihood of management behaviour, reduce psychophysiological reactivity to stress and make improved asthma control more likely. It is possible that a subgroup of stress responsive asthmatics (e.g., those with HPA hyporesponsiveness or parasympathetic hyperresponsivity) can be identified by their coping style and level of self-efficacy. Assessing both asthma self-efficacy and coping style variables is an important addition to a research program examining stress and asthma.

Research Program Objectives

Stress, mediated by coping and self-efficacy, may play a key role in asthma by directly triggering exacerbations or by preventing self-management. A careful review of the literature suggested a number of important questions and generated a set of predictions for empirically exploring the possible connections between stress, coping, self-efficacy and asthma control.

The objectives of this research are to explore: 1) the connection between life event stress, coping style, and self-efficacy on asthma quality of life and ventilatory function, 2) the daily changes in asthma symptoms, airflow and medication use and their relation to daily changes in perceived

stress and to individual differences in coping style, asthma self-efficacy and asthma quality of life, and 3) the acute effects of different types of stressors, and relaxation, on airflow and autonomic reactivity in asthmatics.

The project tests whether stress is associated with increases in self-reported asthma symptoms and decreases in objectively measured respiratory functioning, and examines whether a coping and/or a self-efficacy measure can be used to find those asthmatics whose self-reported symptoms and objectively measured respiratory functioning worsen during periods of high perceived stress.

The objectives of the present thesis overlap to a great extent those outlined by the U.S. National Heart Lung and Blood Institute (NHLBI) who published recommendations for future research on stress and asthma (Busse et al., 1995). A primary need seen for researchers working with humans was to answer the question: How do stressful events affect asthma symptom expression? The NHBLI made a number of recommendations for future research, including: 1) patient classification (is there a particular type of asthma patient who is responsive to stress?), 2) type of stressor - what are the characteristics of the stressors that play a role in triggering asthma symptoms? (e.g., work stress versus interpersonal stress), 3) stress, neuroendocrine factors and asthma, 4) stress and health behaviour (e.g., does stress influence compliance with medication?). This project, though initiated before the NHBLI recommendations were published, explores issues identified as important.

Past attempts to demonstrate a stress-asthma link may have also been limited by specific methodological problems. In particular, over-reliance on subjective symptom reports, failure to recruit a pure asthmatic sample, and

failure to control for other variables which may have affected asthma symptoms (e.g., medication usage, environmental conditions, upper respiratory infections) are shortcomings that are addressed in the current research program.

A number of methodological and theoretical innovations characterize this research program. Psychological stress and its effects can be either acute or chronic; measured subjectively or controlled experimentally. Many of the studies described above have employed vastly different methods of measuring stress. Given the potential importance of both long-term and short-term stress on asthma, in this research program stress was studied in a number of ways: 1) as past-year life event stress (in terms of events experienced and their perceived impact), 2) as daily perceived stress over time (thrice daily perceived stress ratings), and 3) as experimentally manipulated laboratory stress (active, passive and asthma-related). Furthermore, measures of stress were distinguished from measures of asthma symptoms.

Different measures of asthma outcomes have been used in the preceding studies. As some studies suggest discrepancies between symptom reporting and objective measures of ventilatory function, asthma was measured in a number of different ways in this research program: 1) asthma quality of life, 2) ventilatory function, 3) daily reported subjective symptoms, 4) daily peak flow, and 5) acute changes in ventilatory function during the laboratory study. In addition, careful screening of asthmatic subjects ensured that the subjects in this research program had verifiable airway hyperresponsivity. This ensured a purely asthmatic sample - an improvement over previous stress and asthma studies (e.g., Goreczny, 1989).

As well as overcoming the methodological shortcomings of past stress and asthma symptom research, this research project tested whether highly stress- responsive asthmatics could be distinguished from non-stress responsive asthmatics by variables such as coping style, self-efficacy or autonomic reactivity.

Distress experienced by asthmatics may be a result, rather than a cause of the asthma symptoms. In addition, other variables may be responsible for the association between stress scores and asthma symptoms. One such variable may be the medications taken by asthmatics. For example, beta-agonist bronchodilators and other asthma "rescue" medications may produce side effects such as increased heart rate and blood pressure, which may be interpreted by the asthmatic as signs of distress or anxiety, especially if they have not been adequately educated about medication effects. To explore these issues, longitudinal rescue medication use data were collected and time series analyses conducted. Thus, this research project assessed medication effects, by asking, for example, whether longitudinal stress ratings increased as bronchodilator use increased.

The project included multimodal assessment of stress and asthma. I first measured lung function, asthma quality of life, coping style, asthma self-efficacy and stressful life events and classified asthmatics, before beginning a longitudinal study of daily stress, subjective symptoms, medication use and daily peak expiratory airflow. Last, a laboratory study assessed the effects of different controlled laboratory stressors and relaxation on airflow and autonomic reactivity among asthmatics.

The following predictions were tested in this research program:

A) From hospital-based clinic visit study: 1) High life event stress will be associated low asthma quality of life and poor ventilatory function 2) Ineffective coping and low self-efficacy will be associated with low asthma quality of life and poor ventilatory function. 3) Coping and self-efficacy will identify stress-responsive asthmatics.

B) From the longitudinal data from daily diary study: 1) Daily perceived stress ratings will be associated with subsequent daily asthma symptoms and daily airflow drops. 2) Daily perceived stress will be associated with high daily rescue medication use. 3) Coping and self-efficacy will identify asthmatics who have clinically significant drops in airflow after increases in stress.

C) From the laboratory-based experimental study: 1) Passive and asthma-related stressors will trigger parasympathetic reactivity and reduced airflow. 2) Stress-triggered bronchoconstriction will be mediated by parasympathetic activity. 3) Coping and self-efficacy variables will identify asthmatics with the greatest autonomic and airflow reactivity to stress.

Life event stress, coping style and self-efficacy: relationship to quality of life and ventilatory function in adult asthmatics

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Abstract

Asthma is increasing in prevalence, morbidity and mortality despite recent improvements in medical treatment. Many asthmatics have poor asthma control despite receiving appropriate treatment and asthma education. It was predicted that asthmatics with high stress, low asthma self-efficacy and poor coping skills would have low asthma quality of life and ventilatory function. 132 adult asthmatics, followed at a hospital-based asthma clinic, completed the Coping Inventory for Stressful Situations (CISS), an asthma self-efficacy scale (ASE), a checklist of major stressful events in the past year (stress), Juniper's Asthma Quality of Life Scale (AQL), and measures of ventilatory function (e.g., %FEV). Life event stress and emotion-coping (EMO) were both negatively correlated with AQL (ps <.05), while ASE was highly positively correlated with AQL ($p < .01$). Task-coping (Task) was positively correlated with %FEV ($p < .05$). Together, stress, Task and ASE accounted for 39% of the variance in AQL. Stress - %FEV correlations were significantly higher in subgroups with either low Task-, high Emotion- or high Avoidant-oriented coping. Thus, individual differences in coping style appear to identify asthmatics whose symptoms and ventilatory function are associated with life stress.

Keywords: asthma, stress, coping, self-efficacy, quality of life, ventilatory function

LIFE EVENT STRESS, COPING STYLE AND SELF-EFFICACY: RELATIONSHIP TO QUALITY OF LIFE AND VENTILATORY FUNCTION IN ADULT ASTHMATICS

Asthma is a chronic respiratory illness characterized by variable airflow limitation that results in recurring symptoms such as wheezing, coughing, shortness of breath and chest tightness (Ernst, FitzGerald, & Spier, 1996). Unlike other respiratory diseases, the airway limitation in asthma is usually intermittent and reversible (Lemanske & Busse, 1997). This limitation can involve both sudden tightening of bronchial muscles and more gradual inflammation of the airways. The inability to maintain normal airway tone is thought to be caused by underlying autonomic and immunological dysfunction; as such, the etiology and course of asthma may be influenced by factors such as allergy, infection, exposure to airborne irritants, psychological stress, early environment, and genetics (Busse, Kiecolt-Glaser, Coe, Martin, Weiss, & Parker, 1995).

Asthma is a growing health problem, with alarming increases in prevalence, morbidity and mortality rates (Sears, 1997, 1996). An estimated 10 percent of children and 5 percent of adults have asthma (Sears, 1997). In North America, the prevalence of asthma has more than doubled in the last decade (National Heart, Lung & Blood Institute, 1998). This increase has occurred despite significant advances in available medical treatment and the improvement of air quality in many areas where prevalence has increased the most (Lieberman & Kane, 1997).

Self-management problems may explain why many asthmatics have poor control over their symptoms. Asthma is a chronic condition associated with sudden deterioration, making patient cooperation in disease management especially vital (Tatyard, 1997). Yet, Kolbe, Vamos, Ferguson and Elkind (1998) found that despite recent efforts in asthma education, serious self-management errors are common among asthmatics, resulting in many preventable hospital admissions. Specifically, many asthmatics do not use their medications appropriately, avoid known triggers, or monitor changes in airflow (Vollmer, Osborne, & Buist, 1998). What hinders so many asthmatics from managing their condition? Osman (1997) found that asthmatics with difficult-to-control asthma follow a chaotic self-management style which may not be amenable to change even with asthma education. The present study examines several psychological factors which may be associated with poor asthma outcomes.

Psychological Stress, and Asthma

Psychological stressors may impact on asthma in a number of ways (Busse, Kiecolt-Glaser, Coe, Martin, Weiss, & Parker, 1995; Lehrer, Isenberg, & Hochron, 1993; National Heart, Lung & Blood Institute, 1998). 1) Bronchospasm may be triggered directly by acute stress. Unlike non-asthmatics, whose airways dilate when exposed to acute stressors, some asthmatics may have an underlying autonomic abnormality that causes acute stress to result in bronchoconstriction (Lemanske & Kaliner, 1990; Porges, 1995). 2) Stress may activate specific immune system activity such as cytokine production, which results in airway hypersensitivity and subsequent inflammation (Koh & Hong, 1993). 3) Distress may increase respiratory drive which can lead to both hyperventilation, panic and subsequent exacerbation of

asthma symptoms, and greater risk of attacks (Carr, Lehrer, Hochron, & Jackson, 1996; Klein, 1993). 4) Stress may decrease the likelihood of appropriate health behavior (Noeker, 1996), for example, using "rescue" medications when their use is not warranted.

It could be suggested that stress differences reflect psychopathology. Before the physical pathology of asthma was well understood, it had been historically linked to psychiatric problems, especially anxiety. However, a large scale epidemiological study found no evidence that patients with bronchial asthma were more anxious or depressed than those without asthma (Janson, Bjornsson, Hetta, & Boman 1994). In addition, Rocco, Barboni and Balestrieri (1998) recently found that anxiety, depression, and personality characteristics do not distinguish asthmatics from healthy controls or asthmatics who experienced near-fatal asthma from asthmatics with better control over their disease. Therefore, we cannot assume that asthmatics have clinically significant levels of emotionality (Kotses, 1998). Asthmatics may, however, still differ among themselves in how they respond to stress, both in terms of autonomic and immunological reactions that could lead directly to symptoms, and in terms of their ability to adequately manage their asthma in different situations.

Some asthmatics have symptoms or respiratory function that worsen during stressful periods (Brantley & Jones, 1993). For example, hospitalizations due to asthma (Northup & Weiner, 1984) and reported asthmatic wheezing (Tetzlaff, Leplow, Staud, Dahme, & Richter, 1994) are associated with high levels of reported stress. However, not all asthmatics show a connection between stress and asthma. Although it is well known that those who report chronic and acute symptoms also tend to report distress, the

connection between stress and ventilatory function is less consistent. Mood and lung function were significantly correlated in three of seven asthmatics in one study (Steptoe & Holmes, 1985), while both symptoms and ventilatory function were associated with negative mood in three of ten asthmatics in another study (Hyland, 1990). Peak flow, a measure of airway caliber was negatively associated with life event distress in 15 of 39 patients with asthma or chronic obstructive pulmonary disease (Goreczny, 1988). Taken together, the above research suggests that it is reasonable to examine further the relationship between psychological stress and asthma. The ability to identify those who exhibit such a connection appears particularly important. Serious life event stress may be of particular importance, as it may increase the chance that subsequent acute stressors will effect disease expression (Pike, Smith, Hauger et al., 1997).

Coping and Self-Efficacy

It possible that individual differences in style of coping with stressful situations account for the stress-asthma connection found in some asthmatics, but not in others. In particular, those who tend to use more passive coping strategies may be more likely to react to stress in ways that could trigger or exacerbate asthma symptoms. Two recent studies suggest that these kinds of individual differences may play an important role in asthma. Nouwen, Freeston, Cournoyer, Deschesnes, and Boulet (1994) found that some asthmatics mistake distress for actual bronchial closing; thus, differences in asthmatics' "perceptual" styles play a role in symptom perception and subsequent self-management. Isenberg, Lehrer, and Hochron (1997) found that some asthmatics were very inaccurate when estimating the size of an applied inspiratory airway restriction. These asthmatics rated even the mildest

restrictions as extremely unpleasant. The authors suggest that defensiveness may explain why these asthmatics had difficulty coping with even mild increases in airway resistance.

Accurately sensing airflow limitation is an important factor in determining appropriate asthma self-management. It is possible that during stressful situations, asthmatics whose attention is taken up with other processes (e.g., regulating their emotional responses) may not be able to accurately assess worsening airflow obstruction and respond appropriately to asthma-related crises. Furthermore, if they spend most of their energy dealing with their emotional reactions, they may not have the resources to deal appropriately with the stressor. The experience of the stressful situation could then be protracted leading to the autonomic and immunological reactions that exacerbate asthma. While little research has been published relating asthma to coping, defined as "the process of managing demands (external or internal) that are appraised as taxing or exceeding the resources of the person" (Lazarus and Folkman, 1984b), there is a sound rationale for pursuing such a course.

Self-efficacy may also play an important role in determining health behavior and mediating the effect of stressful events on asthma symptoms (Tobin, Wigal, Holroyd, & Creer, 1987). Believing or expecting that your actions can achieve the desired result is an important determinant of whether the actions will continue (Bandura, 1977). Applied to asthma, having confidence that self-management strategies can control asthma symptoms or attacks may explain why some asthmatics self-manage well and others do not (Osman, 1997). Noeker (1996) suggested that asthma can be associated with helplessness, i.e., the lowest levels of self-efficacy, because of its potential for sudden, unpredictable deterioration. Low asthma self-efficacy could reduce

treatment motivation and adherence, which could result in greater risk of attacks, poor coping during asthma crises and worsening symptoms. The current research, therefore, examined individual differences in coping style and confidence in the ability to control symptoms as determinants of the relationship between stress and asthma.

Predictions

Explanations that incorporate stress, coping, and self-efficacy may account for the variability of asthma symptoms, lead to testable predictions, and have important clinical implications. Within a population of asthmatics, stressful events, ineffective coping, and low asthma self-efficacy are likely to lead to exaggerated perception of symptoms, disability and disease-related distress, as well as lower ventilatory function.

This study tests aspects of this model by measuring life event stress, coping style and asthma self-efficacy, and assessing their relationship with subjective measures of asthma quality of life and with objective measures of ventilatory function. It is hypothesized that individual differences in coping with stress and in asthma self-efficacy would identify asthmatics with the lowest quality of life, poorest lung function and whose asthma is most responsive to psychological stress.

Tested in this exploratory study were the following hypotheses: 1. Life event stress in the past year will be negatively associated with asthma quality of life and ventilatory function. 2. Emotion-oriented and avoidant-oriented coping will be negatively associated with asthma quality of life and ventilatory function. 3. Task-oriented coping and asthma self-efficacy will be positively associated with asthma quality of life and ventilatory function. 4. Together, asthma self-efficacy, coping style and life event stress would account for a

considerable proportion of the variance in asthma quality of life and ventilatory function. 5. Asthma self-efficacy, task-oriented coping, emotion-oriented coping and avoidant-oriented coping would identify subgroups of asthmatics whose reported quality of life and observed ventilatory function are more strongly associated with stressful events. Specifically, stress-asthma associations would be greater for asthmatics with ineffective coping (high emotion and avoidant-oriented coping, low task-oriented coping) and low asthma self-efficacy.

Methods

Sample

During a thirty-month period, 574 adult patients were approached by the principal investigator or research assistant when they attended the Montreal General Hospital's Asthma Clinic and informed about the study. 236 clinic patients signed consent forms agreeing to complete the questionnaires and granting the researchers access to their medical file. Of these, 132 patients (78 women and 54 men, mean age 39.7 years, ranging in age from 18 to 68) met all inclusion criteria. The inclusion criteria were: 1) confirmed diagnosis of asthma and absence of significant other lung disease; 2) currently receiving appropriate medical treatment; 3) receipt of asthma education at the clinic; 4) receiving comparable levels of anti-inflammatory (inhaled corticosteroid) and bronchodilator medication.

Diagnosis of asthma was confirmed by the presence of reversibility of airway obstruction after salbutamol, a bronchodilator, was inhaled; and a significant drop in forced expiratory airflow volume in one second (FEV1) after small amounts of an irritant, methacholine, were inhaled, indicating airway hyperresponsiveness. The patients received medical treatment in

accordance with the Canadian Thoracic Society's asthma treatment guidelines (Ernst, FitzGerald, & Spier, 1996) along with asthma education from respiratory therapists. Patients completed the questionnaires immediately prior to taking their ventilatory function tests. No information was gathered regarding those who were approached but declined to participate, but the study sample could be compared with clinic attendees. The sample's mean forced expiratory airflow volume, expressed as a percentage of predicted normal (%FEV), was not significantly different from an equal number of asthmatics drawn randomly from the asthma clinic's database (%FEV = 80.1 and 81.9, respectively). Thus, as a group, study participants were not significantly better or worse off in terms of asthma severity than non-participants, though clinic attendees were probably better controlled than a general sample of asthmatics.

Measures

A. Asthma Measures: 1. The Asthma Quality of Life Questionnaire (AQLQ) (Juniper, Guyatt, Epstein, Ferrie, Jaeschke, & Hiller, 1992) measures the subjective impact of asthma on a person's daily life. This 32-item questionnaire assesses activity limitation (on five activities chosen by the patient), symptom severity (e.g., coughing, wheezing, chest tightness), environmental triggers (e.g., dust, cigarette smoke) and distress caused by asthma (e.g., worry caused by chest tightness).

The AQLQ is used extensively as an asthma outcome measure in drug treatment studies. The AQLQ has stable factor structure, high internal reliability (alpha = .92), high test-retest reliability in stable asthmatics, and significantly correlates with other indices of asthma severity (Juniper et al., 1992; Juniper, Guyatt, Ferrie, & Griffith, 1993). In an independent evaluation, Rowe and Oxman (1993) found similar levels of reliability and validity (e.g.,

AQLQ improved when ventilatory function improved in patients with acute asthma).

The self-administered form of the AQLQ requires ratings made on a 7-point Likert scale. Four subscale mean scores and a composite AQL mean score were calculated for each participant. In this study, within subscale alphas were high: .88 for activity limitation; .85 for symptom severity, .79 for environmental triggers, .72 for distress caused by asthma. The four AQL subscales had Cronbach alpha of .94, similar to that reported by Juniper et al. (1992). The AQLQ includes areas of quality of life impairment that are important to adult asthmatic patients and is responsive to within-subject change and may therefore be used as a measure of asthma outcome (Juniper et al., 1992). In AQLQ units, the minimal important difference in quality of life per item was near 0.5 (range 0.42-0.58); differences of 1.0 represent moderate changes; and differences of greater than 1.5 represented large changes. (Juniper, Guyatt, Willan, & Griffith, 1994).

In a reliability assessment, the AQLQ was found to have an intraclass correlation coefficient of 0.80. In an assessment of cross-sectional construct validity the AQLQ showed moderate correlation with the amount of medication used ($r = 0.38$) but no correlation with either %FEV1 predicted ($r = -.20$) or airway responsiveness ($r = -.16$). In subjects who improved over time, the AQLQ was able to show that these changes were greater than those observed in stable patients ($p = 0.007$). In longitudinal studies, the AQL was moderately correlated with asthma symptoms ($r = .37$) and airway hyperresponsiveness ($r = 0.38$) but not with peak flow variability ($r = .12$). (Juniper, 1998).

Two patients failed to endorse the minimum number of activities required for the activity limitation subscale (Juniper et al., 1992) and their composite AQL could not be calculated.

2. Ventilatory Function tests were carried out in the Pulmonary Function Laboratory of the Respiratory Division of the Montreal General Hospital. Spirometric indicators included: forced expiratory airflow volume in one second (FEV1), which is the volume of air forcefully expelled in one second, and forced vital capacity (FVC) as measured by the total volume of air expelled from the lungs. Raw FEV1 and FVC scores are converted into percentages of normal volume expected for the subject's age, sex, height and weight to allow for meaningful comparison between patients (%FEV and %FVC, respectively). For example, a %FEV of 70 indicates a FEV1 of 70% of the normal based on a corresponding healthy sample.

B. Stress Measure: The Life Experiences Survey (Stress) (Sarason, Johnson, & Siegel, 1979) is adapted from an instrument developed by Holmes and Rahe (1968) to assess individual differences in the amount and impact of life event stress experienced in the past year. It is a 60-item stressful event checklist with a 7-point impact scale for each item. The events include items such as death of spouse, death of family member, marriage, loss of job, and changing residence. Participants in this study were instructed not to include their asthma when considering the "major personal illness" item on the questionnaire. Respondents were given the list of events in order to check off items that they had experienced in the past year. For items selected, the impact of each life event was rated on a scale ranging from -3 (negative) to +3 (positive).

The impact scores were summed. The total perceived negative impact of stressful life events experienced in the past year was computed by adding together all negative impact scores for items endorsed. In this sample, negative impact correlated $r = .69$ with Holmes and Rahe scoring, suggesting that negative event is a valid measure of life event stress. Positive impact scores were not as highly correlated with the Holmes and Rahe score.

C. Coping Measures: The Coping Inventory for Stressful Situations (CISS) (Endler & Parker, 1990) assesses an individual's coping style, a characteristic way of responding to stressful situations. The CISS is a 48-item self-report questionnaire which lists coping strategies and asks respondents to rate on a 5-point scale (1 = never; 5 = all the time) how likely they are to use that strategy. Sixteen items assess task-oriented coping (e.g., "work to schedule my time better"), 16 items assess emotion-oriented coping (e.g., "freeze and not know what to do"), and 16 items assess avoidant-oriented coping (e.g., "go see a movie to try and forget about it"). The avoidance scale has two subscales: distraction (8 items) and social diversion (5 items). Internal consistency of the CISS subscales range from alpha = .80 to .92 for various samples. Test-retest correlations 6 weeks apart range from .60 to .73. Endler and Parker (1994) found that the CISS factor structure was stable when used with different samples and that coping subscale scores were associated with behavior similar to that type of coping (i.e., subscales have construct validity).

Several participants did not complete enough items for a particular subscale to be considered valid; their data were not included in analyses of coping (n=7 for task coping, n = 4 for emotion-coping, and n = 2 for avoidant-coping). Similar to those reported by Endler and Parker (1990), Cronbach's

alphas for coping variables in this sample were: Task-coping alpha = .62, Emotion-coping alpha = .63, and Avoidant-coping alpha = .56.

D. Self-efficacy measure: 1. The Asthma Self-Efficacy Questionnaire (ASE) (Tobin, Wigal, Holroyd, & Creer, 1987). Based on the concept of self-efficacy (Bandura, 1977, 1986), asthma self-efficacy can be defined as asthmatics' belief in their ability to control symptoms and avoid attacks (Tobin et al., 1987). The 80-item ASE questionnaire assesses confidence in being able to control asthma in various triggering situations (e.g., "when exposed to pollen" or "when angry or upset"). Items are rated on a 5-point scale from not at all confident to completely confident. Tobin et al. (1987) reported high internal consistency (alpha = .97) and adequate 2-week test-retest reliability (r = .77). Fourteen of the 80 items deal with emotional and stressful situations.

To eliminate differences in ASE due to asthma education (Boulet, Chapman, Green, & Fitzgerald, 1994), it was confirmed that all patients received asthma education at the clinic prior to completing the questionnaires. Two patients gave invalid responses on the ASE (answering female-only items when male) and their ASE scores were not used in the analyses. In this sample, the ASE responses produced a Cronbach's alpha of .95.

E. Demographic and medication information were collected on a coversheet. Information provided was confirmed by examining each patient's medical file. Data abstracted from the medical files included: years since diagnosis of asthma, age of onset, smoking history, family history of asthma and allergies, height, weight, age, sex, and presence of other respiratory problems. Twenty-nine patients reported that they were currently smokers.

Results

Preliminary analyses, means and standard deviations for all continuous demographic, stress, coping, self-efficacy and asthma variables (at intake) are described in Table 1. Out of the total sample of 132 asthmatics, 20 had previous ER visits and 43 had a previous hospitalization due to asthma.

Table 1

Simple Statistics for Demographic, Stress, Coping, Self-Efficacy and Asthma Variables (n = 132)

	Mean	Std Dev.	Minimum	Maximum
Age	39.66	15.04	18.00	68.00
Duration	15.23	14.74	0.00	63.00
Onset (age)	27.16	17.78	0.00	63.00
Stress	8.00	6.95	0.00	32.00
Task-coping	54.40	12.80	16.00	80.00
Emotion-coping	46.16	12.80	16.00	72.00
Avoidant-coping	39.68	10.88	16.00	64.00
ASE	273.50	64.38	155.00	373.00
AQL	4.59	1.19	1.88	6.88
%FEV	80.12	20.69	32.00	131.00
%FVC	92.51	14.45	62.00	126.00

Note: ASE = Asthma Self-Efficacy, AQL=Asthma Quality of Life

To assess the impact of demographic variables on the psychological variables of interest and on asthma outcome variables, Pearson product-moment correlations were calculated between age, sex, smoking, duration of asthma, age of onset of asthma, and all stress, coping, self-efficacy and asthma variables (see Table 2).

Table 2

Correlations between Demographic Variables and Stress, Coping, Self-Efficacy and Asthma, (n = 132)

History Variables	Demographic, Smoking and Asthma				
	Age	Sex	Smoking	Onset	Duration
Study Variables					
Stress	-.04	.06	-.19	-.09	.06
Emotion-coping	-.22	-.08	-.15	.30*	.02
Avoidant-coping	-.18	.15	.23	-.21	-.13
Task-coping	-.10	.00	.03	-.03	.03
Asthma Self-Efficacy	-.31*	.04	-.07	-.09	-.05
Asthma Quality of Life	-.06	.12	.08	-.13	-.21
%FEV	-.24	.05	.16	-.02	-.24
%FVC	-.12	.01	.09	.06	-.27*

Note: %FEV = percentage of predicted forced expiratory airflow volume in one second, %FVC = percentage of predicted forced vital capacity,
*p < .05 (unadjusted).

Age was found to be significantly negatively correlated with asthma self-efficacy. Duration of asthma was associated with %FVC. Age of onset of asthma was associated with emotion coping. Gender was not associated with any psychological or asthma variable.

Hypothesis 1. To test the hypothesis that life event stress and asthma status would be associated, Pearson product-moment correlations were calculated between life event stress and the indicators of asthma severity (AQL, %FEV and %FVC) with Bonferroni adjustment for multiple comparions. Life event stress was found to be negatively correlated with AQL (r (132) = -.32, p < .05; r (132) = -.33, p <.05, partialling out age and duration; r (132) = -.30, p <.05, partialling out %FEV) but not correlated with %FVC or %FEV.

Hypotheses 2 and 3. To test hypotheses regarding coping styles and asthma, Pearson product-moment correlations with Bonferroni adjustment for multiple comparions were calculated to assess the relation between coping, ASE and asthma indicators (see Table 3). With regard to hypothesis 2, as predicted, emotion-coping (r (132) = -.32, p < .05; r (132) = -.35 controlling for age and duration) was significantly negatively correlated with AQL. Avoidant coping was not significantly correlated with AQL (see Table 3). Neither coping measure was significantly associated with ventilatory function measures. Concerning hypothesis 3, ASE scores correlated positively with AQL (r (132) = .45, p < .01; r = .56, p <.01 with age and duration partialled out). That shared method variance explained this high correlation was a possibility as both the ASE and AQL had subscales dealing with environmental triggers. However, correlation between ASE and AQL with these overlapping subscales temoved (r = .44) was no greater than the overall ASE - AQL

correlation. In addition, ASE was also associated with objectively assessed ventilatory function. ASE scores correlated positively with %FEV ($r(132)$ = .23, $p < .05$; $r = .22$, $p < .05$ with age and duration partialled out) and %FVC (r = .25, $p < .05$, $r = .20$, ns with age and duration accounted for). Task-oriented coping was significantly positively correlated with %FEV ($r = .30$, $p < .05$, r = .26, $p < .05$ with age and duration partialled out). (Task-coping was also associated with improvement in %FEV at clinic follow-ups with a correlation $r(98) = .27$, $p < .05$ with mean improvement in %FEV over time; $r(98) = .23$, $p < .05$, with initial %FEV partialled out).

Table 3

Life Event Stress, Coping Style, Asthma Self-Efficacy and Asthma Correlations with Bonferroni Correction for Multiple Comparisons (n=132)

	Indicators of Asthma Severity		
	AQL	%FEV	%FVC
Study Variables			
Life Event Stress	-.32*	-.13	-.16
Emotion-coping	-.32*	.00	-.05
Avoidant-coping	-.19	.08	.15
Task-coping	-.02	.30*	.12
Asthma Self-Efficacy	.45**	.23+	.25+

+ $p < .10$, * $p < .05$, ** $p < .01$

Hypothesis 4. To determine the independent impact of stress and coping on asthma severity, multiple regression analyses using forward selection were conducted using AQL as a dependent measure. Life event stress, Coping (Task, Emotion and Avoidant) and ASE were included as independent variables in the equation. A standardized regression coefficient was computed by dividing a parameter estimate by the ratio of the sample standard deviation of the dependent variable to the sample standard deviation of the regressor. As summarized in panel I, Table 4, the final step included three predictors, namely ASE, Stress and Task-coping (R-square (132) = .39, ps < .05), with ASE accounting for most of the variance (part-r-square = .30). This suggests that, together, beliefs about controllability of asthma (ASE), the impact of negative stressful events and task-coping accounted for 39% of the variance in AQL. Emotion and avoidant coping did not contribute significantly to the equation. When three demographic variables were forced into the equation (age, duration of asthma and age of onset), a similar model emerged. Four variables explained 39% of the variance in AQL, with duration of asthma replacing task-coping as the third significant variable to be entered into the equation and avoidant-coping also added (see panel II, Table 4).

The same process was followed using %FEV, the more responsive index of ventilatory function, as the dependent variable in the stepwise regression equations. Including the stress, coping and self-efficacy variables as predictors, only one variable, Task-coping emerged as a significant predictor, accounting for 9% of the variance in %FEV (see panel I, Table 5). Including the stress, coping, self-efficacy and demographic variables as independent variables resulted in a model that accounted for 20% of the variance in %FEV

with three significant predictors: Task-coping, duration of asthma, and age (see panel II, Table 5).

Table 4

Summary of Final Step Statistics for Stepwise Multiple Regression for Variables Predicting Asthma Quality of Life (n = 132)

I. Stress,Coping and Self-Efficacy as Predictors

Variable	Part R-square	Std Beta	t-value	Prob t
Self-Efficacy	.30	.55	5.89	.00
Stress	.04	-.03	2.32	.02
Task-coping	.04	.02	2.11	.02

R-square = .39*

II. Stress, Coping, Self-efficacy and Demographic Predictors

Variable	Part R-square	Std Beta.	t-value	Prob t
Self-efficacy	.29	.53	5.69	.00
Stress	.06	-.21	2.45	.02
Duration	.02	-.25	2.03	.05
Avoidant-coping	.02	-.20	2.06	.05

R-square = .39*

*p <. 05

Hypothesis 5. The fifth hypothesis was that certain subgroups of asthmatics, identified on the basis of their coping strategies or ASE, would exhibit significantly greater stress-asthma correlations. First, the correlations of subsamples split at the medians for ASE and for task, emotion or avoidant coping were conducted. Second, Fisher z transformations of the difference between each subsample stress-asthma correlation coefficient were computed

Table 5

Stepwise Multiple Regressions with %FEV as Dependent Variable

I. Stress,Coping and Self-Efficacy as Predictors

Variable	Part R-square	Std Beta	t-value	Prob t
Task-coping	.09	.29	2.6	.01
R-square = .09*				

II. Stress, Coping, Self-efficacy and Demographic Predictors

Variable	Part R-square	Std Beta	t-value	Prob t
Task-coping	.10	.38	2.29	.02
Duration	.07	- .26	2.50	.01
Age	.04	- .20	1.90	.05
R-square = .20*				

*p < .05

(observed rs are converted to r primes, z = the difference between r primes divided by the square root of the sum of: 1 divided by the number in each subsample minus 3) . It was predicted a-priori that stress-asthma correlations would be significantly higher for the low asthma self-efficacy group, the high emotion-oriented coping, the high avoidant coping group and the low task-oriented coping group. In the first case, patients were divided into those with high asthma self-efficacy (ASE > 273; n = 65) and those with low asthma self-efficacy (ASE $\leq$ 273, n=65). There were no significant differences between the stress-asthma correlation coefficients of the high vs. low asthma self-efficacy subgroups (see Table 6).

Patients were also divided into high and low emotion-oriented coping groups (n = 64 for each) with subjects above the median (46) assigned to the high emotion-oriented coping group. The stress-asthma correlations were again compared. As presented in Table 6, while there was no difference between the

stress and AQL correlation coefficients, there was a difference in the stress-%FEV correlation, namely that the high emotion-oriented coping patients had a significantly higher negative correlation than the with low emotion copers.

Table 6

Comparison of Stress/Asthma Correlations for Asthma Self-Efficacy and Coping SubGroups.

Subsample Group	Correlation Stress/AQL	t-test of diff.	Correlation Stress/%FEV	t-test of diff
High ASE (n=65)	-.29		-.13	
		ns		ns
Low ASE (n=65)	-.33		-.12	
Low EMO (n=64)	-.30		-.03	
		ns		p <. 05
High EMO (n=64)	-.32		-.27	
Low AVOI (n=65)	-.30		.12	
		ns		p < .01
High AVOI (n=65)	-.35		-.48	
High TASK (n=63)	-.23		-.01	
		p < .05		p < .05
Low TASK (n=63)	-.40		-.26	

Note:AQL = Asthma Quality of Life, %FEV= percentage of predicted forced expiratory airflow volume in one second, ASE = Asthma Self-Efficacy. EMO = Emotion-oriented Coping. AVOI = Avoidant-oriented coping. TASK = task-oriented coping.

A similar analysis was performed after splitting the sample at the median for avoidant-oriented coping (40, n= 65 for each group). The results were similar to emotion-oriented coping in that stress and AQL were highly

negatively correlated regardless of avoidant coping, while stress - %FEV correlation differed as a function of avoidant coping. A higher correlation between stress and %FEV ($r = -.48$, $p < .01$) was found in the high avoidant-coping subsample than in the low-avoidant coping subsample. Thus, %FEV appears to be more responsive to stress for high rather than low-avoidant copers.

The stress-asthma correlations of low and high task-oriented copers, split at the median for task-oriented coping (54, $n = 63$ in each group), were compared. The low task-coping subjects were found to have significantly larger negative correlations between both stress and AQL and between stress and %FEV than high task-oriented copers.

Discussion

Is stress associated with more severe asthma? Negative life event stress was associated with lower AQL and contributed significantly to multiple regression models explaining AQL, both on its own and in interaction with emotion-coping. Those who reported more negative life stress in the past year tended to experience the greatest impact of asthma on their life, though they did not necessarily have the worst ventilatory function. Thus, life event stress appears to impact on symptom perception, disease-related distress and activity limitation. Coping differences did not play a large role in the stress-AQL associations, as only high task copers showed less responsiveness to stress.

Life event stress did not directly affect ventilatory function. However, the overall correlation between stress and lung function masked differences in responsiveness to stress in certain groups. This was clarified by the subgroup analyses which gave a clear indication that coping style strongly mediated relationships between stress and ventilatory function. Lung function appeared

to be more responsive to stress given ineffective coping, such as emotion and avoidant-coping.

Why might stress have a direct impact on quality of life but only in some patients affect ventilatory function? Stress may directly contribute to symptoms and distress which continue to affect patients even though their ventilatory function, which may be affected temporarily, bounces back shortly after the stress. Furthermore, whenever stress exacerbates symptoms and distress, patients may curtail their activities over the longterm. It is also possible that memory for asthma problems or other stressors outlasts effects on %FEV. Crises may be recalled in great detail and serve as reference points when patients assess the impact of asthma on their life. However, a number of alternative explanations are also possible. Perhaps those who are limited in their activities due to asthma are more likely to experience other negative events (financial, interpersonal, professional). Alternatively, the type of people who report negative stressful life events may also report more symptoms (Cohen & Herbert, 1996). Subsequent longitudinal research is required to determine which explanation best accounts for these findings.

Stress did not directly reduce lung function, but was mediated by the way asthmatics coped with stress. Emotion and avoidant-coping were two strategies that mediated the stress-ventilatory function relationship. Those who use emotion or avoidant coping may develop poor health behaviors perhaps due to the effects of poor coping on disease-management during asthma-related crises over time. These coping styles may be associated with either a tendency to exaggerate the impact of the illness (i.e., poor copers may report more symptoms, limitation and disease-related distress), or may reflect difficulty in distinguishing non-asthma symptoms and distress from symptoms that are

caused by airflow obstruction. In addition, these asthmatics may be more likely to over-react to mild restrictions or spend more energy attending to emotional reactions than to their symptoms of airway obstruction. The largest difference in subsample stress-%FEV correlations was found between the high and low avoidant-coping groups, suggesting that inattention to symptoms leads to particularly ineffective self-management.

Is effective coping associated with better asthma control? Task-coping was particularly important in mediating the impact of stress on quality of life and lung function. As hypothesized, asthma was significantly less responsive to stress in patients who used task-oriented coping. Task-coping may indicate appropriate self-management and a problem-focused response to asthma crises which lead to better asthma control. Task-oriented coping may be associated with better health behaviors, such as medication compliance and trigger avoidance which directly affect ventilatory function. While all coping indirectly impacted on the stress-%FEV associations, only task-coping differences accounted for both stress-AQL and stress-%FEV correlation differences, suggesting that of the three coping styles, task-coping is the best buffer against life event stress impacting on asthma.

In contrast to coping style, which mediated the stress-asthma connection, asthma self-efficacy appears to have a strong direct influence on AQL and a less consistent effect on ventilatory function. The high correlation between asthma self-efficacy and both asthma quality of life and ventilatory function suggests that confidence in one's ability to deal effectively with asthma symptoms and attacks plays a large role in both subjective and objective assessment of asthma severity. Stress-asthma correlations were, however, the same for both the high and low asthma self-efficacy groups,

suggesting that ASE did not reduce the impact of stress on asthma. Thus, self-efficacy is of general value in maintaining AQL and perhaps ventilatory function but does not appear to buffer the impact of stress. Asthmatics with high self-efficacy may be more likely to exhibit appropriate health behavior which then results in better asthma control and less reported asthma severity, and minimize the subjective impact of their disease, reporting fewer symptoms and limitation. Alternatively, high asthma self-efficacy may simply be a result of experiencing less severe asthma. This explanation is consistent with the finding that asthma self-efficacy was associated with better ventilatory function. However, good self-efficacy increased quality of life even when %FEV was partialled out, suggesting that the relationship was not solely due to that fact that asthma self-efficacy identified asthmatics with the least airway obstruction. The improved asthma outcomes associated with asthma self-efficacy are probably due to better self-management or a history of success in responding to asthma crises. Whether asthma self-efficacy is a cause or an effect of health behavior that improves quality of life and ventilatory function remains to be tested in prospective studies.

Previous attempts to explore stress and asthma were limited by over-reliance on subjective symptom reports, failure to recruit a purely asthmatic sample, and failure to control for other variables (e.g., medical treatment and patient education). Therefore, this study's recruitment of a pure asthmatic sample, appropriately treated, educated about their asthma, and all prescribed a comparable medication regimen and the study's use of both subjective and objective indices of asthma severity indicate methodological advances over previous research. However, this study is limited as it relies on data from one time only. Thus, it may be difficult to infer directionality or causal links. The

planned prospective diary study addresses these issues by assessing variables such as perceived stress, symptoms, peak expiratory airflow volume several times a day for an extended period of time. In addition, a laboratory study of physiological responses (including bronchial and parasympathetic tone) of asthmatics to different stressors and to relaxation is also planned.

This study suggests that stress, coping style and self-efficacy play important roles in both asthma quality of life and ventilatory function. Asthma self-efficacy and task-oriented coping appear especially interesting: self-efficacy for its general impact on quality of life and ventilatory function, and task-oriented coping for its value in buffering the impact of stress on asthma. In terms of clinical implications, this study suggests that facilitation of patient confidence in a problem-solving approach toward managing asthma may be an especially effective component of asthma treatment and education. This study also suggests that asthmatics at risk for poor self-management can be identified based on their coping styles and self-efficacy. Once identified, such asthmatics may benefit from interventions including extended asthma education, stress management, and challenging dysfunctional beliefs about asthma.

Programmatic Link to Study 2 - Daily Diaries

The clinic questionnaire and ventilatory function study provided some support for the hypothesized relationship between stress, coping, self-efficacy and asthma control. It also suggested that there might be a subgroup of asthmatics, identified by their coping style, whose symptoms and airway limitation were responsive to stress. In order to test the stress-asthma causal sequence, a prospective study which assesses changes in perceived stress and asthma symptoms and airway limitation over time was required. Such a study would be able to explore temporal links between stress and asthma changes. In addition, variables which may mediate the effect of stress on asthma -- self-management behaviour such as rescue medication use -- can be assessed. In short, the next logical step in this program of research was to conduct an daily diary study assessing daily perceived stress, asthma symptoms, peak flow and rescue medication use.

The role of daily perceived stress in predicting daily variability in asthma symptoms, peak flow rates and bronchodilator use

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Abstract

Asthma is increasing in morbidity and mortality. Daily changes in symptoms, airflow limitation and rescue medication were assessed along with psychosocial variables (daily perceived stress, coping styles, asthma self-efficacy and asthma quality of life) hypothesized to predict changes in asthma. Thirty-five adult asthmatics completed daily stress, asthma symptom, peak flow rate (PEFR) and beta-agonist bronchodilator use (BU) diaries three times daily for at least 21 consecutive days. Daily bronchodilator use was measured by the number of puffs/day from salbutamol 100mcg inhalers. Mean daily asthma symptom and mean daily stress were strongly positively correlated (r = .61, $p < .001$). Mean daily stress was also associated with mean daily PEFR (r = -.35, $p < .04$). Many subjects had high BU despite PEFR stability. Daily BU was strongly correlated with AQL (r = -.51, $p<.005$), ASE (r = -.41, $p <$ .03), and emotion-oriented coping (r = .37, $p<.05$). Mean daily stress and emotion-oriented coping accounted for considerable variance in asthma symptoms (R^2 = .43, $ps<.05$). Daily stress, symptoms and BU use accounted for 33% of the variance in mean daily peakflow (R^2 = .33). AQL, daily PEFR and ASE accounted for 46% of the variance in BU (R^2 = .46). 15 of 35 subjects (43%) had clinically significant drops in peakflow; 58% of these drops occurred after a large increase in perceived stress (F (3, 56) = 5.18, $p <$ .01). Daily stress is strongly associated with daily symptoms. Daily medication use may be a habit that has more to do with beliefs about disease severity and controllability than objective indices of airway limitation. A subgroup of asthmatics may have airway limitation that is responsive to perceived stress. Keywords: asthma, stress, peak flow, bronchodilators, coping, self-efficacy.

THE ROLE OF DAILY PERCEIVED STRESS IN PREDICTING DAILY VARIABILITY IN ASTHMA SYMPTOMS, PEAK FLOW RATES AND BRONCHODILATOR USE

Asthma is a growing health problem among children and adults. Along with increasing prevalence, asthma is becoming associated with more serious symptoms and greater functional limitations (Sears, 1997). The result of these developments is higher death rates from asthma and escalating health care costs (Krahn, Berka, Langlois, & Detsky, 1996). These alarming trends are perplexing given recent clarification of the pathophysiology of asthma, development of highly effective medications (Vianna & Martin, 1998), and stronger asthma education programs. The increased morbidity and mortality among treated asthmatics may be partly due to psychological variables which on a daily basis may effect asthma symptoms and medication use. Study 2 assesses asthma symptoms, peak flow rates, and medication use over a three-week period and examines their connection to daily perceived stress as well as to coping, self-efficacy and quality of life.

Asthma is a chronic respiratory disorder characterized by intermittent inflammation and bronchoconstriction that cause airway limitation and result in recurring symptoms such as wheezing, coughing, shortness of breath and chest tightness (Ernst, FitzGerald, & Spier, 1996). While inflammation and production of mucus may limit airflow over time, bronchoconstriction, i.e., a tightening of the muscles which surround the airways, can result in acute asthma symptoms. Where airway limitation is already significant, sudden bronchospasm or increases in inflammation may be extremely dangerous, resulting in obstructed airways and even death. As asthma is a chronic condition with risk of sudden deterioration, ongoing self-management is

extremely important. However, many asthmatics are not able to achieve adequate control over their symptoms despite receiving appropriate medical treatment and asthma education. Identifying psychosocial variables that predict poor asthma control may help reverse current increases in asthma morbidity and mortality.

Symptoms and airflow change rapidly in asthma, therefore multiple daily measures are best suited to assess asthma variability. Asthmatics may have both acute bronchoconstriction or may respond to triggers with inflamed mucus membranes and swollen airways. Three important indices of daily changes in asthma are: 1) patient self-reports of asthma symptoms; 2) peak flow rates, an objective index of airway caliber which measures expiratory airflow volume via portable devices; and 3) beta-agonist bronchodilator ("rescue") medication use.

Medication use in asthma. Two categories of medication are used to treat asthma: bronchodilators (broadly termed "relievers" or "rescue" medications in asthma education programs) and anti-inflammatory ("controllers" or "preventers") corticosteroids which can reduce inflammation over time. Inhaled beta-agonist bronchodilator medications (for example, salbutamol) are the most widely used medication for symptomatic relief of asthma symptoms. They rapidly relax bronchial muscles. However, while useful in acute attacks, their actions may be short-lived, lasting approximately 4-6 hours (O'Byrne & Kerstens, 1996). These medications can also protect against acute bronchoconstriction if taken before exposure to a known trigger (e.g, cold air, exercise).

The amount of beta-agonist bronchodilator medication used to control asthma symptoms can be seen as an indicator of asthma severity (Spitzer,

Suissa, Ernst, Horwitz, Habbick, Cockcroft, Boivin, McNutt, Buist, & Rebuck, 1992; Suissa, Ernst, & Boivin, 1994). However, it is not known the degree to which observed airway limitation, asthma symptoms, stress or psychosocial variables contribute to daily rescue medication use over time. Many asthmatics, even after receiving asthma education, overuse their bronchodilator medications (Beausoleil &Weldon 1997; Osman, 1997). This overuse may have serious health consequences (Spitzer et al., 1992; Suissa, Ernst, & Boivin, 1994; Vianna & Martin, 1998). Since beta-adrenergic receptors are widely distributed, a number of adverse effects are associated with their use. These include tremor (caused by direct stimulation of beta-adrenergic receptors in skeletal muscle), increased heart rate, vasodilation and risk of tachycardia at higher doses (Nelson, 1995). Thus, both as a index of asthma severity, and as one of several important health behaviours, daily beta-agonist bronchodilator use was examined in relation to daily perceived stress and to coping, self-efficacy and quality of life.

An increased risk of death or near death from asthma is associated with heavy use of inhaled beta-agonist bronchodilators (Spitzer, et al., 1992). The risk of death increased among patients using more than 1.4 canisters of beta-agonist per month (Suissa, Ernst, & Boivin, 1994) and the greatest risk was associated with a pattern of increasing use (Suissa, Blais, & Ernst, 1994). It is unknown, however, if the beta-agonists are directly responsible for this increased risk of death or if heavy use is simply a marker for more severe asthma (Spitzer, et al., 1992, Vianna & Martin, 1998). FitzGerald, and Turner (1997) found that excess use of inhaled beta-agonist bronchodilators, especially in the absence of inhaled corticosteroids, confers a significantly increased risk of fatal and near fatal asthma. Heavy use of these inhaled adrenalin-like

bronchodilators (especially when "preventers" are not used consistently or at all) is associated with increased risk of death or near death from asthma, loss of lung function, and overuse of hospital emergency rooms (Suisa, Blais, & Ernst, 1994). Clearly, heavy use is problematic and should not be seen in a stable well-controlled sample who has received asthma education.

Few studies exist on psychological factors in beta-agonist bronchodilator overuse. Beausoleil and Weldon (1997) studied adolescents who had all received the same warnings against beta-agonist overuse. Of the sample of 55 asthmatics, 17 were found to be overusers. Those in the overuse group were found to have a greater proportion of males (76% compared to 47% of the non-overuse group) and to have lower scores on intelligence and achievement tests. On personality measures, the over-users were found to be, on average, more dominant and undisciplined than those in the non-overuse group. This study suggests that there may be individual differences variables that can identify rescue medication overusers, though the variables may differ for adolescents and for adults.

Peak flow self-monitoring. Creer, Levstak and Winder (1998) note numerous advantages provided by peak flow meter use, including: 1) simplicity of use; 2) providing an objective index of airway obstruction where a patient's subjective assessment is unreliable, 3) helping patients determine triggers, 4) increasing medication compliance; and 5) providing sequential daily values which allow patterns of airflow variability to be assessed.

Despite the benefits of PEFR self-monitoring, most asthmatics do not consistently monitor the changes in their airways. In a survey of 5,580 health maintenance organization members with asthma, Legorretta, Christianherman, O'Connor, Hasan, Evans, and Leung (1998) found that only

26% of the asthmatics had a peak flowmeter, and of those, only 16% used it daily. Increasing age and treatment by an asthma specialist were factors identified as being related to daily use of a peak flow meter and, unexpectedly, to overuse of beta-agonist metered dose inhalers (Legorreta et al., 1998). In a study of an asthmatic sample provided with peak flow meters that electronically recorded PEFR and time/date recorded unbeknownst to their subjects, Cote, Cartier, Malo, Rouleau, and Boulet (1998) found that compliance with PEFR measurement was fairly good during the first month (63% of all measurements done) but even with repeated reinforcement fell to 50% at 6 months and to 33% at 12 months. Furthermore, right from the beginning, a few subjects never or almost never measured PEFR. At 12 months 60% of the subjects were measuring PEFR less than 25% of the time. Poor PEFR compliers could not be identified by demographic and illness severity measures used in the study.

Stress and daily asthma symptoms, airflow and medication use. While asthma patients are warned to avoid known asthma-specific triggers such as allergens and cold air, less recognition has been given to the role that psychological stressors may play in exacerbating asthma on a daily basis. As noted in previous chapters, research has begun to show that psychological stressors can effect asthma control in at least four specific ways (Busse, 1999; Weiss, 1999). First, bronchospasm may be triggered by acute stress (Lemanske & Kaliner, 1990; Porges, 1995). On a daily basis, episodes of high perceived stress may precede asthma symptoms or airflow drops. Second, stress may activate immune system activity such as cytokine production, which results in airway hypersensitivity and subsequent inflammation (Koh & Hong, 1993, Weiss, 1999). A longitudinal study may note time-series effects caused by

stress-triggered inflammation - increases in stress on one day may precede symptoms and airflow drops on subsequent days. Third, stress may make appropriate health behavior, such as appropriate daily medication use, less likely (Noeker, 1996). Assessing medication use over time and assessing whether high daily perceived stress precipitates behaviour such as beta-agonist bronchodilator overuse will help explore this issue.

The association between stress and asthma cannot easily be explained by psychopathology in patients with asthma. A large scale epidemiological study found no evidence that patients with bronchial asthma were more anxious or depressed than those without asthma (Janson, Bjornsson, Hetta, & Boman 1994). In addition, Rocco, Barboni, and Balestrieri (1998) found that anxiety, depression, and personality characteristics do not distinguish asthmatics from healthy controls, or asthmatics who experienced near-fatal asthma from asthmatics with better control over their disease. Therefore, we cannot assume that asthmatics have unusual or clinically significant levels of emotionality (Kotses, 1998). Asthmatics may, however, differ among themselves in how they respond to stress, both in terms of autonomic and immunological reactions that could lead directly to symptoms, and in terms of their ability to adequately manage their asthma in different situations.

Some asthmatics appear to have symptoms or airflow limitation that worsen during stressful periods. Janson-Bjerklie, Ferketich and Benner (1993) followed 95 asthmatics for 60 days. They found that distress during an asthma episode, perceived danger from asthma and appraisal of social support were predictors of emergency room visits. Self-care, perceived life stress, nocturnal symptoms and amount of distress during an asthma episode were predictors of depression. They also found that financial status and the absence of nocturnal

symptoms predicted life satisfaction. This was supported by results of the first study where asthma quality of life was found to be associated with life event stress. Hospitalizations due to asthma (Northup & Weiner, 1984) and reported asthmatic wheezing (Tetzlaff, Leplow, Staud, Dahme, & Richter, 1994) are associated with high levels of stress. However, not all asthmatics show a connection between stress and asthma. Mood and lung function were significantly correlated in only three of seven asthmatics in one study (Steptoe & Holmes, 1985), and in three of ten asthmatics in another study (Hyland, 1990). Peak expiratory airflow rates were negatively associated with life event distress in 15 of 39 patients with asthma or chronic obstructive pulmonary disease. Goreczny, Brantley, Buss, and Waters (1988) asked adult asthma and COPD patients to record daily stress and daily ratings of asthma symptoms over a 21-day period. During high stress periods, subjects averaged more coughing, wheezing and activity limitation than low stress periods. In this study, stress and symptom ratings were both rated subjectively and may have been confounded because people who report high stress also tend to report more physical symptoms. Taken together, the above research suggests that when changes in asthma are assessed on a day to day basis, the nature of the connection between stress and asthma may be more readily examined. The first study was limited by the cross-sectional nature of the data collected. Assessing stress, symptoms, airflow and medication use on a daily basis will generate more accurate data, and allow the temporal order to be examined (e.g., does perceived stress precede, follow or occur at the same time as asthma symptoms?). The present study explores the relationship between stress and asthma several times a day over a 21-day period.

Pre-diary coping, self-efficacy, and quality of life. Specific psychological variables may identify asthmatics whose airway limitation worsens during stress. Results from the first study indicate that individual differences in coping style identified asthmatics whose symptoms and ventilatory function were associated with life stress experienced in the past year. Specifically, a task-oriented style of coping with stressful events appeared to buffer the effects of stress on asthma status and emotion and avoidant-coping appeared to be associated with asthma quality of life. In addition, the perceived level of personal control over asthma, asthma self-efficacy, was found to be directly associated with asthma quality of life and ventilatory function.

A number of hypotheses were tested in this prospective, daily diary study 1. Three-week daily perceived stress ratings will be positively associated with three week aggregated symptoms and beta-agonist bronchodilator use (BU) and negatively associated with three-week peak flow rates (PEFR). 2. Pre-diary coping, self-efficacy and asthma quality of life ratings will identify subjects for whom asthma is most responsive to daily perceived stress. 3. The correlations between daily stress and the daily asthma indicators will be higher when stress precedes, rather than follows, asthma. 4. Any clinically significant drops in peak flow or dangerous overuse of bronchodilators will be preceded by a large increase in perceived stress.

Methods

Subjects

Fifty-four patients out of a sample of 132 adult asthmatics from Study 1 agreed to participate. Their diagnosis of asthma had been confirmed by airway reversibility and methacholine challenge tests and they did not differ

significantly in terms of asthma severity at intake from an equal number of study 1 subjects who did not participate in this study. These participants were receiving appropriate medical treatment for their asthma and received the same asthma education from the clinic's respiratory therapists.

Thirty-five subjects correctly completed and returned the diaries (14 male, 21 female; ages 18-61 years, mean age 38.6 years). On a laboratory measure of ventilatory function at intake, their mean %FEV = 83.4 was not significantly different from that of 35 non-diary study subjects drawn at random from the original 132 (mean %FEV = 82.1), or from a sample of 35 non-study patients drawn at random from the clinic's database (mean %FEV = 80.9). Thus, the disease severity of this study's sample before beginning the diaries was comparable to that of other asthmatics attending this clinic.

Overview

Each participant kept a diary for a minimum of 21 consecutive days, three recordings per day (morning, afternoon and evening). Variables recorded were perceived stress, asthma symptoms, peak flow rate and beta-agonist bronchodilator use. A detailed description of each of these measures is presented below. Information on coping style, asthma self-efficacy and asthma quality of life was available from the Study 1 data set for these subjects, and the description of these measures can be found there. These questionnaires were completed and ventilatory function measures taken on the day the diary forms were provided to subjects.

Daily Diary Record Measures

Daily diary record forms provided a place for patients to record current information on perceived stress, source of stress, five asthma symptoms, and PEFR over three rating periods per day (morning, afternoon and night).

Medication use and other asthma-related adverse events were noted on a daily basis. Forms for thirty consecutive days were provided to each subject, who filled in the dates themselves. Specific instructions for each rating follows.

Perceived stress. Current level of perceived stress was rated on a 0 (completely relaxed) to 8 (complete panic) scale. If possible, the source of perceived stress was to be identified and recorded: 0 for asthma/health-related, 1 for family/interpersonal, 2 for work/career, and 3 for other. In most cases, source of stress was left blank, suggesting that pinpointing one major source of current stress was not possible.

Asthma symptoms. Each of the five cardinal asthma symptoms was rated on a 0 (not at all) to 5 (constantly/severe) scale. The five symptoms were: coughing, wheezing, shortness of breath, chest tightness, and activity limitation (day) poor sleep (night).

Peak flow rate (PEFR). Peak flow rate refers to the volume of air exhaled in one second, measured in liters per minute. Peak Flow rate is considered a good measure of changes in airflow limitation (Cross & Nelson, 1991). It is comparable to the pulmonary function laboratory measure, forced expiratory airflow volume/second, but can be assessed by patients using portable devices. PEFR was measured by Mini-Wright (tm) Peakflow meters provided to participants. Respiratory therapists instructed patients to exhale as hard as they could, in a one second burst, into the peak flow meter's mouth piece. Three consecutive readings were taken, with the highest of the three recorded on their diary form. When used properly, PEFR measurements correlate well with other spirometry measures that are more sensitive to variations in airway obstruction (Cross & Nelson, 1991). A within-subject drop of 20% of best PEFR is considered a clinically significant drop. For

example, if a subject's highest individual PEFR reading was 400, a drop to 320 would be considered a clinically significant drop in PEFR. Normalized (% predicted given each subject's age, sex, height and weight) values were also computed and used for between-subjects analyses. Mini-Wright (tm) Peak Flow Meters are considered among the most reliable portable peak flow meters.

Medication use. Daily beta-agonist bronchodilator use (BU) was recorded once a day in terms of the total number of puffs/day taken from salbutamol 100mcg inhalers. Using a rescue inhaler more than twice a week is considered evidence of a problem in asthma control (Ernst, Fitzgerald, & Spier, 1996). All subjects had received the same instruction on proper use of their bronchodilators during asthma education prior to the study.

A column to indicate any "adverse events which may effect today's ratings" was provided on the back of each day's diary record form to describe any unusual occurrence that may have affected that day's ratings (e.g., flu, allergies, cold).

Intake Questionnaire and Clinic Ventilatory Function

On the same day as they received their diary record forms, subjects completed stress and coping questionnaires along with measures of asthma-related self-efficacy and quality of life. Ventilatory function tests (forced expiratory airflow volume and forced vital capacity) were conducted the same day, before the questionnaires were completed. These measures are described in detail in Study 1.

Procedure

Subjects were first given a battery of intake questionnaires to be completed at the clinic. Ventilatory function measures were taken on the same

day. If they agreed to participate in Study 2, subjects were provided with diary record forms and Mini-Wright (tm) Peak-flow Meters. They were instructed how to complete the daily diary record form and how to use the peak flow meter properly. Completed diaries were returned to the researcher at a clinic appointment four weeks from the diary record start date.

Results

Several questions were addressed in the analyses of these data: 1) Is three-week daily stress associated with daily asthma symptoms, PEFR and bronchodilator use? 2) Are pre-diary coping, self-efficacy and quality of life measures associated with daily symptoms, PEFR and bronchodilator use? 3) Are stress-asthma associations reliable when the daily stress precedes asthma (rather than following or occurring on the same day)? 4) Are clinically significant drops in PEFR and dangerous bronchodilator overuse preceded by large increases in perceived stress? Data aggregated over the 21 days were first assessed, allowing for examination of between-subjects variation in daily perceived stress and asthma indicators. Analysis of within-subject data was then conducted in order to explore within-subject variation in stress and asthma as a function of different time periods.

Correlates of Aggregated Asthma Symptoms, PEFR and Bronchodilator Use

Participants' data were aggregated by calculating the mean stress, symptoms and PEFR scores per recording period (21 days x 3/day) and rescue medication use (21 days). Means of the aggregated data are presented in Table 1. These results suggest that most subjects in this study had adequate asthma control during the diary assessment period, having little significant variability in terms of symptoms, PEFR or bronchodilator use (see Appendix A for individual diary means). Symptoms correlated with peak flow, $r(35) = -.40$, p

< .05, and with ventilatory function %FEV, r(35) = .38, p < .05, however, not with AQL r(35) = -.23, ns. Asthma quality of life (r = .08, ns) was not associated with peak flow.

Table 1

Simple Statistics for Aggregated Daily Stress, Symptoms, PEFR, and Bronchodilator Use. n = 35, (63 observations each)

	M	sd	Range
Perceived Stress (0 to 8)	1.38	1.16	0.07 to 4.43
Asthma Symptoms (0 to 5)	0.80	0.61	0.01 to 2.28
Peak Flow Rate (liters/min)	354.96	23.45	104 to 513
Normalized Peak Flow Rate(%)	84.12	5.64	31 to 114
Bronchodilator use (puffs/day 100mcg salbutamol inhaler)	3.18	0.98	0.06 to 9.83

Daily stress. The first hypothesis, that 3-week levels of stress would be associated with asthma symptoms, PEFR, and bronchodilator use was tested with between-subject Pearson product-moment correlations (see Table 2). Stress correlated positively with symptoms, r(35) = .61, p < .001; r = .53, p <.001 with PEFR partialled. Stress correlated negatively with normalized

PEFR, $r(35) = -.35$, $p < .05$; $r = -.34$, $p < .05$ with symptoms partialled out. Thus, stress is strongly related to daily asthma symptoms, and moderately to PEFRover a 21-day period. Aggregated stress and mean bronchodilator use were not significantly correlated. Bronchodilator use was modestly, but significantly, associated with both symptoms ($r = .30$, $p < .05$) and peakflow ($r = .34$, $p < .05$). Thus, stress did not appear to be a significant determinant of rescue medication use, while symptoms and peak flow did.

Coping and self-efficacy. The second hypothesis, predicting that pre-diary measures of coping would be associated with aggregated asthma symptoms and PEFR, was tested with Pearson correlations between subjects' coping, asthma self-efficacy, asthma quality of life scores and aggregated daily symptoms and peak flow scores. Emotion coping was positively correlated with asthma symptoms. Symptoms and peak flow were not associated with any other questionnaire measure (see Table 2). Thus, people who reported more symptoms tended to be people who reacted to stress by spending their energy regulating their emotions.

Stepwise multiple regression analyses, using forward selection, were conducted to determine the independent and combined impact of selected questionnaire and diary variables. A maximum of three variables were forced into each equation. The three variables that correlated highly with symptoms were chosen. Daily stress and emotion-oriented coping together accounted for 43% of the variance in daily asthma symptoms (see Panel I, Table 3). Thus, emotion-coping, in combination with daily stress, predicted substantial variance in daily symptoms.

Table 2

Pearson Product-Moment Correlation Coefficents Between Aggregated Asthma Symptoms, PEFR and Bronchodilator Use with Daily Stress and Questionnaires (n = 35)

	Diary Stress	Pre-diary measure				
Diaries		AQL	ASE	EMO	AVOID	TASK
Symptoms	.61***	-.23	-.17	.37*	.13	.08
PEFR(%)	-.35*	.08	-.05	-.06	-.22	-.15
Bron Use	.23	.51**	-.41*	.37*	.07	-.19

Symptoms = composite for 5 asthma symptoms aggregated across all diary days. PEFR% = normalized peak expiratory airflow volume. AQL = Asthma Quality of Life, ASE = Asthma Self-Efficacy, EMO = emotion oriented coping, AVOID = avoidant oriented coping, TASK = task oriented coping. * $p < .05$, ** $p < .01$, *** $p < .001$.

To determine if there was a greater stress-symptom correlation among those with high emotion-coping, as in the first study, subjects were split at the median for emotion-coping and the stress-symptom correlations for each group were compared. The high emotion copers (n = 17) did not have a significantly greater correlation than the low copers (n = 18), both were high, $r(17) = .64$,

$r(18) = .58$. Two subjects with the highest emotion-coping scores (patient MM and GG) had extremely high individual daily stress-symptom correlation ($r = .92$ and $r = .89$).

For daily PEFR, a similar stepwise multiple regression procedure was followed (see Panel II, Table 3). The best model included daily stress, daily symptoms and daily bronchodilator use, accounting for 33% of the variance in daily PEFR. No questionnaire variable contributed significantly. Thus, diary variables were the best predictors of daily PEFR.

Daily bronchodilator use was strongly negatively associated with both asthma quality of life and asthma self-efficacy and was positively correlated with emotion-oriented coping (see Table 2). In a stepwise multiple regression, three variables: asthma quality of life, daily PEFR and asthma self-efficacy, accounted for 46% of the variance in beta-agonist bronchodilator use (see Panel III, Table 3). This suggests that bronchodilator use is well predicted by variables such as beliefs about disease severity and controllability along with a smaller contribution from peak flow.

Within-Subject Time Series Correlational Analysis

To address the third hypothesis, that stress would precede asthma exacerbations, analyses were conducted on each subject's data separately. Correlations were calculated between daily stress and indices of asthma (symptoms, PEFR and bronchodilator use) across five different time frames. For example, for each subject, day *i* asthma symptoms were correlated with stress ratings on day *i*-2, *i*-1, *i*, *i*+1, and *i*+2. Five symptom-stress correlation coefficients were calculated for each subject, as well as five peak flow-stress and five rescue medication-stress correlations. Next, the mean correlation

Table 3

Summary of Final Step Statistics for Stepwise Multiple Regressions of Aggregate Data (n=35)

I. Asthma Symptoms as dependent variable, daily stress, PEFR(%) and EMO included.

Variable	Part R-square	Std Beta	t-value	Prob t
Daily stress	.34	.61	6.77	.01
Emo-coping	.10	.13	3.32	.02

R-square = .43

II. PEFR as dependent variable; daily stress, symptoms and bronchodilator use included.

Variable	Part R-square	Std Beta	t-value	Prob t
Daily stress	.20	-.44	4.38	.01
Symptoms	.07	-.21	2.45	.04
BronUse	.06	-.18	2.19	.04

R-square = .34

III. Bronchodilator Use as dependent variable; PEFR(%), AQL and ASE included.

Variable	Part R-square	Std.Beta	t-value	Prob t
AQL	.29	-.51	5.53	.01
Daily PEFR	.09	-.26	2.69	.02
ASE	.08	- .20	2.22	.04

R-square = .46

across all subjects for each time series was computed. In each case, the strongest association between stress and each asthma indicator was found between measures taken the same day, with significantly lower correlations generally emerging when the stress and asthma indicator were separated by two days ($p < .05$), the exception being stress day *i* and symptom day *i*+2 correlations (see Table 4). Thus, in addition to being concurrently associated with stress, asthma appears to be associated with higher subsequent stress and to follow stress, but there is generally no relationship between the variables when separated by more than one day.

These results indicate that increases in daily perceived stress precede, by one day, increases in asthma symptoms, drops in PEFR and increases in bronchodilator use. While same day and following day stress-asthma associations are equally strong, the results suggests that stress does not merely follow or occur at the same time as airflow changes, but that stress also tends to precede airflow, symptom and medication use changes that occur the next day.

Analyses conducted on individual diary data explored whether incidents of significant drops in PEFR and dangerous bronchodilator overuse were preceded by large increases in perceived stress. Incidents of clinically significant drops in PEFR (defined as a decline of greater than 20% of the individual's best PEFR) and dangerously heavy bronchodilator use (12 or more puffs per day) were first identified. Sixty incidents of PEFR drops among 15 asthmatic subjects were identified. Twenty-two incidents of dangerous bronchodilator overuse among 10 asthmatics were identified. Next, perceived stress ratings around these incidents were examined. Incidents falling in one of four categories were tallied: where a significant increase in perceived stress

Table 4

Mean Within-Subject Correlations of Stress and Asthma for Five Different Time Frames (n = 35; minimum of 63 observations per subject), SPSS time-series autocorrelations.

	Perceived Stress				
	2 days before	1 day before	same day	1 day after	2 days after
	i-2	*i*-1	*i*	*i*+1	*i*+2
Symptoms	.13	.46*	.47*	.43*	.39*
PEFR (l/min)	-.12	-.34*	-.37*	-.34*	.11
Bron Use	.08	.34*	.35*	.32*	.01

i = diary day; PEFR = Peak expiratory airflow rate (liters/minute); Bron Use = number of puffs from 100mcg salbutamol inhalers; * p <.05

(defined as an increase of greater than one standard deviation from the patient's mean stress) either preceded (one day or less), followed (one day or less), occurred at the same time (includes subjects where stress may also have preceded and followed the incident), or did not occur adjacent to a perceived increase were counted.

Overall, the sample was relatively stable in terms of PEFR during the diary data collection period. However, 15 out of 35 subjects exhibited a total

of 60 clinically significant drops in PEFR. In many cases large jumps in perceived stress preceded the significant drops in PEFR. To illustrate, two of these stress-preceded PEFR drops are described. On day 18, patient M.M. reported an afternoon perceived stress score of 6, up from 1's on day 17 and on that morning (subject's mean stress = 1.05, sd = 1.3). On day 19, this subject's night PEFR dropped from 470 to 365 (this subject's best PEFR was 480 and mean PEFR during diary period was 445, sd=24). Similarly, patient P.D. reported an afternoon perceived stress of 4 on day 1, a jump from 1 that morning (subject's mean stress = 1.06, sd = 1.0), and a morning peakflow on day 2 of 175 , dropping from 325 the night before (subject's best PEFR = 340, mean during diary = 224, sd = 34). No other asthma-related adverse events (e.g., cold or allergy onset) were noted during the days in question for both subjects.

Of the total of 60 clinically significant drops in PEFR, 28 were preceded by large increases in perceived stress, or a mean of 1.87 episodes for each of the 15 patients who showed a significant peakflow drop. Three significant PEFR drops were followed by large perceived stress increases and 16 PEFR drops occurred at the same time and were both preceded and followed by large stress increases. Thirteen significant PEFR drops occurred without any stress immediately before or after perceived stress increases. These data clearly indicate that in 15 patients increases in perceived stress were associated with subsequent clinically significant increases in airflow limitation measured by PEFR. This was confirmed by an ANOVA conducted on mean significant peak flow drop per subject for different stress condition, $\underline{F}$ (3, 56) = 5.18, $\underline{p}$ <.01 (see Table 5).

With respect to bronchodilator use, 10 subjects (29%) dangerously overused their bronchodilators on a total of 22 days. Following a similar process as above, six of these days were found to be preceded by a large stress increase, 5 followed, 5 occurred on the same day and 4 were not adjacent to an increase in perceived stress. Dangerous bronchodilator overuse was not more likely to occur after high stress than the other alternatives when tested by ANOVA conducted on mean dangerous beta-agonist bronchodilator use/ subject for differnt stress condition, $\underline{F}$ (3, 17) = 0.31, ns (see Table 5).

Discussion

Analysis of the aggregated diary data found three-week stress to be strongly associated with asthma symptoms. The findings linking stress and symptoms are consistent with research suggesting people who report more stress are also likely to report more symptoms (e.g., Cohen & Herbert, 1996). However, two findings presented above imply something more is going on with asthmatic subjects. First, the magnitude of the association between stress and symptoms found in this study ($\underline{r}$ = .61) was considerably greater than those found between stress and symptom reporting in other samples (generally around $\underline{r}$ = .30). Second, the fact that daily stress was also significantly associated with airway limitation (assessed as peak flow rates) is further evidence for a specific connection between stress and asthma, rather than a general tendency to report distress.

Table 5

Summary of Clinically Significant (> 20%) Drops in Peak Flow and Dangerous Beta-agonist Bronchodilator overuse (10+ puffs/day) and Association with High Perceived Stress (60 Drops Exhibited in 15 Different Subjects; 22 Days of Dangerous Medication Overuse in 10 subjects)

	Episodes of Significantly High Perceived Stress			
	Precedes Only	Follows Only	Same day	No relation
I. Sig PEFR drops:				
Total occurences	28	3	16	13
Mean number per subject (15)	1.87**	0.20	1.07	0.86
II. Bronchodilator Overuse:				
Total occurrences	6	5	5	4
Mean number per subject (10)	0.6	0.5	0.5	0.4

PEFR = peak flow rate (litres/min) observed 3 times per day;

** $p < .01$

While peak flow scores were correlated with perceived stress, they were not related to any coping measure. In other words, observed airway limitation over the diary period could not be predicted from the intake questionnaires. The best model predicting daily peak flow included the diary stress, symptoms and bronchodilator use, implying that actual daily airflow limitation is predicted by current behaviour or symptom perception rather than stable individual differences in coping style. It was somewhat surprising that asthma quality of life was not more highly associated with peak flow as the quality of life subscales (symptoms severity, activity restriction, etc.) are seen as signs of increasing airway limitation, however this is consistent with Juniper et al. (1993) findings. The other asthma measures, diary symptoms and peak flow and clinic ventilatory function hung together as expected.

In the within-subject time series analyses, stress ratings on a given day were found to be associated with asthma symptoms, and peak flow rates the following day. This suggests that perceived stress can precede changes in asthma symptoms and airway caliber. Correlations of similar magnitude were found between both stress the same day as the symptoms, peak flow and bronchodilator use and between stress one day following the symptoms and peak flow. Further than one day removed, the stress-asthma association generally dropped off significantly. It is possible that stress immediately precedes worsening asthma and then stays high for a couple of days as the symptoms worsen and peak flow rates decline. These findings show that the subjective experiences of "feeling bad" (stressed and symptomatic) appear to cluster together, with high stress occurring around the same time as bad asthma episodes (see Northup & Weiner, 1984). Tetzlaff et al. (1994), however, suggest the picture may be more complicated and these results support their

conclusion that stress factors are not represented by "a simple relationship between psyche and asthma as time-concurrent or time-lagging coincidences to shortness of breath." (p 243).

A significant proportion (15/35) of subjects had clinically significant drops in peak flow during the diary study period. When these drops were analyzed, it was found that they were more likely to occur after a large increase in perceived stress. This strongly suggests a prospective link between significant distress and large increases in airway limitation. Possible mechanisms explaining this link include: autonomic abnormality in asthma which allows acute stress to trigger bronchoconstriction (Lemanske & Kaliner, 1990); airway inflammation resulting from immune system activity triggered by stress (Kang & Hoh, 1993); or decreased self-management during times of stress. Study 1 found evidence of a subgroup of asthmatics with symptoms and airway caliber that were responsive to stress (see also Goreczny, 1989). Additional research is required to determine more conclusively whether a distinct stress-responsive asthma subgroup exists and which mechanism or combination of mechanisms best explain their responses.

Emotion-oriented coping was associated with diary asthma symptoms, suggesting a link between ineffective coping and symptom reporting. Perhaps poor coping (such as not responding appropriately to asthma crises) makes appropriate asthma management more difficult, leading subsequently to more symptoms. An alternative explanation, that emotion-coping may simply identify individuals with more severe symptoms was not supported, in that emotion coping was not associated with peak flow. Emotion-coping may identify asthmatics with high emotionality and a tendency to report asthma symptoms even when there are no changes in airway limitation. Interestingly,

emotion-coping was also significantly correlated with bronchodilator use, implying that it plays a role in action taken in response to subjective symptoms. Emotion-coping appears to be associated with subjective symptom reporting and the health behaviour of rescue medication use, rather than simply being a marker for more severe asthma. Emotion-coping also combined with daily stress in the best model predicting daily asthma symptoms. This suggests that daily subjective assessment of asthma symptoms over three weeks may have more to do with daily perceived stress and coping than with objectively assessed airway limitation. Thus, asthma symptom reporting, but not peak flow appears to be related to both perceived stress and individual differences in emotion-oriented coping. It is possible that emotion-coping is both associated with symptom reporting (as in both the diary study and in the clinic study) and is a mediator for the effect of stress.

Rescue Medication Use

Beta-agonist bronchodilator use was associated with emotion-coping and asthma self-efficacy variables as well as asthma quality of life, diary peak flow and diary asthma symptoms. Asthma quality of life, asthma self-efficacy and emotion-oriented coping were as strongly associated with rescue medication use as were the concurrent indices of asthma severity, namely daily peak flow and asthma symptoms. Given the overall lack of variability in bronchodilator use and the comparatively modest correlations found between bronchodilator use and both daily symptoms and daily peak flow, this suggests that bronchodilator use is a habit that may be more related to beliefs about disease severity (asthma quality of life) and controllability (asthma self-efficacy) than daily experienced symptoms or peak flow. However, the model which accounted for most variance in bronchodilator use incorporated peak

flow along with asthma quality of life and asthma self-efficacy. These beliefs about asthma severity may interact with observed airway limitation to determine bronchodilator use. Asthma education programs may increase appropriate bronchodilator use by addressing patients' beliefs about disease severity and controllability.

There was little within-subject variability in beta-agonist bronchodilator use. Subjects who used high levels of beta-agonist bronchodilators continued to do so throughout the diary period. Pre-diary asthma quality of life, asthma self-efficacy and emotion-coping were associated with rescue medication use, most noticeably among the heavy users.

A number of incidents of potentially dangerous overuse of bronchodilator medication were recorded. Large increases in perceived stress during the diary period were not found to precede these incidents more frequently than otherwise. Recalling that diary measures did not predict bronchodilator use as well as pre-diary measures of asthma self-efficacy and asthma quality of life, it appears that medication use is a habit determined by factors other than recent experiences. Effects of preceding stress on bronchodilator use may have been minimized due to their side effects. Bronchodilator overuse can have many unpleasant side effects (increased heart rate, dizziness, tremulousness), these may have resulted in elevated stress ratings the same day or the day after the bronchodilator overuse, thus evening up observed frequencies.

Methodological Advances and Limitations

This study allowed aspects of asthma health behavior and both subjective and objective indices of asthma severity to be monitored over time. As such, it was an improvement over past attempts to study stress and asthma

which relied upon retrospective reports (Northup & Weiner, 1984). The patients in this study were all well-screened, to include only those who were clearly asthmatic. Some previous research did not adequately distinguish between asthmatics and those with other respiratory diseases such as COPD (e.g., Goreczny, 1989). In addition, measuring stress, symptoms, peak flow and medication use on a daily basis ought to be much more accurate than relying on retrospective self-reports or data from a single clinic visit.

Peak flow ratings are responsive to variables such as effort during exhalation. While the taught method of recording the highest of three consecutive peak flow ratings should minimize peak flow variance due to effort, it is possible that level of effort provided by the subjects influenced their peak flow scores (Nelson, 1995). This effort might have decreased during times when they were feeling "bad" (stressed and/or symptomatic).

The asthmatics in this study were fairly stable and well-controlled. They were all being medically treated in accordance with the latest treatment guidelines and had received asthma education. While these characteristics helped ensure that treatment received and information provided to them about their illness did not have significant effects on study findings, the fact that this was a well-treated, knowledgeable group of asthmatic subjects may limit the generalizability of the results. It is likely that the asthmatics who at the greatest risk of mortality or longterm morbidity are not regular attendees of asthma clinics but have more in common with Osman's (1997) chaotic self-managers - perhaps going to the ER when there is a crisis but not following a regimen of regular care and disease management. Although it may be difficult, accessing these asthmatics and studying why they make decisions would be useful.

The lack of variability in asthma symptoms and airflow limitation, possibly a result of being well-controlled, may have limited the power of some of the analyses. Some important relationships may have been overlooked due to the lack of variance among some subjects during the 21-day period. Future research using larger samples of less well-controlled, unstable asthmatics, studied for longer periods of time, may advance understanding of stress and asthma relationships further.

Programmatic Link to Study 3 - Laboratory Experiment

The diary study provided further evidence for some aspects of the proposed relationship between stress, individual differences and asthma control. It also provided further evidence for the existence of a stress responsive sub-group of asthmatics. The final step of this program of research involved bringing these asthmatic subjects into a laboratory setting and continously monitoring autonomic and airflow reactivity during exposure to a number of experimentally manipulated stressors (and one relaxation condition). The laboratory study explored questions concerning: 1) the effect of different stressors (e.g., active, passive and asthma-related) on airflow and autonomic reactivity; 2) the role of autonomic reactivity in stress-triggered bronchoconstriction; and 3) whether coping and self-efficacy variables can identify asthmatics with the greatest autonomic and airflow reactivity to the laboratory stressors.

Psychophysiological reactivity of asthmatics to laboratory stressors: Stress type, autonomic responses and airflow changes

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Preliminary data from this study are to be presented at the 2000 American Thoracic Society/American Lung Association International Conference.

Abstract

The role of stress-triggered autonomic reactivity in asthma exacerbation is unclear. A laboratory-based experimental study of adult asthmatics was conducted. 31 adult asthmatic subjects completed coping and asthma self-efficacy questionnaires and were exposed to five experimental conditions: baseline, active stressor (math test), passive stressor (cold immersion), asthma-related stressor (crisis recall and interview) and relaxation (progressive muscle relaxation). Physiological variables assessed included: airflow (forced expiratory airflow volume in one second in litres/minute), vagal (parasympathetic) tone, galvanic skin response (GSR). The passive and asthma-related stressor condition, as well as the relaxation condition were associated with a significant decrease in airflow from baseline. In addition, the passive stressor and relaxation condition were associated with a significant increase in vagal (parasympathetic) tone, while the active stressor condition was associated with a significant increase in GSR (sympathetic tone). Coping style was not associated with airflow or autonomic reactivity. Asthma self-efficacy was associated with vagal (parasympathetic) reactivity. Results provide support for the role of parasympathetic mediation in stress-triggered asthma. In addition, they suggest that different types of stressors may impact differently on autonomic functioning and airflow in asthmatics and that self-efficacy may identify asthmatics with greater levels of parasympathetic reactivity to stress.

Keywords: asthma, stress, peak flow, autonomic, vagal tone, GSR, coping, self-efficacy.

PSYCHOPHYSIOLOGICAL REACTIVITY OF ASTHMATICS TO LABORATORY STRESSORS: STRESS TYPE, AUTONOMIC RESPONSES AND AIRFLOW CHANGES

As described in earlier chapters, psychological stressors may impact on asthma in a number of ways (Busse, Kiecolt-Glaser, Coe, Martin, Weiss, & Parker, 1995; Lehrer, Isenberg, & Hochron, 1993; National Heart, Lung & Blood Institute, 1998; Wright et al., 1998). Of particular interest to this study is the research suggesting that bronchospasm may be triggered directly by acute stress. Unlike non-asthmatics, whose airways dilate when exposed to acute stressors, it appears as though some asthmatics may have an underlying autonomic abnormality such that acute stress results in bronchoconstriction rather bronchodilation (Porges, 1995). Stress can have a significant impact on asthma symptoms, asthma quality of life and medication use; however, the psychophysiological mechanisms that account for these relationships are not yet well understood.

The present study examines autonomic reactivity, particularly parasympathetic and cholinergic activation, and bronchial tone during controlled laboratory stressors. The goals of this laboratory study are to examine: 1) the effect of different stressors (namely, active, passive and asthma-related) on airflow and autonomic reactivity; 2) the role of autonomic (particularly parasympathetic) reactivity in stress-triggered bronchoconstriction; and 3) whether coping and self-efficacy variables can identify asthmatics with the greatest autonomic and airflow reactivity to the laboratory conditions.

Rationale for Experimental Conditions

The first goal of this laboratory study is to assess the effect of different stressors (e.g., active, passive and asthma-related) on airflow and autonomic reactivity. As described in the Introduction, stress may impact on asthma due to stress-mediated parasympathetic reactivity. The question of abnormality of autonomic control of the airways is unanswered (Kotses, 1998). Different types of stressors may impact on autonomic reactivity and airflow differently. In particular, an active stressor that requires the subject to actively face a challenge may be associated with sympathetic arousal and different physiological reactions than passive stressors that are associated with parasympathetic reactivity and bronchoconstriction. In this study, both active and passive experimental stressor conditions were used. In addition, a third, asthma-related, stressor was devised in order to test whether a disease-specific stressor impacted differently than the other stressors. Finally, a relaxation condition provided the opportunity to compare the effects of stressors to the effects of relaxation on autonomic reactivity and airflow in asthma.

A baseline measurement condition was required as a comparison point for airway and autonomic changes triggered by the four experimental conditions. An active stressor, math test, was predicted to not be associated with a decrease in airflow or an increase in vagal tone. Mental arithmetic tasks have been used as laboratory stressors in previous airflow change experiments. Mathé and Knapp (1971) found that the performance of mental arithmetic reduced air flow in asthma patients. They also found that mental arithmetic combined with criticism of errors further reduced air flow in asthmatics (Mathé & Knapp, 1971). Conversely, this math task has also been found to be a potent

elicitor of blood pressure increases mediated primarily by beta-adrenergic myocardial responses, and may therefore be associated with bronchodilation. Sympathetic arousal is a usual response to active stressors among non-asthmatics and it was predicted that laboratory measures of sympathetic nervous system (SNS) activity would increase during the math test.

A passive stressor may demonstrate effects of an environmental demand where an active response cannot alleviate the demand. The cold immersion task is a well-established potent stimulus causing increases in blood pressure. There is evidence of elevated alpha-adrenergic reactivity in asthma (Weiss, 1999). Therefore, it was expected that an inescapable physical stressor would be likely to trigger both increased vagal tone and decreased airflow. Finally, an asthma-related stressor may have more ecological validity than more traditional laboratory stressors in that it involves the recalling of an actual life event involving asthma. It was predicted that this task would be associated with decreased airflow and increased vagal (parasympathetic) tone.

In addition to the stress conditions, a progressive muscle relaxation (PMR) condition is of interest in this study. PMR is one of the most common psychotherapeutic procedures today and has been used with asthma patients (Kotses, 1998). Studies on the effects of progressive muscle relaxation in asthmatics have yielded inconclusive and sometimes contradictory results. Freedberg et al. (1987) found an increase in peak expiratory flow rate after progressive muscle relaxation, whereas Erskine and Schonell (1979) found no such change in air flow. Lehrer (1999) reports that relaxation is associated with reduced airflow in the short term. It is predicted that relaxation would be associated with an increase in parasympathetic reactivity and a decrease in airflow. Due to the expected effects of respiration on HRV (e.g., Giardino,

Lehrer, & Hochron, 1999) a progressive muscle relaxation task will be used rather than a relaxation task, such as paced diaphragmatic breathing which would directly effect respiration.

Both Lehrer and his colleagues and Miller and Wood conduct laboratory research on asthmatics which monitors airflow changes and autonomic reactivity measured by cardiac vagal tone (e.g., Lehrer, 1997; Miller & Wood, 1997). These studies have found that increased vagal tone is associated with reduced airflow. This study is innovative in a number of important ways: it creates a number of different stressful laboratory situations in order to assess the effects of different types of stressors (passive, active and asthma-related) on asthmatic autonomic reactivity and airways and it assesses the role that coping and self-efficacy may play in autonomic and airflow reactivity to stress among asthmatics.

Stress, Asthma, and Autonomic Function

The second goal of this study is to examine the role of autonomic reactivity in stress-triggered bronchoconstriction. Asthma is characterised by an inability to maintain normal airway tone. This inability to maintain normal airway tone may be caused, in part, by underlying autonomic dysfunction (Busse, Kiecolt-Glaser, Coe, Martin, Weiss & Parker, 1995; Lemanske & Kaliner, 1990; Porges, 1995). Normal airway caliber is dependent on both autonomic nervous system branches: the parasympathetic and sympathetic nervous system (Szentivanyi et al., 1988) and involves both cholinergic and adrenergic mechanisms. Bronchomotor tone may be largely determined by cholinergic influences arising from parasympathetic vagal activity. Electrical stimulation of vagal efferents to the lungs results in the release of acetylcholine and immediate bronchoconstriction. Adrenergic mechanisms play an

important role in control of airways smooth muscle. However, whereas beta-sympathetic activity is associated with bronchodilation, increased alpha-sympathetic activity is believed to indirectly increase airway resistance by activating pressure sensors (baroreceptors) in the carotid artery and aortic arch. These communicate directly with autonomic centres in the hypothalamus, and reflexively increase parasympathetic activity.

Explanations for stress-triggered bronchoconstriction have been proposed that emphasize abnormalities of the autonomic control of airways smooth muscle (e.g., Lehrer et al., 1993). A number of theories have been proposed which focus on abnormalities of autonomic control of airways smooth muscle. These theories have suggested either an increase in parasympathetic activation, an increase in alpha-sympathetic activation or a decrease in beta-sympathetic function as the source of autonomic abnormalities in asthma. Asthma research has focused mainly on alpha-sympathetic activation and parasympathetic activation of the airway (Lehrer et al., 1993). Increased alpha-sympathetic activation and increased parasympathetic tone, via the vagus nerve, produce increased tone in the smooth muscles of the lung and subsequent bronchoconstriction (Kaliner et al., 1971; Nadel & Barnes, 1984). Bronchomotor tone appears to be largely determined by cholinergic influences arising from parasympathetic vagal activity (Nadel, 1980). Alpha-sympathetic arousal causes bronchoconstriction by reflexively increasing parasympathetic activity through increased blood pressure and "activation of baroreceptors in the carotid artery and aortic arch... [which] communicate directly with autonomic centers in the hypothalamus" (Jewett, 1964).

Research findings suggest that increases in vagal activity produce disproportionate constriction of larger, more proximal airways (Nadel et al.,

1971). Interestingly, asthmatics with obstruction primarily in upper airways may be more likely to have attacks triggered by emotional stress (Isenberg et al., 1992). These studies suggest that stress-triggered increases in vagal activity may be associated with bronchoconstriction.

Coping, self-efficacy and autonomic and airway reactivity

The third goal of this study is to find out whether coping and self-efficacy variables can identify asthmatics with the greatest autonomic and airflow reactivity to the laboratory stressors. Laboratory research on stress and asthma has suggested that there is a subgroup of approximately 35-40% of asthmatics who have symptoms that are highly responsive to stress. Recall that Nouwen et al. (1994) showed that exposure to an acute laboratory stressor produced bronchoconstriction in 35% of an adult asthmatic sample. Isenberg, Lehrer and Hochron (1992) conclude that the proportion of asthmatics exhibiting bronchoconstriction when exposed to acute stress or suggestion averages 35-40%, but that a more conservative interpretation of their data may put this figure lower. Thus, the possibility exists that there is a significant subgroup of asthmatics who experience stress-mediated bronchoconstriction. Carr (1998) notes that there is evidence that asthmatics who show the greatest autonomic reactivity also show the greatest airway reactivity in response to psychological stress (e.g., such as being told they are inhaling a potent bronchoconstrictor).

It is possible that the relationship between stress and asthma may be mediated by a number factors. The first study in this research program found that task-coping appeared to buffer the effects of life event stress on asthma quality of life. The same study also found significant stress-ventilatory function correlations for those asthmatics who reported low task, high emotion

and high avoidant-oriented coping strategies, suggesting that there is a sub-group of asthmatics who may be particularly vulnerable to the effects of stress. The diary study found that self-efficacy and coping was associated with beta-agonist bronchodilator use and that there was a significant subgroup of the diary sample who exhibited clinically significant drops in air flow preceded by high perceived stress. Both suggest a stress-responsive asthmatic subgroup. This study tests the extent to which coping and self-efficacy identify asthmatics with the greatest autonomic and airflow reactivity to different stressors and relaxation.

Hypotheses

It was hypothesized that reduced airflow and increased vagal tone would result from the passive stressor and asthma-related stressor experimental conditions. Reduced airflow was expected to be associated with an increase in vagal (parasympathetic) tone during the tasks. It was predicted that the active stressor would not result in reduced airflow and that it would be associated with an increase in sympathetic tone (as measured by GSR). It was predicted that blood pressure and negative mood would increase during all the stressors. The relaxation condition was expected to be associated with an increase vagal (parasympathetic) tone and a decrease in airflow. Ineffective coping and low asthma self-efficacy were expected to be associated with stress-triggered reduction in airflow and with parasympathetic reactivity.

Methods

Subjects

Subjects were drawn from 132 adult asthmatics who participated in Study 1. The airway hyperresponsivity of these participants was confirmed during screening for the first study. Participants had previously consented to

be contacted by researchers as part of follow-up to the initial studies. They were told that they could withdraw from the study at any time and that their decision to participate in the study would have no bearing on the medical treatment they received. Participants were asked to refrain from the use of bronchodilator medication, caffeine and nicotine six hours prior to participation. They were paid $20 for participating in the study.

It was determined that risks posed by the laboratory stressors were slight, as they were stressors that people encounter in everyday life (math, cold, talking about a distressing episode). However, an emergency action plan was in place in case of any serious asthma exacerbation. Relaxation and debriefing were expected to reduce any mild discomfort experienced during the experiment. Fast-acting bronchodilator medication was available for participants who had been prescribed such medication for as-needed use, if they chose to, after the experiment was over. Subjects for whom peak flow rates were significantly lower than expected were directed to contact the asthma clinic during the debriefing. The experiment received full approval from the McGill University Department of Psychology Ethics Committee.

Forty-two asthmatics from the clinic study sample agreed to participate after being informed of the experimental requirements. Thirty-seven showed up for their appointment at the Department of Psychology. Data from three subjects were not used because of equipment failure during the experiment. Two subjects chose to withdraw during the study, and interpretable signals could not be generated for one subject. A total of thirty-one subjects completed the experimental protocol and generated usable data. These subjects did not differ significantly in terms of %FEV at last clinic visit than that of an equal number of patients drawn randomly from the clinic's database or from an

equal number of study 1 participants. 16 subjects participated in all three subjects.

Procedure

Subjects participated in the following sequence: 1) information and signing of informed consent forms, 2) completion of coping and asthma self-efficacy questionnaires (see Study 1 for complete description), 3) instrumentation (for blood pressure, ECG and GSR), 4) Baseline assessment, 5) Stressor condition 1, 6) Stressor condition 2, 7) Stressor condition 3, 8) Relaxation condition, 9) De-briefing. The stressor conditions -- cold immersion, math task and asthma-recall -- were counterbalanced to eliminate order effects (i.e., three different orders were used).

Baseline. After being connected to instruments, the subjects were asked to sit quietly for ten minutes. Physiological measures, including respiratory sinus arrhythmia and GSR, were measured at baseline and continually throughout the experiment. These values were averaged to obtain baseline autonomic values. During the last five minutes of this rest period, blood pressure and peak flow measurements were taken. Forced expiratory airflow volume in one second (FEV1) was measured immediately after baseline, after each stressful task and after relaxation. Immediately following baseline assessment and each task, the subjects rated a self-report affect scale rating feelings of anger, anxiety, upset, irritation, happiness, and depression on a Likert-type scale. Instructions for all tasks were presented immediately prior to each task.

Following baseline assessment the stressor tasks were presented in a counterbalanced order and the autonomic and other data collected in a similar manner. Each experimental condition was followed by a 10-minute recovery

period. Autonomic measurements were recorded each minute of the stressor period and these values were averaged over the task period. Three peak flow readings were taken immediately after each experimental condition.

Cold Immersion Test. Subjects immersed one hand in a container of approximately four degrees Celsius water for four minutes. Since most individuals are unable to tolerate four minutes of continuous cold, the subject's hands were immersed for two, two-minute periods, separated by a one- minute rest period. Subjects placed the arm not instrumented by the blood pressure cuff in a plastic container with ice water at a consistent temperature. Autonomic measurements were averaged over the 4 immersion minutes of the task.

Asthma Crisis Recall Interview. This task was eight minutes in duration and required subjects to recall an upsetting asthma-related incident from their past. The subjects were first requested to think of the situation for four minutes while breathing through a medium gage drinking straw, which was designed to simulate asthma-like sensations. Following the straw-breathing, subjects were asked to describe the scenario, their emotions, and the outcome of the event. In recalling the event, the subjects were encouraged to imagine themselves in the situation and to re-experience the emotions involved. Autonomic measurements were averaged over each four-minute period (four minutes preparation and four minutes interview).

Active Stressor: Mental Arithmetic. A computerized mental arithmetic task consisting of mathematical subtraction equations was used in this condition. Subtraction equations were presented on a computer monitor with either a correct or incorrect solution. Programmed into the computer were 10 series of problems at 10 levels of difficulty. Each problem was presented for 3

seconds, and the subjects responded by computer mouse indicating whether the correct response had been displayed on the monitor (left click for incorrect, right click for correct). Equations became more difficult or easier depending on the performance of each subject, and the task was designed so that each subject attained a 50 to 60 percent correct response rate. Subjects were informed that if their score did not reach an unspecified criterion, they would receive an electric shock to the arm. This maximized the novelty, engagement, and uncertainty in the task. No shocks were actually delivered and subjects were fully debriefed following the experiment.

Relaxation. After the three stress sessions, a ten-minute session of Progressive Muscle Relaxation (Barlow, 1995; Jacobson, 1938) ends the experiment. An audio cassette containing a 10-minute standard progressive muscle relaxation was played, via headphones, to the subjects. Taped instructions ask the subjects to systematically tense, hold the tension, then relax specific muscle groups.

Measures

Questionnaires provided prior to the experiment were: 1) Asthma Quality of Life Questionnaire (Juniper, Guyatt, Epstein, Ferrie, Jaeschke, & Hiller, 1992), 2) Coping Inventory for Stressful Situations (Endler & Parker, 1990), 3) the Asthma Self-Efficacy Scale (Tobin et al., 1978). (See full Study 1 descriptions).

In addition, at baseline, after each stress task, and after relaxation, a self-report affect scale rating feelings of anger, anxiety, upset, irritation, happiness, and depression were completed. Ratings were made by striking a 10-cm straight line between labelled endpoints (e.g., very happy and not happy at all).

Apparatus

Physiological measures were assessed continuously at baseline, during each stress task, and during relaxation.

Vagal (parasympathetic) tone (in units) were derived using spectral analysis of heart rate variability to assess different aspects of cardiac autonomic activity. Measurements of heart rate (in beats per minute) were derived from an electrocardiogram recorded using disposable electrodes. The electrodes were placed on either side of the lower rib cage and on the left hipbone. The signal was amplified and a continuous record of cardiac interbeat interval was measured using a Delta Biometrics Vagal-Tone Monitor-II and averaged over 30 seconds. The VTM-II yielded measurements of vagal tone (in log units) derived from spectral analysis of heart rate. Heart rate variability associated with breathing or "respiratory sinus arrhythmia" is a well-established index of vagal tone (Porges, 1995; Turner, 1994). The VTM-II evaluates respiratory sinus arrhythmia for adults by quantifying heart rate variability in the 0.12 to 0.40 Hz frequency band (see Appendix B for further discussion of the measurement of cardiac vagal tone and parasympathetic reactivity).

Skin conductance (GSR - sympathetic tone) readings (in μS) were obtained using a Grass DC amplifier, the computer and large Beckman electrodes attached to the first phalanges of the subject's non-dominant index and second fingers. The computer used Dataq CODAS software and sample blood volume pulse and skin conductance at 10 Hz. GSR is a sensitive and pure measure of SNS activity.

Systolic and diastolic blood pressure (in mmHg) was measured using a Critikon Dinamap 845XT automatic blood pressure monitor. Systolic and diastolic blood pressure (in mmHG) were obtained using a Critikon Dinamap

845XT automatic blood pressure monitor. The blood pressure cuff was placed on the subjects non-dominant arm. Continuous measurements of an index of vascular constriction, blood volume pulse amplitude (in units) will be obtained using a Grass Model PPS photoplethysmograph attached to the first phalange of the subject's non-dominant third finger. The signal was amplified by another Grass Model 7P4 amplifier and transmitted to the computer.

Airflow. Mini-Wright(tm) Peak-Flow meters were used to measure forced expiratory airflow volume in one second (PEFR). Peak flow measurement allows the airway limitation in asthma to be assessed. These portable meters measure airflow with acceptable accuracy. The highest value of three consecutive forceful exhalations is recorded each time peak flow is recorded.

Physiological Data Reduction

Physiological data were reduced in the following manner. Data were collected for the last four minutes of the baseline and relaxation periods. Data were also collected throughout each stressful task. A mean value was then calculated for each time period, for each physiological measure. This resulted in mean values of vagal tone, GSR, systolic, diastolic and mean arterial blood pressure for baseline, each of the three stressful tasks, and the relaxation condition.

Results

Twenty-two females and nine males successfully completed this experiment. The average age of participants was thirty-five years, with the youngest aged nineteen and the oldest aged sixty-seven. Subject physical characteristic data are described in Table 1. This subsample was similar to the larger Study 1 sample in terms of mean ventilatory function (%FEV) at last

clinic visit and %PEFR in the diary sample. Asthma quality of life, coping and self-efficacy questionnaire results were also similar (see Table 1).

Table 1

Simple Statistics for Subject Physical and Questionnaire Variables (n = 31; 22 females, 9 males)

	Mean	Range	Standard Deviation
Age (years)	35.13	19 to 67	15.37
Height (inches)	65.70	58.25 to 70.75	3.57
Weight (pounds)	164.35	92.80 to 253.00	39.55
M.A.P. (baseline)	85.16	70.00 to 109.00	9.74
PEFR% (baseline)	87.89	38.82 to 120.29	7.56
AQL	4.90	3.06 to 6.56	0.84
ASE	286.38	159.00 to 363.00	57.14
Task-coping	52.96	18.00 to 71.00	11.71
Emotion-coping	41.76	20.00 to 72.00	10.88
Avoidant-coping	37.97	16.00 to 37.00	10.93

M.A.P. = Mean Arterial Pressure (in mmHg), PEFR% = normalized peak airflow rate, AQL = Asthma Quality of Life, ASE = Asthma Self-Efficacy

As would be expected, gender was associated with both peak flow and blood pressure (males in the study having significantly higher mean arterial pressures and peak flow than the females). Gender was also associated with GSR and mean arterial pressure reactivity, suggesting that males experienced

greater sympathetic response to the experimental conditions than the females in the study. Gender was not associated with sympathetic or parasympathetic (vagal) reactivity. Data for males and females were combined for the study analyses. Also as would be expected, age was associated with peak flow, blood pressure and heart rate; ventilatory function declined with increasing age and mean blood pressure and heart rate increased with age. Age was also associated with ASE ($r = -.30$, $p<.05$), similar to the full Study 1 sample. The same association was found between asthma quality of life and asthma self-efficacy ($r = .45$; $p < .05$) in the laboratory sample as in the clinic sample. Asthma self-efficacy was also positively correlated with task-oriented coping ($r = .40$; $p<.05$).

Descriptive statistics were calculated for the variables of central interest to this study: peak flow, vagal tone and GSR (see Table 2).

Repeated measures ANOVAs

Repeated measures analysis of variance (ANOVA)s were conducted on the physiological measures. There were no stress task order effects on airflow, parasympathetic or sympathetic reactivity. To test the first hypothesis, namely that airflow would decrease after the passive stressor, asthma related stressor and relaxation, a one-way repeated-measure ANOVA on peak expiratory flow rate revealed that experimental condition had a significant effect on air flow, $F(4, 120) = 18.76$; $p<.01$ (see Table 2). Planned comparisons revealed significant drops in air flow, as compared to baseline, after the cold immersion task ($t(30) = 4.36$; $p < .01$), asthma recall ($t(30) = 2.56$; $p <.05$) and the relaxation exercise ($t(30) = 4.14$; $df = 30$; $p < .01$) as predicted. No significant differences in peak expiratory flow rate were found between the baseline(M=430.32) and mental arithmetic task (M=439.84) (see Figure 2).

Table 2

Peak Flow, Vagal Tone, GSR by Laboratory Condition (n = 31)

	Peak Flow (l/ min)			Vagal tone (log units)			GSR (μS)		
	M	range	SD	M	range	SD	M	range	SD
Condition									
Baseline	430.3	180-690	114.6	6.53	0.8-9.5	1.70	7.51	4-11	1.9
Cold	402.7	180-640	110.9	6.87	2.6-9.5	1.49	5.05	1-11	1.5
Recall	413.9	190-655	116.2	6.47	1.2-8.6	1.55	6.95	1-11	1.7
Math	439.8	240-660	110.4	5.79	1.6-7.9	1.40	9.62	3-15	2.1
Relax	404.5	200-630	112.1	7.15	2.9-7.9	1.42	5.13	1-11	1.5

Table 3

Repeated Measures Analysis of Peak Expiratory Flow Rate (PEFR)

Source	SS	df	MS	F	p
Exp. cond.	32863.55	4	8215.89	18.76	<.0001
Error	52556.45	120	437.97		

Note: Exp. cond. = experimental conditions include baseline, cold immersion, asthma recall, math test, and relaxation

To test the hypothesis that vagal tone would increase in certain conditions, a one-way repeated-measures ANOVA was computed which indicated that condition had a significant effect on vagal tone, F (4,120) = 27.06; $p < .001$ (see Table 3 and Figure 1). Planned comparisons between condition means were computed and revealed that, as predicted, vagal tone was significantly higher than baseline during both the cold immersion task ($t(30) = 2.39$; $p < .05$) and relaxation ($t(30) = 5.93$; $p < .01$). Furthermore, vagal tone during the math task was significantly lower than baseline ($t(30) = 5.07$; $p < .01$). However, there were no significant differences in vagal tone between the asthma recall stress condition ($M = 6.47$) and baseline ($M = 6.53$). A similar analysis of between-condition differences in GSR found that condition had a significant effect on GSR, F (4,120) = 35.12, $p < .0001$. Planned comparisons found that mean GSR during the math task (M=9.62) was significantly higher than baseline ($t(30) = 6.33$; $p < .01$) and markedly higher than all other conditions.

Table 4

Repeated Measures Analysis of Variance for Vagal Tone and GSR

	Source	SS	df	MS	F	p
Vagal Tone:	Exp cond.	3222.19	4	805.15	27.06	<.0001
	Error	3573.45	120	30.24		
GSR:	Exp. cond.	4672.57	4	1168.32	35.12	<.0001
	Error	4903.33	120	41.14		

Figure 1 - Vagal Tone as a Function of Stress Task

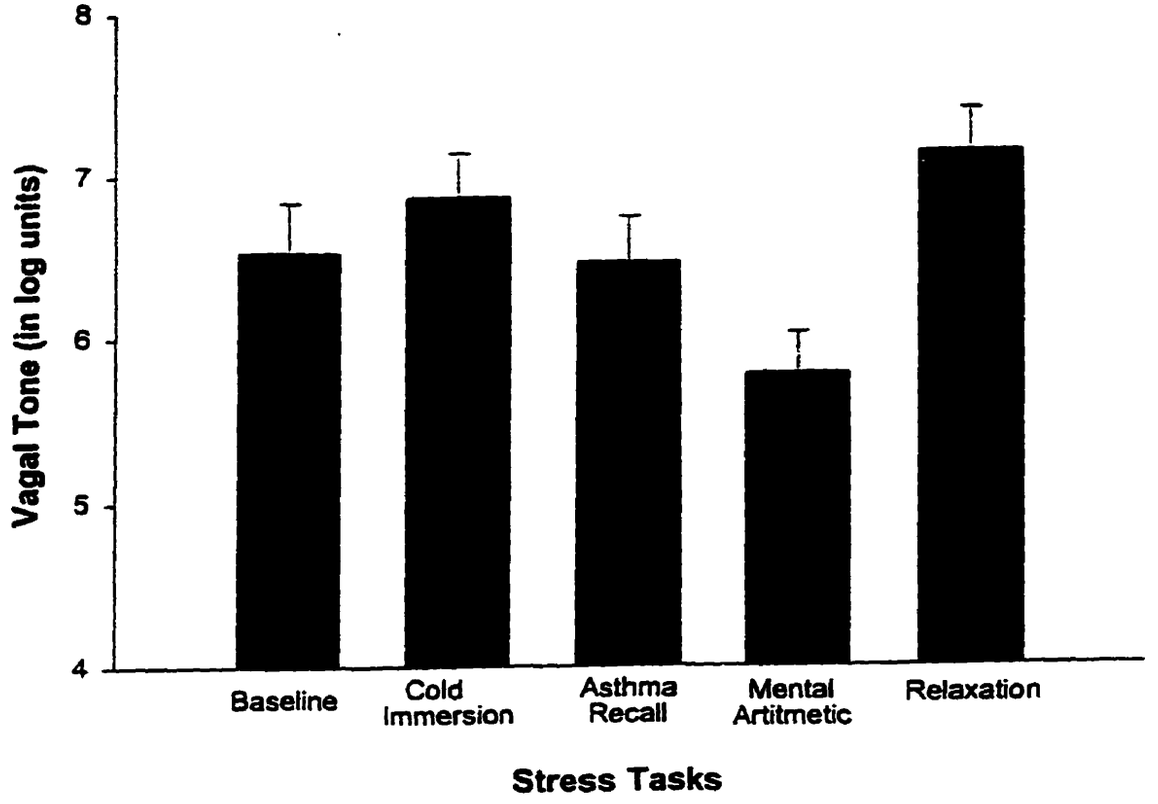
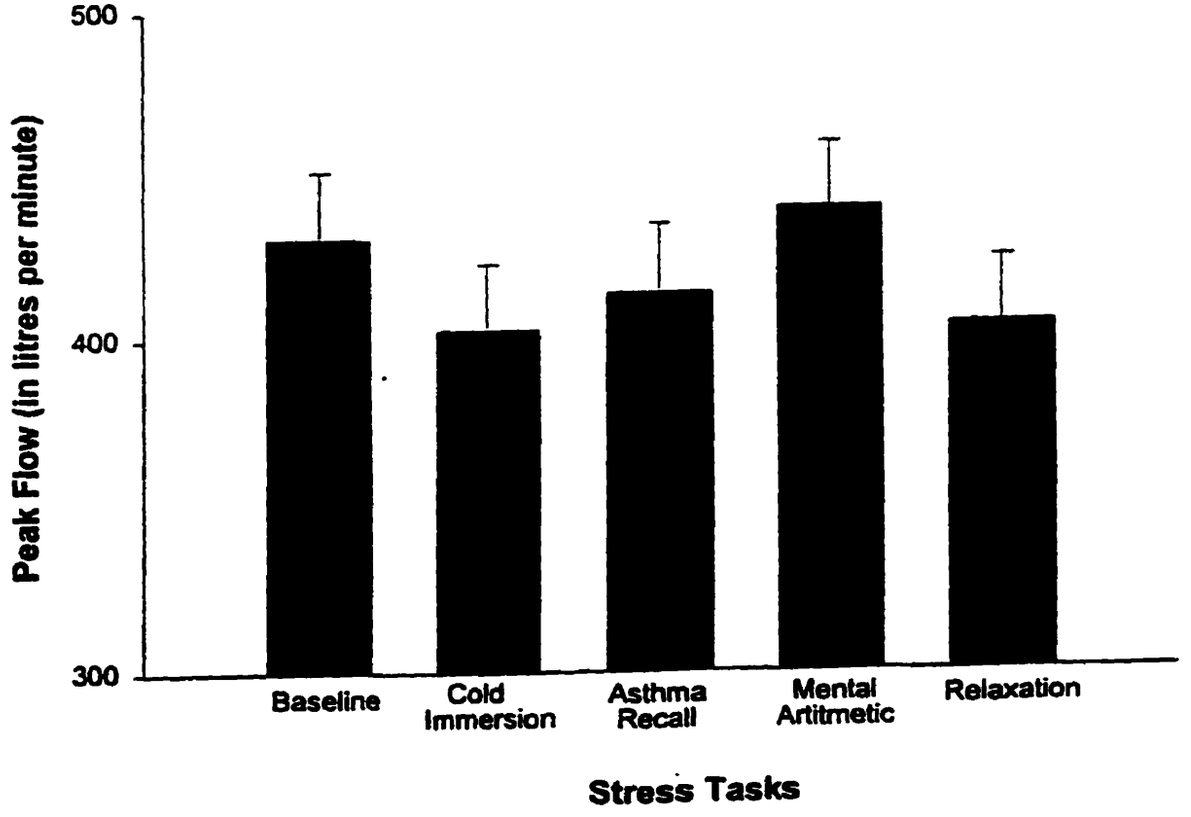


Figure 2 - Peak Flow as a Function of Stress Task



With respect to blood pressure, the same pattern of results was found for both systolic and diastolic blood pressure, under each experimental condition. Therefore, mean arterial pressure was an appropriate shorthand method of reporting blood pressure. A repeated-measures ANOVA indicated that condition had a significant effect on mean arterial pressure, F (4, 116) = 76.23; $p < .001$ (see Table 4). Planned comparisons found that there were significant increases in mean arterial pressure, as compared to baseline, during the cold immersion task ($t(29) = 12.82$; $p < .01$), asthma recall task ($t(30) = 10.96$; $p < .01$) and mental arithmetic ($t(29) = 7.99$; $p < .01$). There were no significant differences in mean arterial pressure between the baseline period ($M = 85.16$) and the relaxation exercise ($M = 86.81$). The largest increase in blood pressure was found in the cold immersion condition.

Table 5

Repeated Measures Analysis of Mean Arterial Pressure (MAP)

Source	SS	df	MS	F	p
Exp. cond.	11389.43	4	2847.36	76.23	<.0001
Error	4332.97	116	37.35		

Note: Exp. cond = experimental condition: baseline, cold immersion, asthma recall, math test, and relaxation

Similar results were found in the post-condition mood reporting after the tasks using one-way ANOVAs assessing mean differences by experimental condition. Level of negative emotions (e.g., annoyance, anger, irritation) reported were significantly higher after the cold immersion task than during baseline or the other conditions. In addition, the positive mood rating for "relaxed" was highest after the relaxation task, as would be expected.

Within-subject correlations across conditions

Within-subject correlations of vagal tone and peak expiratory flow rate across conditions were computed. These within-subject correlations ranged from -.94 to .41. The average correlation between measures of these two variables was -.52 (SD = 0.36). After conducting a Fishers transformation, this correlation was found to be significantly different from zero ($t(30) = 7.96$; $p < .01$). Within-subject correlations across conditions were also conducted for the other variables and mean correlations computed. Peak flow ratings were also positively associated with physiological measures linked to sympathetic arousal: heart rate (mean $r = .34$), mean arterial pressure (mean $r = .37$) and GSR (mean $r = .39$). These correlations were not planned a priori and were significant when corrected for multiple comparisons.

A multiple regression analysis conducted with peak flow as the dependent variable and vagal tone, GSR and mean arterial pressure forced into the equation found that vagal tone, GSR and mean arterial pressure accounted for 42% of the variance in peak flow ($R^2 = .42$, $p < .05$) with vagal tone accounting for most of the variance in peak flow (part $R^2 = .33$).

Table 6

Mean Change Scores by Condition from Baseline for Peakflow, Vagal Tone, and GSR

	Laboratory Condition			
Measure	Math	Cold	Asthma	Relax
Peak Flow (l/min)	+9.5	-27.6	-16.4	-25.8
Vagal Tone (log units)	-0.74	+0.35	-0.06	+0.62
GSR (log units)	+2.08	-2.36	-0.56	-2.38

GSR = Galvanic Skin response (sympathetic reactivity).

Correlates of PEFR, GSR and Vagal tone change scores

The final hypothesis predicted that condition-triggered airway and autonomic reactivity would be associated with coping and self-efficacy variables. To test this hypothesis, change (from baseline), of peak flow, vagal tone and GSR were calculated for each condition (see Table 6).

Pre-experiment questionnaire scores were then correlated with absolute values of these change scores. As noted in Table 7, asthma self-efficacy was strongly associated with mean vagal tone changes from baseline for all four experimental conditions. These results suggest that asthma self-efficacy is strongly related to parasympathetic reactivity to stress in adult asthmatics. However, these results provide no evidence for any association between the other questionnaire measures with observed laboratory airflow or autonomic reactivity (see Table 7).

Table 7

Correlations of Questionnaire and Lab Variable Change Scores, Planned A-priori (n = 31) with Bonferroni Adjustment

	Pre-experiment Questionnaires				
	ASE	AQL	Task Coping	Emotion Coping	Avoidant Coping
Peak Flow Change					
Mean r	.01	-.11	.11	-.14	.22
GSR Change					
Mean r	.07	.08	.03	.01	-.20
Vagal Tone Change					
Mean r	-.50*	-.24	-.22	.07	-.22

*p < .05, with Bonferroni adjustment

Discussion

This study had three specific goals: 1) assess the effect of different types of stressors (e.g., active, passive and asthma-related) on airflow and autonomic reactivity; 2) explore the role of autonomic reactivity in stress-

triggered bronchoconstriction; and 3) determine whether coping and self-efficacy variables can identify asthmatics with the greatest autonomic and airflow reactivity to the laboratory stressors. Results of this laboratory study suggest that significant airflow changes in asthma can be triggered by a passive, physical stressor, an asthma-related stressor, or by progressive muscle relaxation. In addition, the results suggest that these airflow drops may be mediated by changes in autonomic activity, specifically increases in vagal tone (as seen the relaxation and passive stressor task

This study's results provide support for the role of parasympathetic reactivity in stress-triggered asthma. Increased galvanic skin response is present when stress does not result in bronchoconstriction (active stressor). Pre-experiment coping and self-efficacy were not associated with task-triggered airflow changes. However, asthma self-efficacy was strongly associated with vagal tone changes in all tasks, suggesting that low asthma self-efficacy may identify asthmatics with greater parasympathetic reactivity to stress.

Asthma self-efficacy was strongly associated with parasympathetic reactivity. Interestingly, however, asthma self-efficacy was not associated with short-term airflow reactivity. This appears to be somewhat at odds with Study 1 findings where it was associated with clinic ventilatory function. It seems likely that asthma self-efficacy is related to appropriate asthma self-management that contributes to asthma control (and higher ventilatory function). If this is the case, explaining the correlation between asthma self-efficacy and laboratory vagal reactivity may be more difficult. It has been suggested that variable response to acute challenges may have different implications for disease expression (Pike, Smith, Hauger et al., 1997). Furthermore, Nolan (1999) suggests caution about interpreting vagal tone autonomic reactivity as autonomic activity. Perhaps asthmatics with low self-efficacy react poorly to stress but this translates to indirect effects on asthma, seen over the long term (see Study 1), rather than direct, immediate, effects on

airflow. Low asthma self-efficacy may be a consequence of high parasympathetic reactivity to stress. Heightened parasympathetic reactivity may make asthma management more difficult, resulting in lowered perceived asthma controllability. In short, this result suggests another reason why asthma self-efficacy may identify at-risk asthmatics.

As predicted, the cold immersion task resulted in a significant decrease in air flow as compared to baseline. It was also associated with a drop in sympathetic (GSR) and an increase in blood pressure. However, the fact that cold immersion was also associated with an increase in vagal tone suggests that parasympathetic, rather than alpha-sympathetic, activity accounts for the impact of this stressor on airflow.

The relaxation task resulted in a similar pattern: a drop in peak flow with a corresponding increase in vagal tone. The acute effects of relaxation may be parasympathetically-mediated bronchoconstriction (Lehrer et al., 1997). It is possible that relaxation methods may be effective for asthmatics in the long-term (i.e., after multiple sessions) rather than in the short-term for highly anxious or panicky asthmatics.

The active stressor did not result in a decreased airflow, in fact there appeared to be an increase in airflow (which did not reach significance as it was not a planned prediction). Active stressors may result in bronchodilation among asthmatics due to their effects on sympathetic arousal. The role of autonomic reactivity as a mediator of stress-related airflow changes was supported as vagal tone appeared to decrease and GSR (sympathetic tone) exhibited a dramatic increase in this condition. Taken together, these results suggest that active problem solving, as in the math test, may be a more beneficial response to stressors than would relaxation.

In the asthma recall task, significant drops in airflow from baseline were not accompanied by any significant differences in vagal tone. The drop in airflow resultant after imagining a stressful asthma-related experience is consistent with previous research (Thorn & Fisher, 1978); however, this study does not suggest a vagally mediated mechanism between the imagination of aversive stimulation and airflow. Further research needs to be conducted to determine the mechanism of action in situations where imagination of aversive stimulation leads to reductions in airflow.

This experiment provides support for the prediction that parasympathetic mechanisms are important in stress-related bronchoconstriction. However, limitations of this present study include the sample size which limited power in the analyses. In addition, the fact that all participants were regular attendees of an asthma clinic may limit the generalizability of findings. Future research with larger samples of less well-controlled and compliant asthmatics is required to determine whether the results generated from this sample can be generalized to all asthmatics.

While statistically significant, it could be argued that the airflow changes found in this study may not be clinically significant. However, it should be noted that the same degree of bronchoconstriction will result in vastly different reduction in airflow depending on the initial state of the airways (resistance to airflow in the airways is related inversely to the fourth power of the radius) (Kotses, 1998). A stimulus that minimally affects resistance to airflow when the airways are open may affect airflow profoundly when the airways are obstructed. Thus small, but statistically significant, changes in airflow, as were demonstrated in the present study, may be of clinical importance to asthmatics.

None of the pre-experiment questionnaire results were associated with the airflow changes. Dales, Ernst, Hanley, Battista, and Becklake (1987) found that questionnaire information is not adequate for discriminating between those with and those without increased airway reactivity. It is possible that questionnaires may not be able to predict adequately the small acute changes in airflow as was triggered by three of the experimental conditions.

The finding that asthma self-efficacy was associated with parasympathetic (vagal tone - RSA) reactivity may have implications for asthma treatment. Lehrer et al. (1997) found a decrease in respiratory impedance in a group of asthmatic patients using respiratory sinus arrhythmia (RSA) biofeedback. Biofeedback may be used to help relax facial muscles and thereby reduce vagal activity which is associated with bronchoconstriction. Creer (1991) notes that relaxation used with biofeedback can result in significant improvements in pulmonary function in some patients, effects comparable to the effects achieved with their medications. Lehrer, Hochron, McCann, Swartzman, and Reba (1986) found that relaxation therapy shows greater effect on measures of parasympathetic reactivity than on measures of tonic levels of parasympathetic activity. It is possible that, as was found in this study, low asthma self-efficacy may identify asthmatics who have greatest vagal reactivity and who may benefit most from interventions such as vagal tone biofeedback.

These results have many implications for future psychophysiological asthma research. The results suggest autonomic abnormalities in asthma. However, abnormalities in the autonomic control of airways' smooth muscle may not be limited to asthma; they may be present in other lung diseases (CF, emphysema, chronic bronchitis). It is also possible that any observed

autonomic abnormality may be the result of drugs used to treat asthma. A study assessing autonomic reactivity to different stressors with non-asthmatic controls (both healthy and non-asthma chronic and chronic respiratory illness) would help to answer this important question.

In conclusion, this study provided evidence that airflow decreases in asthma could be triggered by acute stressors and that the nature of the stressor may be important in determining the physiological response. Evidence that vagal (parasympathetic) tone mediated bronchoconstriction in some conditions was generated as was evidence that low self-efficacy appears to identify asthmatics with greater event-related parasympathetic reactivity.

General Discussion: Research Program Synthesis, Limitations and Implications

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GENERAL DISCUSSION: SYNTHESIS, LIMITATIONS AND IMPLICATIONS

Asthma remains a growing problem despite recent advances in its medical treatment and in patient education. This program of research comprised original attempts to explore links between stress-related psychological variables and asthma control. This program made a number of important theoretical and methodological advances. It has contributed findings that help explain both how one poorly understood asthmatic trigger, stress, impacts on asthma symptoms and ventilatory function and how psychological variables such as coping style and self-efficacy may mediate the effects of stress or how they may effect asthma control directly. Specifically, advances were made in the understanding of how stress impacts on asthma control, for which asthmatics, and under what conditions.

This research program has provided evidence that stress plays a role in asthma status, daily symptom expression, and that certain types of stressors can have acute effects on airways. In addition, the results of the studies suggest why these relationships exist and what may account for individual differences in stress-responsiveness among asthmatics. As noted by Tetzlaff et al. (1994) the relationship between stress and asthma may be complicated and may not be represented by simple, linear relationships. This is likely due to the fact that there is tremendous variability in how both asthma and stress are experienced. There is considerable heterogeneity among asthmatics in terms of type of symptoms experienced, underlying pathophysiology (e.g., bronchoconstriction versus inflammation) and triggers. Similarly, there is great variability in experiences of stress, in terms of: 1) the events different individuals are exposed to; and 2) how they react psychologically and

physiologically to the events. By assessing stress and asthma in different ways and by exploring both individual difference and psychophysiological reactivity variables that may be related to stress responsiveness, this research advanced understanding of these complex issues.

Taken together, this program of research made a significant methodological advance by studying stress and asthma in three different modalities, cross-sectionally at clinic intake, longitudinally in the diaries and experimentally in the laboratory. This allowed results from different stress and assessment methods to be compared. In addition, subjects were closely screened at intake to ensure a pure asthma sample. On a theoretical level, assessing the effects of the psychological variables coping style and asthma self-efficacy on the stress-asthma relationship at each level was innovative.

In the first study, a hospital clinic-based study of the relationship between life event stress, coping style, asthma self-efficacy upon asthma quality of life and ventilatory function, a number of important methodological and conceptual advances were made. Both subjective and objective indices of asthma status were used and all subjects were carefully screened for airway hyperreactivity, a methodological advance over previous work in this area. Coping appeared to buffer the effect of stress on asthma, while self-efficacy appeared to effect asthma status directly. Evidence for a stress-responsive asthmatic subgroup identified by poor coping was found.

The first study provided support for the idea that stress, in this case life event stress, impacts on perceptions of symptom severity (asthma quality of life). However, there was no evidence that life event stress was associated with ventilatory function. Study 1 also provided strong evidence that self-efficacy was associated with both subjective assessment of asthma symptoms (asthma

quality of life) in addition to ventilatory function. Coping variables were found to be associated with subjective assessment of asthma quality of life, providing support for the model, but were not found to be associated with ventilatory function. In terms of buffering the effect of life event stress on asthma, as predicted, coping, especially task coping, appeared to reduce the impact of life event stress on asthma quality of life and ventilatory function while asthma self-efficacy appeared to only have direct effects on asthma quality of life and ventilatory function. Future research with a non-clinic asthma sample would provide evidence for the generalizability of the research program's findings.

In a second study, a prospective daily diary study assessing perceived stress, peak flow (a portable objective index of airway limitation) and beta-agonist bronchodilator ("rescue") medication use was conducted. Aggregated daily stress-asthma symptom association was higher than the life stress-asthma quality of life association found in the first study. Prospectively examining stress-asthma links and their relationship to self-management behaviour of medication was an innovation. Further evidence for a stress-responsive asthma subgroup was found as perceived stress preceded clinically significant drops in peak flow in some diary study participants

The diary study suggests that daily bronchodilator use may be a habit that has more to do with general beliefs about disease severity (AQL) and controllability (ASE) than actual daily asthma symptoms or daily PEFR. Rescue medication use appeared to be more associated with pre-diary asthma quality of life and self-efficacy than diary measures. Addressing patients' beliefs about symptom control and medication may increase appropriate bronchodilator use and effective self-management. This suggests that asthma

education interventions should target the beliefs associated with habitual health behaviors like inhaler use. It may not be sufficient for lasting behaviour change to simply instruct an asthmatic on what to do, finding out what they are actually doing and why they are doing it may be required in many cases. Self-efficacy and coping appear to play a role in asthma management and outcome. Providing tools to asthmatics - such as clear asthma action plans - may make effective problem-focused responses to asthma crises more likely. Interventions designed to increase asthma self-efficacy, such as rigorous self-monitoring during a first course of inhaled corticosteroid treatment may be extremely beneficial. Asthma self-efficacy may change as a result of keeping track of the improvements during early treatment.

In terms of the predictions tested, the daily diary study results provided evidence that daily perceived stress and asthma symptoms were related. Diary perceived stress was strongly associated with diary asthma symptoms and significantly associated with diary peak flow. Although the diary sample size was smaller than the clinic study sample, the thrice daily ratings are likely far more accurate than the one time retrospective reports of life stress and asthma symptoms generated by the clinic study. Questionnaire coping and self-efficacy variables were generally not associated with diary symptoms or peak flow, with the exception of emotion-coping which was negatively associated with diary symptom reporting. Regarding determinants of self-management behaviour, no support for the prediction that perceived stress would impact on medication use was generated. However, strong evidence for the influence of pre-diary asthma self-efficacy, asthma quality of life and emotion-coping on daily beta-agonist bronchodilator use was provided. Time-series analysis provides some support for predictions that small fluctuations in daily perceived

stress precede drops in airflow, symptom reporting and beta-agonist bronchodilator use. Additional support for the stress-asthma predictions came from analysis of antecedents of the clinically significant diary peak flow drops which found that high perceived stress preceded these drops more often than the other possibilities.

The diary study suggests that there is a subgroup of asthmatics who have important increases in airway limitation preceded by high stress. This also appeared to be the case with the entire clinic study sample. These findings suggest that identifying these asthmatics and providing specialized asthma education or interventions such as stress management may help such asthmatic patients attain adequate asthma control.

In the third study, possible mechanisms for stress triggered bronchoconstriction were explored. The effect of different types of stressors and relaxation were tested in a laboratory experiment where exposure to stressors were controlled and a variety of important indices of sympathetic and parasympathetic nervous system function were assessed. In particular, pure measures of sympathetic nervous system reaction (skin conductance) and of parasympathetic activity (vagal tone) had not been previously continuously measured while exposing asthmatics to different types stress and to relaxation. This study provided evidence for a distinctive pattern of autonomic responses to certain stressors in a subgroup of asthmatics.

In terms of the predictions made, the laboratory study provides strong experimental support for the effects of certain types of stressful situations (a physical stressor where only passive coping was possible, and an asthma-related stressor) as triggers for decreased airflow in asthmatics. Another stressor, the math task, did not result in reduction of airflow. This suggests

that stress-asthma effects are complicated, with some types of stressors more likely to affect ventilatory function and others not. Further research with different types of experimental stressors is warranted.

The laboratory study results suggested that parasympathetic reactivity may be one factor that accounts for asthmatic airflow reduction during stress. It is possible that other physiological differences, such as site of airway obstruction, may also be associated with airflow responsiveness to stress observed among some asthmatics. There may be significant differences in the response to stress between non-allergic and allergic asthmatics. It is possible that for the intrinsic asthmatics, emotional stress may be both the acute trigger and the factor which causes the airway hyperresponsiveness. Other possible distinguishing features of stress-triggered asthma may be HPA hyporesponsiveness (see Introduction) or site of airway obstruction (e.g., large vs. small airways obstruction). Future stress and asthma studies should be conducted that explore the possible role of these factors in determining psychophysiological asthma responses to stress.

The laboratory study also provided empirical support for the components of the model dealing with stress-triggered autonomic reactivity. The passive and asthma-related stressors were associated with significant increases in vagal (parasympathetic) tone while the active stressor was associated with increases in galvanic skin response (sympathetic tone). This provides empirical support for the prediction that stressors impact on autonomic reactivity in asthma. The pre-experiment coping and self-efficacy measures were not associated with changes in airflow during the laboratory tasks. However, asthma self-efficacy was strongly associated with changes in vagal tone (parasympathetic reactivity), providing strong support for the

prediction that self-efficacy plays an important role in determining asthmatics physiological responses to stressors. This result may explain findings from the clinic study which suggested that asthma self-efficacy impacted on asthma status and ventilatory function directly, while coping variables did not. Future research looking at these variables and their impact on other aspects of asthmatic health behaviour (e.g., peak flow self-monitoring, trigger avoidance) may be warranted.

This research program does have certain unavoidable limitations. First, the generalizability of research program findings may be somewhat limited. All subjects were generally well-controlled regular attendees of one hospital-based asthma clinic. Second, the power of the diary and laboratory study analyses were limited by the available sample size. Conducting similar studies at other sites with a larger, more diverse asthma sample (such as non-compliant asthmatics who manage their illness with crisis ER visits) may improve generalizability of findings. The role of variables that could not be assessed in this research program, such as specific asthma-related immune function, should also be assessed in future stress and asthma studies.

A number clinical implications can be drawn from this research program's findings. Given the observed relationship between the stress-related variables and asthma indices, it may be useful for asthma clinics to assess psychosocial stress, coping style and especially asthma self-efficacy just as they routinely assess allergic triggers. In terms of asthma self-management behaviour, the diary study results suggest that beliefs about disease severity and controllability play a very important role in determining actual rescue medication use. Stress management or intensive asthma education may be beneficial for asthmatics identified as at-risk based upon their life stress,

coping style or asthma self-efficacy profile. Furthermore, treatments targeting parasympathetic reactivity (such as RSA biofeedback) may be worth exploring, especially for asthmatics with low asthma self-efficacy.

In summation, some predictions suggesting that stress and asthma connections are mediated by coping, self-efficacy or parasympathetic reactivity were supported by the results of the studies in the research program. In particular, asthma self-efficacy appears to be play an important role in determining asthma quality life, ventilatory function and parasympathetic reactivity to experimentally manipulated stressors. As discussed above, the findings of these studies have important theoretical and methodological implications for the study of psychophysiological aspects of asthma and may have useful clinical implications for asthma treatment and education. However, there are a number of possible mechanisms that may explain observed connections between stress and asthma and additional research is required to replicate and futher explain some of this research program's more intriguing findings and to further assess the interactive effects between stress-related psychological variables and asthma control.

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Appendices

Appendix A: Study 2 Individual Diary Record Simple Statistics (minimum of 63 observations for each diary subject).

	PEFR				Symptoms		Stress		Bron use	
DyS	l/min		%		0-5		0-8		0-14	
	M	sd	M	sd	M	sd	M	sd	M	sd
01	445	24	94	5	0.83	.90	1.05	1.3	2.12	.75
02	224	33	42	11	0.06	.01	1.06	1.0	1.95	.51
03	469	20	98	3	0.87	.75	2.68	1.7	3.10	1.2
04	410	24	93	4	0.29	.56	0.29	0.6	3.86	1.3
05	435	10	84	2	0.40	.67	0.08	0.3	2.0	1.6
06	513	9	101	1	0.02	.12	0.07	0.2	3.8	1.2
07	280	23	72	8	0.84	.82	4.43	1.4	3.9	1.6
08	482	44	78	9	0.41	.45	1.02	1.2	3.05	.97
09	280	22	55	10	1.54	.90	2.14	0.6	9.83	1.5
10	336	20	49	8	1.30	1.1	3.46	1.0	2.25	.84
11	104	26	31	22	2.28	1.3	1.59	.95	6.78	2.08
12	321	45	53	12	1.48	1.1	1.17	1.9	.1	.30
13	457	25	89	6	0.04	.03	0.24	.35	.06	.20
14	349	38	71	9	0.05	.05	0.11	.21	2.08	.40
15	305	22	80	5	0.85	.19	2.58	.80	.61	1.07
16	421	17	99	4	0.61	.22	2.54	1.0	1.42	1.02
17	423	28	93	7	0.20	.11	0.36	.55	1.86	.62
18	339	23	80	5	1.09	1.2	2.83	1.4	3.7	1.12
19	366	19	92	3	2.23	.56	2.36	1.2	2.8	1.1
20	301	28	77	10	0.48	.90	0.36	.69	1.8	2.76
21	396	30	84	7	0.01	.07	0.12	.38	.07	.41

22	360	12	78	4	0.95	.51	1.00	.00	3.25	1.65
23	200	26	55	11	0.65	.82	2.44	1.8	3.3	1.27
24	426	18	83	4	0.01	.06	0.07	.36	.09	.45
25	330	8	85	2	1.80	.28	2.48	.51	4.0	0.00
26	255	12	56	5	1.69	.65	3.53	.75	6.16	.82
27	321	31	69	8	0.05	.10	0.08	.30	.08	.28
28	485	17	114	3	0.86	.41	0.15	.45	.26	.45
29	433	25	70	6	1.47	.73	1.49	.55	5.9	.44
30	327	21	58	9	0.42	.48	1.33	1.3	1.5	.59
31	192	30	48	13	0.66	.68	0.42	.66	3.15	.75
32	431	29	90	7	0.71	.56	1.51	.83	4.5	2.3
33	296	39	56	10	0.13	.48	1.83	1.4	3.46	1.2
34	381	17	75	6	0.85	.11	2.09	1.2	2.45	1.1
35	394	33	89	9	1.41	.55	1.08	.49	1.23	.32

Appendix B

Laboratory study vagal tone as a measure of parasympathetic reactivity

Behaviorally induced parasympathetic reactivity can be assessed by changes in respiratory sinus arrhythmia (RSA). RSA is the cyclical variation in cardiac interbeat interval that rises and falls in synchrony with breathing. Changes in vagus nerve activity are proportionately reflected by changes in amplitude of RSA and are thought to reflect the level of central vagal tone (Porges, 1995). By quantifying the amplitude of RSA, it is possible to assess the tonic and phasic regulation of the vagal pathways originating in the nucleus ambiguus. This method is based on the ability to monitor accurately the outflow of the branch of the vagus (the tenth cranial nerve) that regulates the chronotropic control of the heart. The brainstem regulation of heart rate via the vagus (vagal tone) has been proposed as an index of homeostasis (Porges, 1995). Procedures that depress homeostatic processes (such as environmental demands posed by stressors) should result in depressed vagal tone. Chronically depressed vagal tone would reflect poor homeostasis and vulnerability to stress.

There are cyclical rhythms in normal heart rate. Heart rate variability (HRV) is experimentally defined as variability in the time interval between successive R waves (spikes associated with ventricular contraction - the beat) in an electrocardiogram signal. The baroreceptors and vagus nerve are primary mechanisms that regulate HRV. HRV is an index of continuous adjustment in the balance of sympatho-vagal influence on the heart. It can be measured by the standard deviation of normal intervals between the R waves, by measuring the square root of variance for all R-R intervals; it reflects all of

the cyclic components responsible for variability in heart rate. Low frequency bands (e.g., .04Hz to .15 Hz) can be interpreted as measures of sympathetic and parasympathetic tone. However, it should be noted that HRV measures fluctuations in autonomic regulation not the level of autonomic input (Nolan, 1999). Heart rate variability is measured by deriving R-R intervals from QRS complexes. Inter-beat intervals which differ >20% should be excluded and the sampling period should be ten times the length of the slowest wave. Patterns of stress reactivity may be derived as follows: one pattern would include active coping, problem solving (such as during a arithmetic stressor) and cardiovascular features such as increased blood pressure (BP), lowered vagal tone, increased beta-adrenergic response and vaso- and bronchodilation. An alternative pattern would involve aversive vigilance (relevant to passive stressors such as cold immersion), inhibitory coping, passive avoidance and cardiovascular features such as increased vagal tone, increased alpha-adrenergic response, vasoconstriction (Nolan, 1999) and bronchoconstriction .

Medullary structures continuously monitor peripheral autonomic state and regulate vagal efferent outflow to the sinoatrial node of the heart. A medullary structure known as the nucleus ambiguus contains the primary source nuclei for the branch of the vagus that regulates heart rate via the sinoatrial node. The activity of efferent fibers in this branch fire with a frequency similar to breathing frequency and produce a respiratory rhythm in the heart rate. As the vagal activity through this pathway increases, there is a parallel increase in heart rate changes associated with respiratory frequencies. This pattern is known as respiratory sinus arrhythmia (RSA) and is characterized by an increase in heart rate (observed usually during inspiration) and a decrease in heart rate (observed usually during expiration). Thus, the

amplitude of RSA provides a validated and easily obtainable index of parasympathetic tone via the cardiac vagus (Turner, 1996)