

Relationships among quality of life, severity, and control measures in asthma: An evaluation using factor analysis

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Background: Validated psychometric tools measuring quality of life, asthma control, and asthma severity have been developed, but their relationships with each other and with other important patient-centered outcomes have not been rigorously assessed.

Objective: To use factor analysis to evaluate the relationships of these validated tools with each other and with other patient-centered outcomes.

Methods: Surveys were completed by a random sample of 2854 Health Maintenance Organization members age 18 to 56 years with persistent asthma. Surveys included demographic information; validated tools measuring generic (Short Form-12; SF-12) and asthma-specific (Juniper Mini Asthma Quality of Life Questionnaire; AQLQ) quality of life, asthma control (Asthma Therapy Assessment Questionnaire), and asthma symptom severity (Asthma Outcomes Monitoring System); self-described severity, control, and course over time; and history of acute exacerbations.

Results: Principal component analysis suggested a 5-factor model that accounted for approximately 59% of the variability. The most prominent rotated factor reflected asthma symptom frequency (19.4% of variability), was measured by the symptom subscale of the AQLQ, and was the only factor significantly related to the Asthma Therapy Assessment Questionnaire, Asthma Outcomes Monitoring System, or the self-reported assessments of severity, control, or course. Other factors included symptom bother (12.1% of variability), reflected by the environment and emotion AQLQ subscales; activity limitation (13.9% of variability), reflected by the activity AQLQ subscale and the SF-12 physical component

scale; mental health (8.3% of variability), reflected by the SF-12 mental component scale; and acute exacerbations (5.0% of variability), not measured by any of the validated scales.

Conclusion: Distinct components of patient-reported asthma health status can be identified by factor analysis. Distinct constructs of severity versus control cannot be identified by the use of these tools alone. (*J Allergy Clin Immunol* 2005;115:1049-55.)

Key words: Asthma, severity, control, exacerbations, quality of life, factor analysis

Asthma is a very common chronic symptomatic disease, with more than 10 million Americans reporting an asthma episode during the previous 12 months.¹ Asthma is usually assessed clinically on the basis of patient-reported symptoms, although clinical trials have usually relied heavily on pulmonary function tests as objective asthma outcome measures. More recently, attempts have been made to use patient-centered asthma outcomes in an objective and standardized way. Thus, validated psychometric tools have been developed to provide valid, reliable, and reproducible measures of various subjective aspects of the asthma patient experience, including quality of life,² asthma severity,³ and asthma control.^{4,5}

Although it is assumed that these tools measure distinct, although correlated,⁴⁻⁸ aspects of the patient asthma experience, this has not been rigorously investigated. Moreover, it is not clear how these tools relate to other important patient-centered parameters, such as self-described severity or control, history of exacerbations, and course over time. The purpose of this study was to address these issues by means of factor analysis of surveys containing several types of validated psychometric tools that had been administered to patients with asthma enrolled in a large managed care organization.

METHODS

Patients

Surveys were sent in August 2000 to a random sample of Kaiser-Permanente Medical Care Program adult (age 18 to 56 years)

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Abbreviations used

AOMS: Asthma Outcomes Monitoring System
 AQLQ: Mini Asthma Quality of Life Questionnaire
 ATAQ: Asthma Therapy Assessment Questionnaire
 MCS: Mental component scale
 PCS: Physical component scale
 SF-12: Short Form-12

members with persistent asthma from the Northern California (n = 3072), Northwest (n = 543), and Southern California (n = 3251) regions. Persistent asthma was diagnosed on the basis of the presence of 1 or more of the following administrative database criteria (during 1999): (1) 4 or more asthma medication dispensings, (2) 1 or more emergency department visits or hospitalizations with a principal diagnosis of asthma, and (3) 4 or more asthma outpatient visits with 2 or more asthma medication dispensings. Completed surveys were returned between August and October 2000 from 4175 members (61%), of whom 3765 (90%) answered yes to the question, "Have you ever been told by a doctor that you have asthma?" These 3765 respondents are the subjects of this study. The study was approved by the Northern California, Northwest, and Southern California Regional Kaiser-Permanente Institutional Review Boards. Surveys were initially sent as a quality improvement project. When use of the data for research was subsequently considered, informed consent was waived by the Institutional Review Boards because of minimal risk.

Survey information

The cross-sectional survey included information regarding age, sex, race-ethnicity, education (expressed as a 6-point scale from eighth grade or less to a postgraduate or professional degree), annual household income (expressed as a 7-point scale from less than \$10,000 to more than \$50,000), and current (versus never or past) smoking. The validated tools included (1) the generic quality of life Short Form-12 (SF-12)⁹; (2) the Mini Asthma Quality of Life Questionnaire (AQLQ)²; (3) the Asthma Outcomes Monitoring System (AOMS),³ a symptom severity scale; and (4) the Asthma Therapy Assessment Questionnaire (ATAQ),⁴ an asthma control tool. All of these tools assess status over the period of the previous 2 to 4 weeks. Additional questions addressed self-reported asthma severity (very mild, mild, moderate, severe, very severe), asthma course compared with 1 year ago (much better, somewhat better, about the same, somewhat worse, much worse), self-reported use of oral steroids (regularly, bursts in past year, bursts more than 1 year ago, none), self-reported history of asthma hospitalizations (never, within past year, more than 1 year ago), and self-reported number of unscheduled (office, urgent care, or emergency department) visits for asthma in the previous 12 months.

Factor analysis

Factor analysis with 53 outcome variables was used to identify the main themes of the tools. The variables included all of the individual questions of the validated scales; the mental component scale (MCS) and physical component scale (PCS) scores of the SF-12; the AQLQ subscale scores (symptoms, activities, environment, emotions); total scale scores for the AQLQ, ATAQ, and AOMS; and additional questions addressing self-reported severity, asthma course over time, and history of exacerbations requiring oral steroids, unscheduled visits, or hospitalizations.

Factor analysis was performed by means of principal component analysis followed by varimax orthogonal rotation.¹⁰ The number of

TABLE I. Characteristics of the study sample

Characteristic	Results
N	3765
Age (mean $\pm$ SD)	41.3 $\pm$ 10.3
Female (%)	67.0
Race (%)	
White	57.1
Black	11.9
Hispanic	13.8
Other	11.3
Unknown	5.9
Education (%)	
Eighth grade or less	0.8
Some high school or technical school	4.6
High school or technical school graduate	18.2
Some college	32.3
College graduate	20.1
Postgraduate	14.2
Unknown	9.9
Income (%)	
<\$10,000	3.3
\$10,000-\$14,999	2.6
\$15,000-\$19,999	2.7
\$20,000-\$24,999	3.9
\$25,000-\$34,999	9.2
\$35,000-\$49,999	14.8
>\$50,000	44.1
Unknown	19.3
Smoking/d (%)	
Never smoked	59.8
Past smoker	28.1
$\frac{1}{2}$ pack or less	5.6
$\frac{1}{2}$ -1 pack	3.6
1-2 packs	1.4
>2 packs	0.1
Unknown	1.3

factors chosen for the varimax rotation was based on the Eigenvalues (variance explained out of the total of 53) of the factors in the principal component analysis. Significant loading (correlation of an item with a factor) was considered to be greater than 0.40. Factor analysis was performed on 2854 participants because of missing data on 1 or more of the 53 variables for 911 patients.

To address possible demographic influences on the results of the factor analysis, the above factor analysis was performed on the following demographic subsets of the study sample: (1) nonwhite, (2) lower quartile of education (high school or less), (3) lower quartile of annual household income (<\$35,000), and (4) current smokers. Specifically, the following were compared between the overall results and the subgroup results: (1) number of unrotated factors with Eigenvalues ≥ 2 ; (2) Eigenvalue of the largest factor; (3) percent variance explained by the first 5 factors; (4) loading on SF-12-MCS, SF-12-PCS, AQLQ subscales, AOMS, and ATAQ; and (5) loading on any steroids, unscheduled visits, and any hospitalization.

RESULTS

The demographic characteristics of the study populations are shown in Table I. The majority of the patients were white, female, well educated (at least some college), nonpoor (annual income >\$35,000), and nonsmokers.

TABLE II. Description of the 5 unique factors identified in this study and the tools that measure them

Factor	Percent of variation explained (varimax rotation)*	Measured by validated tools
Asthma symptom frequency	19.4	AQLQ AOMS ATAQ
Asthma symptom bother	12.1	AQLQ
General physical health and activity	13.9	SF-12–PCS, AQLQ (activity scale)
General mental health	8.3	SF-12–MCS
History of acute exacerbations	5.0	None

*Total = 58.7% of variation explained by the 5 factors.

On the basis of the Eigenvalues of the factors in the principal component analysis, a 5-factor model was chosen (which explained 59% of the variability). After rotation, all but 1 of the 53 factors loaded significantly on at least 1 of the 5 factors—asthma symptom frequency, asthma symptom bother, general physical health and activity, general mental health, and history of acute exacerbations (Table II). The content of the questions loading significantly on each factor was used to define their interpretation. Thus, loading on factors by individual questions and summary scores of the SF-12 (Table III), AQLQ (Table IV), AOMS (Table V), ATAQ (Table V), and other questions (Table V) suggests the interpretation of these factors shown in Table II. The most prominent factor reflected asthma symptom frequency. It is a factor measured by the AQLQ, predominantly the symptom subscale, and is the only factor measured by the AOMS asthma severity scale (which showed the highest loading on that factor) and the ATAQ asthma control tool (which demonstrated the second highest loading). In addition, asthma course, self-determined asthma severity, and self-described asthma control also appeared to be determined by this factor (Table V).

A second factor is the bother, discomfort, or inconvenience caused by asthma symptoms. This is captured only by the AQLQ, especially the emotion and environment subscales (Table IV). The third factor was a physical health and activity factor, captured most strongly by the SF-12 physical component scale (Table III) but also by the AQLQ activity subscale (Table V).

Although asthma may cause emotional distress, the general mental health factor, captured by the SF-12 mental component scale, did not load on any of the asthma-related tools (Table IV). Finally, a fifth factor related to a history of acute exacerbations requiring hospitalization, unscheduled visits, or oral steroids. This factor was distinct from the other factors and not captured by any of the survey tools (Tables III–V).

Results of factor analyses in demographic subsets were quite similar to the results in the total sample regarding number of factors with Eigenvalues ≥ 2 , Eigenvalue of the first factor, and proportion of variance explained by the first 5 factors (Table VI). The interpretation of the factors was the same in each of the subgroups as in the total sample. For example, loading on the 5 rotated factors by the scales varied less than 0.10 between any of the

demographic subsets and the total population except for 2 factors in smokers (versus total): (1) AQLQ activity subscale loading on symptom bother factor (0.50 vs 0.39), and (2) any hospitalization loading on acute exacerbations factor (0.35 vs 0.48). It should be noted that current smokers were the smallest subgroup assessed (Table VI).

DISCUSSION

This study identified 5 distinct factors or domains (Table II) from a survey assessing the asthma patient experience by using several validated tools. The most prominent factor is symptom frequency, which appears to be separate from the domains of symptom bother, activity limitation, and acute exacerbations. Strengths of this study include the large number of patients surveyed, the use of validated tools, the relatively homogenous medical care system that served the participants, the real world setting, the use of random sampling, and the inclusion of patients from several geographical areas. The results provide insight into both constructs regarding the asthma experience and the validated tools used to measure them.

Factor analysis may not be familiar to all readers. Juniper et al¹¹ have explained it by using the analogy of educational assessment. Overall, brighter students will score higher on a general examination, just like patients with more severe asthma will demonstrate greater effects on the overall questionnaire. However, the varimax rotation reveals the specific themes or topic areas covered by the questionnaire and shows heterogeneity among patients with asthma the same way performance on the specific topics of an examination reflects specific talents of the students.

Asthma severity is thought to be distinct from asthma control.^{12–14} The former is the inherent intensity of the disease process, whereas the latter is the degree to which the disease manifestations are minimized. The current study shows that the severity and control tools used herein do not really distinguish between these constructs, because both appear to measure primarily symptom frequency (Table V). One way to differentiate asthma control from severity would be to adjust these types of measures for medication use, as has been suggested (although not validated) in the recent Global Initiative for Asthma guidelines.¹⁵ For example, either the AOMS

TABLE III. Varimax rotated factor pattern using SF-12 outcomes (significant loading in bold)

Outcome question (4-week window)	Symptom frequency	Symptom bother	General health and activity	General mental health	Acute exacerbations
General health	0.22	−0.10	0.59	−0.23	0.11
Moderate activity limitation	−0.13	0.11	0.73	0.10	−0.07
Limited in climbing several flights of stairs	−0.21	0.16	0.66	0.07	−0.11
Accomplished less because of physical health	−0.19	0.09	0.64	0.18	−0.09
Limited in the kind of activities because of physical health	−0.20	0.14	0.67	0.12	−0.09
Accomplished less because of emotional problems	−0.06	0.09	0.16	0.77	−0.05
Didn't do activities as carefully as usual because of emotional problems	−0.09	0.12	0.13	0.72	−0.04
How much did pain interfere with normal work	0.09	−0.08	− 0.66	−0.21	0.04
Frequency of feeling calm and peaceful	0.16	−0.04	−0.17	− 0.70	0.03
Frequency of having a lot of energy	0.17	−0.04	− 0.46	− 0.48	0.05
Frequency of feeling downhearted and blue	−0.10	0.09	0.13	0.78	0.00
Interference with social activities because of physical health or emotional problems	−0.13	0.16	0.44	0.62	−0.07
PCS score	−0.20	0.12	0.91	−0.05	−0.10
MCS score	−0.10	0.09	0.07	0.98	−0.03

TABLE IV. Varimax rotated factor pattern using AQLQ outcomes (significant loading in bold)

Outcome question (2-week window)	Symptom frequency*	Symptom bother	General health and activity	General mental health	Acute exacerbations
Frequency of shortness of breath because of asthma	− 0.67	0.37	0.30	0.06	−0.10
Frequency of being bothered by dust	−0.22	0.67	0.21	0.06	−0.10
Frequency of feeling frustrated because of asthma	− 0.48	0.57	0.27	0.14	−0.10
Frequency of bothered by coughing	− 0.50	0.40	0.25	0.12	−0.01
Frequency of fear of not having asthma medicine available	−0.36	0.59	0.00	0.08	−0.07
Frequency of chest tightness or heaviness	− 0.62	0.43	0.21	0.11	−0.04
Frequency of being bothered by cigarette smoking	−0.02	0.69	0.14	0.02	−0.09
Frequency of difficulty getting a good night's sleep because of asthma	− 0.59	0.46	0.23	0.15	−0.08
Frequency of feeling concerned about having asthma	−0.38	0.66	0.14	0.10	−0.09
Frequency of feeling a wheeze in chest	− 0.65	0.39	0.17	0.05	−0.08
Bothered by weather or air pollution	−0.17	0.59	0.35	0.16	−0.10
Limitation of strenuous activities because of asthma	−0.38	0.33	0.59	0.11	−0.10
Limitation of moderate activities because of asthma	−0.34	0.36	0.65	0.15	−0.08
Limitation of social activities because of asthma	−0.27	0.33	0.55	0.20	−0.07
Limitation of work-related activities because of asthma	−0.28	0.33	0.62	0.15	−0.05
AQLQ symptoms	− 0.73	0.50	0.28	0.12	−0.07
AQLQ activities	−0.37	0.39	0.70	0.17	−0.09
AQLQ environment	−0.15	0.83	0.28	0.00	−0.12
AQLQ emotions	− 0.48	0.72	0.15	0.13	−0.10
AQLQ total score	− 0.51	0.74	0.39	0.15	−0.11

*Loading is negative because lower scores indicate more symptoms.

or ATAQ tool could presumably be used to address relative severity if all patients received the same (or no) treatment. Similarly, severity could also be defined, as has been suggested by others,^{13,14} by the least amount of medication needed to achieve a given level of symptom frequency (control). We did not have the information in the current study to be able to make such adjustments for medication.

The current study suggests that there is a symptom-related factor separate from symptom frequency that substantially influences the asthma subjective experience. This appears to be the bother, frustration, concern, or

discomfort caused by the symptoms or the need to modify one's environment to avoid the symptoms. Only the AQLQ captured this factor (Table IV).

Physical health appeared to be a separate factor from the asthma symptom factor. However, this domain included interference with various types of activity caused by asthma and was measured by the AQLQ activity questions and subscale (Table IV). It is of interest that this factor did not seem to influence the patients' report of their own asthma severity or control or to be related to their perceived asthma course over time. This may relate to the observations that many patients report acceptable

TABLE V. Varimax rotated factor pattern using AOMS, ATAQ, and other outcomes (significant loading in bold)

Outcome question	Symptom frequency*	Symptom bother	General health and activity	General mental health	Acute exacerbations
AOMS (4-week window)					
Frequency of wheezing	0.75	−0.09	−0.12	−0.03	0.09
Frequency of tightness in your chest	0.68	−0.13	−0.17	−0.08	0.05
Frequency of shortness of breath	0.75	−0.14	−0.26	−0.08	0.06
Frequency of coughing	0.59	−0.10	−0.20	−0.11	−0.01
Frequency of asthma symptoms waking you up at night	0.72	−0.23	−0.16	−0.10	0.13
Frequency of asthma episode, flare-up, attack	0.69	−0.14	−0.21	−0.09	−0.07
AOMS total score	0.79	−0.14	−0.19	−0.10	0.03
ATAQ (4-week window)					
Any missed normal activity because of asthma	0.30	−0.16	−0.31	−0.10	0.24
Any night awakening because of asthma	0.64	−0.19	−0.08	−0.07	−0.15
Asthma well controlled	− 0.62	0.12	0.14	0.11	−0.05
Highest number of puffs in 1 day of quick relief inhaler	0.63	−0.13	−0.11	−0.03	0.21
ATAQ total score	0.76	−0.19	−0.23	−0.13	0.20
Other					
Self-assessment of asthma severity	0.44	−0.26	−0.25	−0.05	0.36
Use of steroids (daily, bursts, none)	0.09	−0.05	−0.09	−0.01	0.88
Any steroid use vs none	0.01	−0.01	−0.04	0.00	0.85
Number of unscheduled asthma visits past year	0.23	−0.18	−0.21	−0.08	0.46
Any asthma hospitalization	0.02	−0.07	−0.03	−0.03	0.48
Asthma hospitalization within past year	0.08	−0.08	−0.10	−0.03	0.40
Course of asthma compared with 1 year ago	− 0.50	0.01	−0.09	−0.03	−0.11

*Loading is positive because higher scores indicate more symptoms.

TABLE VI. Factor analysis in total population compared with demographic subgroups*

Parameter	Sample				
	Total	Nonwhite	Education†	Income†	Smokers
Sample size	2854	1177	655	642	302
Factors ≥2	5	5	5	5	5
Eigenvalue, first factor	19.9	20.5	19.8	20.8	19.7
% Variance, first 5 factors	59	60	59	60	59

*No substantial differences between groups are appreciated.

†Lower quartile.

asthma control in spite of substantial activity limitation^{16,17} and that asthma severity is much higher when based on activity limitation than when based on symptom frequency alone.¹⁸ In addition, impaired activity has been shown to be independent of symptom severity and previous utilization in predicting subsequent asthma hospitalizations or emergency department visits.¹⁹

Asthma and depression frequently coexist,²⁰ and depression may increase the risk of subsequent acute exacerbations.²¹ It would be possible, then, that answers to questions reflecting general anxiety or depression may also reflect frustration or concern regarding asthma specifically. However, the general mental health factor appeared to be totally separate from all other factors in this study, including the asthma symptom bother factor.

Finally, acute exacerbations are a critical part of the adverse asthma experience. The current results suggest that this factor is totally separate from all of the other factors. Thus, asthma symptom frequency, self-reported severity or control, asthma symptom bother, and in-

terference with activity because of asthma reflect different domains than a history of severe exacerbations (Table V). It should be noted that the time frame for exacerbations (1 year) was substantially longer than the time frame for the questions associated with the other domains (2–4 weeks). There is, however, a relationship between higher ATAQ scores²² or lower asthma-specific quality of life scores²³ and an increased risk of subsequent acute exacerbations requiring emergency hospital care.

Vollmer¹⁴ has suggested that asthma severity is a stable characteristic that may change, but only slowly, whereas asthma control is a relatively short-term assessment of adequate management. He has also suggested that asthma severity is best assessed by a combination of long-term control, medication use, and past acute health care utilization. Thus, the acute exacerbation factor in this study, which reflected acute health care utilization (hospital, other unscheduled visits, and steroids) over the past year or longer, may be the only factor in this study to reflect inherent asthma severity. Correlating this factor

with biologic markers of asthma severity would be necessary to confirm this conjecture.

This study has implications regarding the theoretical dimensions of the subjective asthma experience, but it has practical clinical implications as well. For those using validated psychometric tools clinically or for clinical research, this study shows that the AQLQ reflects more dimensions than the ATAQ or AOMS and that general quality of life tools are only necessary above and beyond the AQLQ to reflect general physical or mental health in patients with asthma. For most clinicians who do not use validated psychometric tools in practice, this study suggests that symptom frequency is the most prominent determinant of the asthma experience and is thus the minimal essential information necessary to obtain to evaluate a patient's subjective asthma status. In addition to symptom frequency, this study suggests that 3 other lines of questioning are necessary to assess fully the patient asthma experience and determine whether further intervention is needed: (1) symptom bother (bothered by environmental factors, fear of not having medication available, frequency of feeling concerned about having asthma); (2) activity limitation (strenuous, moderate, social, work-related); and (3) exacerbations requiring hospitalization, other unscheduled visits, and oral steroids.

We are aware of 2 previous studies that have used factor analysis to determine whether asthma health status is a homogeneous or heterogeneous construct. Bailey et al²⁴ studied asthma symptoms and pulmonary function in 199 patients and concluded that these represented separate domains. More recently, Juniper et al¹¹ assessed symptom diaries, asthma-specific quality of life, and measures of airway caliber in 763 patients participating in 3 randomized controlled trials. These authors identified 4 distinct factors: quality of life, nighttime symptoms, daytime symptoms, and airway caliber. It is very difficult to compare our findings with the results from the study by Juniper et al.¹¹ In contrast with the study by Juniper et al,¹¹ our study (1) involved patients who were not in a clinical trial, were not necessarily uncontrolled, and did not necessarily have abnormal spirometry (<80% predicted); (2) assessed primarily questions from validated tools; (3) did not include measures of airway caliber; and (4) did include a history of acute exacerbations. The main shared conclusion between the 2 studies is that asthma health status is composed of distinct components that can be identified by means of factor analysis.

This study does have several potential limitations. Not all potential participants completed the survey, although a 60% response rate is not unreasonable for a survey of this type. A major issue is the generalizability of the results. Although the inclusion of subjects from 3 different Health Maintenance Organization service locales should increase generalizability, all locales were on the west coast. This survey was completed in primarily white, well educated, nonpoor patients with persistent asthma enrolled in a large Health Maintenance Organization. These results may not apply to other populations, especially populations whose literacy (on which the survey responses depend) is sub-

stantially less than that of the current sample. However, other than literacy issues, there is no particular reason to suspect that the other demographic characteristics of this population influence the unique asthma experience factors identified in this study. Indeed, the similarity of the results of the factor analyses in demographic subgroups compared with the total population supports that contention (Table VI).

In summary, this study has shown that asthma symptom frequency is a major factor that influences patients' perception of their asthma burden. Other separable asthma factors include asthma symptom bother and interference with activity (measured by the AQLQ but not the other scales), and history of acute exacerbations (that is not measured by any of the scales evaluated). Disease severity or control cannot be distinguished from symptom frequency by means of these tools. Further studies will be necessary to identify survey measures, probably combined with medication use assessment and possibly with ascertainment of histories of severe exacerbations, that would distinguish the important construct of inherent severity from that of control.

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