

Quantifying asthma symptoms in adults: The Lara Asthma Symptom Scale

Pamela Runge Wood, MD,^a Brad Smith, PhD,^b Louise O'Donnell, PhD,^{a,c} Autumn Dawn Galbreath, MD, MBA,^{d,e} Marielena Lara, MD, MPH,^f Emma Forkner, RN, MS,^b and Jay I. Peters, MD^d *San Antonio, Tex, and Santa Monica, Calif*

Background: Accurate assessment of asthma symptoms is critical in research and clinical settings. A multidimensional asthma control questionnaire could provide more accurate information about asthma symptoms than global assessments, which often overestimate asthma control.

Objective: We sought to evaluate the efficacy of the Lara Asthma Symptom Scale (LASS) in adults with persistent asthma.

Methods: Participants were 18 to 64 years of age with persistent asthma. Data were collected at baseline, 6 months, and 12 months. We described the construct and predictive validity of the LASS by comparing it with measures of pulmonary function (FEV₁), asthma-specific quality of life (Juniper's Asthma Quality of Life Questionnaire [AQLQ]), and health care use (emergency department [ED] visits and hospitalizations).

Results: Three hundred eighty-three participants provided baseline data. The LASS had high internal consistency reliability (Cronbach $\alpha = .84$). LASS scores correlated significantly with baseline measures of FEV₁ ($-0.20, P = .0002$), AQLQ ($-0.68, P < .0001$), ED visits ($0.17, P = .002$), and hospitalizations ($0.15, P = .008$). Baseline LASS scores were associated significantly with ED visits ($P = .03$) and hospitalizations ($P = .04$) over the subsequent 12 months. Change in LASS scores over time correlated significantly with changes in FEV₁ ($-0.22, P = .001$) and AQLQ ($-0.70, P < .001$).

Conclusions: The LASS demonstrated good internal consistency, excellent validity based on concurrent criterion validity and longitudinal predictive validity, and good discriminatory properties in a heterogeneous sample of adults with persistent asthma.

Clinical implications: This study validates a simple multidimensional asthma questionnaire as a clinical tool in the assessment of asthma control in adults. (*J Allergy Clin Immunol* 2007;120:1368-72.)

Key words: Health status indicators, asthma symptoms, quality of life, Hispanic Americans, psychometrics, severity of illness index, questionnaire, asthma, outcome assessment

The 2006 Global Initiative for Asthma guidelines emphasize the importance of optimizing asthma control based on objective assessment of asthma symptoms.¹ The symptoms of many patients with asthma are not well controlled.^{2,3} Both patients and their physicians tend to overestimate the level of asthma control.^{4,5} A good asthma control assessment tool can provide more specific information about asthma symptoms and in turn help guide medical management.

Several questionnaires have been developed to measure asthma control: the Asthma Control Test (ACT),^{6,7} the Asthma Control Questionnaire (ACQ),⁸ the Asthma Therapy Assessment Questionnaire,^{9,10} the Lara Asthma Symptom Scale (LASS),¹¹ and the Pediatric Asthma Control Tool (PACT).¹² Although most are short and designed to be used in either research or clinical settings, few data are available on use in underserved populations. The optimal instrument for clinical practice demonstrates excellent reliability and validity, is brief and easy to administer and score, and is appropriate for use with diverse populations of both adults and children.

The LASS is an 8-item questionnaire that was developed to measure control of child asthma symptoms. A previous study with parents of Latino children with asthma showed good reliability and validity.¹¹ The purpose of this study is to evaluate the reliability and concurrent and predictive validity of the LASS in a large heterogeneous population of adults with persistent asthma.

METHODS

Participants

Data for this study were obtained from the baseline and follow-up evaluations of adult participants in the South Texas Asthma Management Project, a large, single-center, prospective, randomized controlled trial of disease management interventions to improve clinical asthma outcomes.¹³ The institutional review boards of all participating institutions approved this study. All participants signed a written informed consent form. Adult participants were between 18 and 64 years of age with a physician diagnosis of asthma and

From the Departments of ^aPediatrics, ^cPsychiatry, and ^dMedicine, University of Texas Health Science Center at San Antonio; ^bthe Altarum Institute, San Antonio; ^ethe Texas Transplant Institute, San Antonio; and ^fRand Health, Santa Monica, Calif.

Supported by the US Department of Health and Human Services (DHHS), the Office of Minority Health (OMH), grants no. D52MP03114-01-0 and D52MP03114-02-0, and the Centers for Disease Control and Prevention (CDC), grant no. R01 EH000095-01.

Disclosure of potential conflict of interest: M. Lara is employed by Rand Corporation. J. I. Peters has received grant support from the National Institutes of Health and Centocor and is on the speakers' bureau for Merck, GlaxoSmithKline, Boehringer Ingelheim, and Pfizer. The rest of the authors have declared that they have no conflict of interest.

Received for publication June 14, 2007; revised September 6, 2007; accepted for publication September 17, 2007.

Available online November 5, 2007

Reprint requests: Pamela R. Wood, MD, Department Pediatrics, UTHSCSA (MS7808), 7703 Floyd Curl Dr, San Antonio, TX 78229-3900. E-mail: woodp@uthscsa.edu.

0091-6749/\$32.00

© 2007 American Academy of Allergy, Asthma & Immunology

doi:10.1016/j.jaci.2007.09.025

Abbreviations used

ACQ: Asthma Control Questionnaire
ACT: Asthma Control Test
AQLQ: Juniper's Asthma Quality of Life Questionnaire
ED: Emergency department
LASS: Lara Asthma Symptom Scale

evidence of active disease based on recent health care use, regular use of inhaled β_2 -agonists, or a physician's diagnosis of moderate-to-severe persistent asthma. At enrollment, participants were randomized to one of 3 groups: traditional care, telephonic disease management, or telephonic disease management augmented with in-home visits. Each participant completed a baseline evaluation, followed by study visits at 6 and 12 months.

Procedure

At each study visit, a physician or nurse practitioner administered an intake questionnaire, which included the Lara symptom questionnaire and questions about self-reported prior health care use, asthma care, and asthma symptoms. Based on this information, the study physician categorized the level of asthma severity according to National Heart, Lung, and Blood Institute (NHLBI) criteria.¹⁴ A trained research nurse or research assistant then asked about the patient's current medication regimen, performed pulmonary function testing, and administered the Juniper Asthma Quality of Life Questionnaire (AQLQ).^{15,16} All questionnaires were interviewer administered.

Data sources

LASS. This 8-item questionnaire was tested previously in low-literacy Spanish- and English-speaking pediatric populations and found to be reliable and valid in both languages.¹¹ Individual items assess cough, wheezing, shortness of breath, asthma attacks, chest pain, nighttime symptoms, and overall perceived severity of asthma by using a 5-point scale (eg, "never," "a few days," "some days," "most days," and "every day"). Total scores range from 8 to 40, with higher scores representing more severe asthma symptoms. To tailor the questionnaire for use with adults, we changed the referent from "your child" to "you" (see Table E1 in the Online Repository at www.jacionline.org).

AQLQ. The AQLQ is a 32-item questionnaire that measures quality of life for adults with asthma in 4 domains (symptoms, emotions, exposure to environmental stimuli, and activity limitation).^{15,16,17} Each item is rated on a 7-point scale; total score is calculated as the mean score from all the items (1 = maximal impairment, 7 = no impairment). The AQLQ has strong evaluative and discriminative measurement properties and has been used successfully in clinical trials.¹⁸

Pulmonary function studies. Trained study personnel performed pulmonary function studies with a KoKo Portable Spirometer (Pulmonary Data Services, Inc, Louisville, Colo). Study participants were asked to withhold all asthma medications for 4 hours before testing. The best expiratory effort was selected by using American Thoracic Society criteria.¹⁹ Subjects self-administered 2 puffs of albuterol by means of metered-dose inhaler and were retested for postbronchodilator response. Predicted values were computed by using the National Health and Nutrition Examination Survey III criteria.²⁰

Health care use. Respondents were queried about self-reported health care use at baseline and at each follow-up study visit. In addition, we collected comprehensive health care use data verified by

reviews of electronic hospital records, documents received from physicians, and clinic charts.

Independent assessment of asthma severity. An independent assessment of asthma severity was available for participants in the 2 intervention groups. Based only on information obtained from the participant during the first intervention telephone call, the National Jewish disease manager recorded an independent assessment of the level of asthma severity based on the NHLBI guidelines.¹⁴

Statistical methods

Because of the small number of subjects who spoke only Spanish, analyses were limited to English-speaking participants. We used descriptive statistics to characterize the study population and the distribution of responses to individual questionnaire items. All statistical tests are 2-tailed. All analyses were performed with the SAS statistical software package version 9.1.3 (SAS Institute, Cary, NC) or STATA 9 (StataCorp, College Station, Tex). We calculated internal consistency by using the Cronbach α value. We examined the factor structure of the LASS by using exploratory factor analysis. We used Pearson correlations and ANOVA to compare baseline LASS scores with other measures of health (asthma quality of life, asthma severity level, pulmonary function studies, and health care use). We used ANOVA and negative binomial regression to compare changes in LASS scores over 12 months with changes in other health measures. All longitudinal analyses were adjusted for study group membership. Analyses of rates of health care use over the 12-month study period also were adjusted for number of months the subject was actually enrolled.

RESULTS

We enrolled 429 adults, of whom 383 (89%) spoke English as their primary language. Three hundred seventy-five had complete LASS data at baseline and verified asthma health care use data ($n = 224$ had valid questionnaire data at both baseline and 12 months). At baseline, subjects who failed to complete the 12-month questionnaires were similar to completers in symptom score, severity, health care use, quality of life, and most demographic variables. Noncompleters were younger (mean age, 39 vs 45 years; $P < .0001$), were less likely to use inhaled corticosteroids (62% vs 73%, $P = .02$), were more likely to be exposed to smoke at home (45% vs 31%, $P = .008$), were more likely to be uninsured (23% vs 10%, $P < .001$), and had slightly lower FEV₁/forced vital capacity ratios (75% vs 78%, $P = .05$) compared with completers. As noted in Table I, our sample was ethnically and socioeconomically diverse. By using NHLBI criteria, 22% of participants had mild intermittent or mild persistent, 24% had moderate persistent, and 28% had severe persistent asthma, as determined by study physicians. See Galbreath et al¹³ for further details about the study population at enrollment.

The mean LASS total score was 23.8 (SD, 6.7; range, 8–39). Individual items demonstrated acceptable variability (Table II). The reliability estimate (Cronbach α) was .84, suggesting good internal consistency.

Validity

Construct validity. Baseline LASS scores correlated significantly with measures of pulmonary function,

TABLE I. Sample characteristics (n = 383)

Variable	Baseline
Race (%)	
Black/other	20.4
White	34.2
Hispanic	45.4
Female sex (%)	76.8
Age at enrollment (y)	42.8 ± 12.4
High school diploma or less (%)	83.5
Funding source (%)	
Medicaid	14.7
Enrolled in indigent-care program	19.1
Private insurance	51.3
Uninsured	14.9
BMI (% BMI ≥30)	58.0
Current smoker (%)	17.0
Tobacco exposure in the home (%)	36.6
NHLBI asthma severity category (%)*	
Moderate persistent	42.6
Severe persistent	57.4
Pulmonary function testing	
Prebronchodilator FEV ₁ (% predicted)	76.6 ± 19.1
Pre-BD FVC (% predicted)	81.2 ± 17.1
Pre-BD FEV ₁ /FVC ratio (*100)	76.6 ± 11.7
12% BD response in FEV ₁	25.8
Medications (%)	
SA bronchodilator	96.3
Inhaled long-acting β ₂ -agonist	55.9
Oral steroid	6.3
Theophylline	2.9
Leukotriene inhibitor	35.5
ICS alone	14.4
ICS + long-acting β ₂ -agonist	54.3
ICS alone or in combination	68.7
LASS score	23.8 ± 6.7
AQLQ score	4.0 ± 1.3
Health care use	
Asthma ED visits past 12 mo (self-report)	1.5 ± 3.1
Asthma hospitalizations past 12 mo (self-report)	0.4 ± 1.1

BMI, Body mass index; BD, bronchodilator; FVC, forced vital capacity;
SA, short-acting; ICS, inhaled corticosteroid.

*Assigned by National Jewish disease manager (n = 242).

quality of life, and self-reported health care use (Table III). The strength of association was highest for the quality-of-life measure, the AQLQ.

Discriminative properties. LASS scores were significantly higher for participants whose asthma was severe persistent, as assessed independently by a National Jewish disease manager, compared with those with moderate persistent asthma (mean score, 26.0 vs 21.5; $P < .0001$).

Predictive validity. Baseline LASS scores were associated significantly with both verified and self-reported health care use over the following 12 months. For each 1-point increase in baseline LASS score, the rate of verified asthma emergency department (ED) visits from 0 to 12 months increased by 9.4% ($P = .03$), and the rate of verified asthma inpatient admissions increased by 7% ($P = .04$). Similar results were seen for self-reported total

TABLE II. Description of individual items from the LASS

Item	Mean	SD	Range
1. Cough	3.55	1.29	1-5
2. Wheezing	3.27	1.23	1-5
3. Shortness of breath	3.59	1.14	1-5
4. Asthma attack	2.23	1.15	1-5
5. Chest pain	2.48	1.21	1-5
6. How many attacks	2.65	1.38	1-5
7. Awakened at night	2.88	1.29	1-5
8. Overall severity	3.14	1.02	1-5
Total score	23.8	6.7	8-39

TABLE III. Correlations between LASS score and baseline measures

Variable	Pearson correlation coefficient	P value
FEV ₁ % predicted (before bronchodilator)	−0.20	.0002
FEV ₁ % change With bronchodilator	0.08	.17
AQLQ total score	−0.68	<.0001
Asthma ED visits past 12 mo (self-report)	0.17	.002
Asthma hospitalizations past 12 mo (self-report)	0.15	.008

ED visits and self-reported total inpatient visits (9.5% increase for each 1-point increase in baseline LASS score, $P < .0001$; 8% increase, $P = .0006$).

Relationship of change in LASS scores over time and change in other measures. Mean LASS scores decreased over time (mean change, −4.3 [7.1 SD]; range, −25 to 21). Change in LASS scores correlated significantly and in the expected direction with change in pulmonary function and quality-of-life scores over 12 months (Table IV).

Responsiveness: The clinically important difference

To identify the magnitude of change in LASS scores that represents a clinically importance difference, we compared changes in LASS scores with clinically important changes in 2 other measures, FEV₁ and AQLQ overall score, using standards identified in previous studies or by means of consensus: 0.5 for AQLQ²¹ and 12% change in FEV₁.²² We compared mean change in LASS score over 12 months for individuals with and without a clinically significant change in FEV₁ or in quality of life (AQLQ). Based on these analyses, a change in LASS score of 7 or more points (slightly more than 1 SD) would represent a clinically important change in score.

Factor analysis

An unrotated exploratory factor analysis suggested a single-factor structure with an Eigenvalue of 3.3. The individual LASS items loaded on the single factor, with loadings between 0.47 (cough) and 0.82 (asthma attack).

TABLE IV. Relationship between LASS score change over time and other variables

Partial correlation with:	LASS change measure	Partial correlation	P value
AQLQ change (0-12 mo)	Absolute*	-0.70	<.001
	Percent†	-0.68	<.001
FEV ₁ % predicted change	Absolute	-0.22	.001
	Percent	-0.20	.005
FEV ₁ /FVC change (0-12 mo)	Absolute	-0.14	.04
	Percent	-0.14	.049

Percentage change statistics are computed as follows: (T2-T1)/T1.

Analysis is adjusted for study group membership.

FVC, Forced vital capacity.

*Absolute change in LASS score from 0 to 12 months.

†Percentage change in LASS score from 0 to 12 months.

DISCUSSION

The LASS demonstrated good internal consistency, excellent validity based on concurrent criterion validity and longitudinal predictive validity, and good discriminatory properties in a heterogeneous sample of adults with persistent asthma. The internal consistency reliability (Cronbach $\alpha = .84$) was in the same range as previously reported values for another validated questionnaire, the ACT (0.79-0.85).^{6,23} Our findings of strong correlations with other measures of asthma health status are similar to those reported in a pediatric study by Lara et al.¹¹ They reported correlations with other measures of health status (ie, school days lost [$r = 0.53$, $P < .001$], parental worry [$r = 0.31$, $P < .001$], ED visits [$r = 0.18$, $P < .05$], and hospitalizations [$r = 0.19$, $P < .05$]) and that the scale was responsive to changes in clinical status. Our finding of stronger correlations of LASS scores with quality of life than with pulmonary function testing is not surprising. Other investigators have reported only weak correlations between objective measures of pulmonary function and patient reports of asthma symptoms.²⁴

Our study has several limitations. We enrolled very few subjects who only spoke Spanish. Therefore we cannot compare questionnaire properties by language use in our study. In our study trained research personnel administered the questionnaires, and therefore we cannot assess the ease with which the LASS can be self-administered or incorporated into an office-based practice. However, the questionnaire was short and seemed to be easily understood by respondents, many of who were from lower educational levels. Finally, our participants came from a single geographic region, and the majority was Hispanic; therefore the results might not be applicable to all populations. However, our sample was heterogeneous and included many underinsured/uninsured adults, who often experience disproportionate asthma morbidity.²

How should we measure the health of individuals with asthma? Several authors have pointed to the complex effect of asthma on health and have suggested a multidimensional

TABLE V. Asthma control questionnaires

Name	No. of questions	Format	Timeframe	Administration method
ACT	5	5-point scale	4 wk	Patient completed in person; telephone voice recognition
ACQ	5	7-point scale	7 d	Patient completed in person; mailed surveys
ATAQ	7	Yes/no	4 wk; 12 mo	Mailed surveys
LASS	8	5-point scale	4 wk	Interviewer administered; telephone interview

ATAQ, Asthma Therapy Assessment Questionnaire.

approach to the clinical assessment.²⁵⁻²⁸ In a factor analysis of data from 3 clinical trials, Juniper et al²⁹ showed that overall asthma health status has at least 4 components: asthma-specific quality of life, pulmonary function, daytime symptoms (and daytime β -agonist use), and nighttime symptoms (and nighttime β -agonist use).

Accurate assessment of asthma symptoms is critical both in research settings and in the clinical evaluation and management of individuals with asthma.¹ Despite the availability of effective anti-inflammatory medications for asthma, the symptoms of many patients with asthma are not well controlled.^{2,3} In a busy practice setting many physicians rely on patient responses to global questions about asthma control, which might fail to elicit accurate information about symptoms and lead the physician to underestimate the severity of his or her patients' asthma.^{4,5} A multidimensional asthma control assessment tool can provide more specific information about the level of asthma symptoms and in turn help guide medical management.

Several short asthma control questionnaires have been used in research settings, and at least one has been widely disseminated nationally by a pharmaceutical company.⁶ All of these questionnaires are short and have appropriate psychometric properties (Table V). The ACT has been used as a self-administered questionnaire in asthma clinic patients, in community based samples, and as a voice-recognition telephone call to health maintenance organization members.^{6,23,30} The ACQ was validated in 50 adults; it has been used subsequently in large clinical trials and as a mailed survey.^{8,31,32} The Asthma Therapy Assessment Questionnaire has been used extensively as a mailed survey to HMO members.^{9,33} Child versions of these questionnaires have been developed. In contrast, the PACT was developed specifically for use in children, and there is no adult version.¹² The LASS was tested in an ED study of 234 inner-city children with asthma (69% Latino) and was found to have good reliability and validity in English and Spanish.¹¹ Our study evaluates the reliability and validity of the LASS in adults with persistent asthma.

Each of these questionnaires has certain limitations. Some questionnaires are limited to either adults or children. The child version of the ACQ is still being tested,

and the PACT¹² is designed for use in pediatric settings. Although all of the questionnaires address different aspects of asthma control, only the LASS includes items about asthma exacerbations (“attacks”). Finally, with the exception of the child version of the ACT³⁴ and the adult and child versions of the LASS, there are very few data on use of these questionnaires in socioeconomically and educationally diverse populations.

In summary, the LASS is an effective tool to assess asthma control in adults. A previous study demonstrated that it was reliable, valid, and responsive to change when administered to caregivers of children 3 to 17 years of age.¹¹ Our data show that the LASS has excellent psychometric properties when administered to adults with persistent asthma. The LASS can be used to assess asthma control in both adults and children.

We thank Cathy Sherbourne, PhD (RAND Health), for her suggestions. Clinical space was provided by the University Health System, CHRISTUS Santa Rosa Healthcare System, TEAM Research of Seguin, the Community Care Services Department of the City of Austin and Travis County, the South Texas Veterans Health Care System, the Comal County Health Department, the Children’s Specialty Center of San Antonio, MLK Community Health Services, the Round Rock Health Center, and Leigh Ann Ware, RN, CPNC. We also thank National Jewish Medical and Research Center; the Altarum Institute; Pulmonary Therapies, Inc; the Brackenridge Hospital of Austin; and Steve Conti, RRT, for their assistance with recruitment, data collection, or both.

REFERENCES

- Global Initiative for Asthma (GINA). GINA report: global strategy for asthma management and prevention; 2006. Available at: <http://www.ginasthma.org>. Accessed May 14, 2007.
- Centers for Disease Control and Prevention (CDC). Asthma prevalence and control characteristics by race/ethnicity—United States, 2002. *MMWR Morb Mortal Wkly Rep* 2004;53:145-8.
- Fuhlbrigge AL, Adams RJ, Guilbert TW, Grant E, Lozano P, Janson SL, et al. The burden of asthma in the United States. Level and distribution are dependent on interpretation of the National Asthma Education and Prevention Program Guidelines. *Am J Respir Crit Care Med* 2002;166:1044-9.
- Vermeire PA, Rabe KF, Soriano JB, Maier WC. Asthma control and differences in management practices across seven European countries. *Respir Med* 2002;96:142-9.
- Osborne ML, Vollmer WM, Pedula KL, Wilkins J, Buist AS, O’Hollaren M. Lack of correlation of symptoms with specialist-assessed long-term asthma severity. *Chest* 1999;115:85-91.
- Nathan RA, Sorkness CA, Kosinski M, Schatz M, Li JT, Marcus P, et al. Development of the Asthma Control Test: a survey for assessing asthma control. *J Allergy Clin Immunol* 2004;113:59-65.
- Liu AH, Zeiger R, Sorkness C, Mahr T, Ostrom N, Burgess S, et al. Development and cross-validation of the Childhood Asthma Control Test. *J Allergy Clin Immunol* 2007;119:817-25.
- Juniper EF, Svensson K, Mork AC, Stahl E. Measurement properties and interpretation of three shortened versions of the asthma control questionnaire. *Respir Med* 2005;99:553-8.
- Vollmer WM, Markson LE, O’Connor E, Sanocki LL, Fitterman L, Berger M, et al. Association of asthma control with health care utilization and quality of life. *Am J Respir Crit Care Med* 1999;160:1647-52.
- Skinner EA, Diette GB, Algatt-Bergstrom PJ, Nguyen TT, Clark RD, Markson LE, et al. The Asthma Therapy Assessment Questionnaire (ATAQ) for children and adolescents. *Dis Manage* 2004;7:305-13.
- Lara M, Sherbourne C, Duan N, Morales L, Gergen P, Brook RH. An English and Spanish pediatric asthma symptom scale. *Med Care* 2000;38:342-50.
- Zorc JJ, Pawlowski NA, Allen JL, Bryant-Stephens T, Winston M, Anguaco C, et al. Development and validation of an instrument to measure asthma symptom control in children. *J Asthma* 2006;43:753-8.
- Galbreath AD, Ellis R, Fallot A, Inscore S, Peters JI, Smith B, et al. Impact of two disease management strategies in an underserved asthma population [abstract]. *Am J Respir Crit Care Med* 2007;175:A59.
- National Heart, Lung, and Blood Institute. National asthma education and prevention program. Expert panel report: guidelines for the diagnosis and management of asthma update on selected topics—2002. Bethesda (MD): National Heart, Lung, and Blood Institute; 2002. National Institutes of Health publication no. 02-5074.
- Juniper EF, Buist AS, Cox FM, Ferrie PJ, King DR. Validation of a standardized version of the Asthma Quality of Life Questionnaire. *Chest* 1999;115:1265-70.
- Juniper EF, Norman GR, Cox FM, Roberts JN. Comparison of the standard gamble, rating scale, AQLQ and SF-36 for measuring quality of life in asthma. *Eur Respir J* 2001;18:38-44.
- Leidy KN, Chan KS, Coughlin C. Is the asthma quality of life questionnaire a useful measure for low-income asthmatics? *Am J Respir Crit Care Med* 1998;158:1082-90.
- Bateman ED, Boushey HA, Bousquet J, Busse WW, Clark TJ, Pauwels RA, et al. Can guideline-defined asthma control be achieved? The Gaining Optimal Asthma Control Study. *Am J Respir Crit Care Med* 2004;170:836-44.
- American Thoracic Society. Standardization of spirometry. 1994 Update. *Am J Respir Crit Care Med* 1995;152:1107-36.
- Hankinson JL, Odencrantz JR, Fedan KB. Spirometric reference values from a sample of the general U.S. population. *Am J Respir Crit Care Med* 1999;159:179-87.
- Juniper EF, Guyatt GH, Willan A, Griffith LE. Determining a minimal important change in a disease-specific quality of life questionnaire. *J Clin Epidemiol* 1994;47:81-7.
- Pellegrino R, Viegi G, Brusasco V, Crapo RO, Burgos F, Casaburi R, et al. Interpretative strategies for lung function tests. *Eur Respir J* 2005;26:948-68.
- Schatz M, Sorkness CA, Li JT, Marcus P, Murray JJ, Nathan RA, et al. Asthma Control Test: reliability, validity, and responsiveness in patients not previously followed by asthma specialists. *J Allergy Clin Immunol* 2006;117:549-56.
- Shingo S, Zhang J, Reiss TF. Correlation of airway obstruction and patient-reported endpoints in clinical studies. *Eur Respir J* 2001;17:220-4.
- Fuhlbrigge AL. Asthma severity and asthma control: symptoms, pulmonary function, and inflammatory markers. *Curr Opin Pulm Med* 2004;10:1-6.
- Graham LM. Classifying asthma. *Chest* 2006;130(suppl):13S-20S.
- Moy ML, Israel E, Weiss ST, Juniper EF, Dube L, Drazen JM. Clinical predictors of health-related quality of life depend on asthma severity. *Am J Respir Crit Care Med* 2001;163:924-9.
- Bukstein D, Kraft M, Liu AH, Peters SP. Asthma end points and outcomes: what have we learned? *J Allergy Clin Immunol* 2006;118(suppl):S1-15.
- Juniper EF, Wisniewski ME, Cox FM, Emmett AH, Nielsen KE, O’Byrne PM. Relationship between quality of life and clinical status in asthma: a factor analysis. *Eur Respir J* 2004;23:287-91.
- Schatz M, Zeiger RS, Drane A, Harden K, Cibulak A, Oosterman JE, et al. Reliability and predictive validity of the Asthma Control Test administered by telephone calls using speech recognition technology. *J Allergy Clin Immunol* 2007;119:336-43.
- Juniper EF, O’Byrne PM, Guyatt GH, Ferrie PJ, King DR. Development and validation of a questionnaire to measure asthma control. *Eur Respir J* 1999;14:902-7.
- Pinnock H, Juniper EF, Sheikh A. Concordance between supervised and postal administration of the Mini Asthma Quality of Life Questionnaire (Mini AQLQ) and Asthma Control Questionnaire (ACQ) was very high. *J Clin Epidemiol* 2005;58:809-14.
- Schatz M, Mosen D, Apter AJ, Zeiger RS, Vollmer WM, Stibolt TB, et al. Relationships among quality of life, severity, and control measures in asthma: an evaluation using factor analysis. *J Allergy Clin Immunol* 2005;115:1049-55.
- Schmier JK, Manjunath R, Halpern MT, Jones ML, Thompson K, Diette GB. The impact of inadequately controlled asthma in urban children on quality of life and productivity. *Ann Allergy Asthma Immunol* 2007;98:245-51.