

Association of the Asthma Control Test with Peak Flow Measures in a Population in Puerto Rico

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Objective: The Asthma Control Test (ACT) questionnaire has been widely used and validated in various ethnic groups, showing an adequate correlation with physician assessment of asthma control. We sought to evaluate the relationship between ACT-defined asthma control and peak flow measures in subjects living in Puerto Rico.

Methods: A retrospective evaluation of data collected by a mobile asthma clinic in 2 cities in Puerto Rico was conducted. The participants completed an asthma and rhinitis survey. Self-reported asthmatics answered the age-appropriate Spanish version of the ACT. Peak flows (PEF) were measured. Subjects were skin-tested against the common local aeroallergens. The study was approved by the University of Puerto Rico's IRB.

Results: We evaluated data from 70 subjects aged 4 to 68. Of them, 82.85% were 12 years old or older, 64.3% reported having a history of asthma, 57.14% reported that they still suffered from asthma, 81.4% reported that they suffered from rhinitis, and 78.57% were sensitized to at least 1 antigen. The mean ACT score of current asthmatics was 18.97, while that of past asthmatics was 23.83 ($p = 6.6e-6$). The variability of PEF increased as the ACT score increased. Age had no impact on asthma control ($p > 0.25$), while the effect of PEF on the control of asthma was tied to gender. Rhinitis was also associated with poor asthma control as defined by the ACT score. No other covariate was found to be statistically significant ($p < 0.05$).

Conclusion: Our study supports the use of the ACT to evaluate asthma control in asthmatics living in Puerto Rico. Research into factors associated with poor asthma control, and the importance of rhinitis with regard to such control, is needed. [*P R Health Sci J* 2014;33:122-128]

Key words: Asthma, Puerto Rico, Skin test

Puerto Ricans have one of the highest asthma prevalences of all Hispanics and of various other ethnic groups in the United States (1). The National Health Interview Survey (NHIS) for 2006–2008 determined that the current asthma prevalence for Puerto Rican children was 18.4%, compared to being 14.6% for non-Hispanic black children, 13.6% for multiracial children, and 8.2% for non-Hispanic white children (2). Additionally, according to the NHIS (2006-2008), asthma morbidity in children from Puerto Rico was elevated (3), lung function was reduced, and bronchodilator response was impaired compared with such evaluative criteria in children of other racial groups (4, 5).

The Global Initiative for Asthma (GINA) guidelines and the National Asthma Education and Prevention Program (NAEPP) both emphasize the importance of asthma control in terms of decreasing asthma-related impairment and future health risk. Validated instruments to measure asthma control include the Asthma Control Test (ACT), Childhood ACT (cACT), Asthma Control Questionnaire (ACQ), and Asthma Therapy Assessment Questionnaire (ATAQ) (6).

Few studies have assessed asthma control in Puerto Ricans. Esteban et al used a computer-generated score (ranging from 0-2) based on asthma symptoms (as determined by GINA), pre-albuterol FEV1, and the number of exacerbations over the 4 weeks prior to a given appointment to assess asthma control in children attending government-sponsored pediatric clinics as well as in those visiting independent providers (7). Oh et al used the GINA asthma symptom score and FEV1/FVC ratio $\geq 85\%$ to categorize control in black and Latino children (and including children from Puerto Rico), aged 8 to 17 years, participating in the GALA (Genetics of Asthma in Latino Americans) II study

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(8). Martin et al used ACQ to assess asthma control in Puerto Rican youths in the midwestern US (9).

The Asthma Control Test (ACT) is a practical, 5-item tool used by primary care physicians or specialists to assess asthma control within the 4 weeks previous to a given appointment. (10) The ACT assesses asthma symptoms by analyzing shortness of breath and nighttime symptoms, the use of rescue medications, daily functioning, and the overall perception of asthma control. Each item is scored from 1 to 5. A total score of 20 or more is consistent with controlled asthma (77% sensitivity and 84% specificity), a score of 16 to 19 with not-well-controlled asthma (75% sensitivity and 82% specificity), and a score less than or equal to 15 with uncontrolled asthma (49% sensitivity and 92% specificity) (11). Validity, reliability, and responsiveness have been established in subjects 12 years of age and older (12, 13, 14). The ACT was recently identified as one of the core measures for NHLBI-based asthma research in adults (15). A pediatric version for children 4 to 11 years old, the Childhood Asthma Control Test (C-ACT), was developed (16). This questionnaire has 7 items scored from 0 to 27 and is completed by the patient as well as that patient's caregiver.

By measuring peak expiratory flow (PEF) levels, health care workers can assess lung function at a given point in time. An individual's PEF level is an important indicator of the severity of an acute asthma exacerbation and correlates with forced expiratory volume in 1 second (FEV1); PEF levels have been moderately associated with symptom scores. The correlation of PEF variability with impairment and risk or other indices of asthma control is uncertain (17). Predicted PEF varies with ethnicity and with atopy (18, 19). PEF rate measurements, however, have not been validated in Hispanics. No published study has reported on a comparison of ACT and peak flow measures in subjects living in Puerto Rico.

Our objectives were to evaluate the relationship between ACT-defined asthma control and peak flow measures in a cohort of subjects living in Puerto Rico and to evaluate the different relationships between ACT scores, PEF rates, asthma history, rhinitis, and skin sensitivity results. Our hypotheses were that lower ACT scores would be associated with lower PEF rates in asthmatics living in Puerto Rico and that atopy would be associated with lower ACT scores and lower PEF rates than would non-atopy.

Methods

Subjects

A transverse cross-sectional study was organized by APMA (Puerto Rican Allergist Association, by its English translation). Four health fair clinics were conducted during August 2008 in Ponce (in the south) and Guaynabo (in the north) in Puerto Rico. Via several radio and newspaper advertisements, subjects older than 4 years of age were invited to participate.

Procedures

The subjects answered demographic questions; filled in items related to physician-diagnosed asthma, rhinitis, or both; and took an age-appropriate Spanish version of the ACT. (A pediatric version of the questionnaire was used for subjects 4–11 years of age.) The questionnaire was self-administered in subjects who were 12 years of age or older. The pediatric version has some items that are to be answered by children (4–11 years old) and some that are to be answered by a given child's caregiver. Three hundred and one individuals participated in the study. We had complete data on the demographics of and the ACT scores, PEF rates, and skin tests for 70 subjects, upon whom we are reporting here.

Skin test

Subjects who were not actively wheezing or coughing and who had not taken any oral antihistamines in the 48 hours prior to their visits were skin tested using Multi-Test® (Lincoln Diagnostics, Inc., Decatur, Ill.). Skin prick tests were done for dog, cat, mosquito, insect, mites, feathers, molds, local grass, trees, and weeds (GREER®, Lenoir, NC), as described previously (20). A skin test was considered positive if the induration was 3 mm larger than the negative control 15 minutes after its application. The clinic provided free allergy skin testing and a discussion of the results with an allergist.

Peak expiratory flow

Using a mini-Wright peak flow meter (KW-Med, Inc., Antioch, Ill.) 3 consecutive peak flow measures were obtained for each subject (while in a standing position). The measures were averaged and compared to standard measures by height and sex (21, 22). Test results were given as a percent of the predicted values for patients of similar height and sex.

Approval was obtained from the University of Puerto Rico Medical Sciences Campus Institutional Review Board. Written informed consent was obtained from all research subjects before their enrollment.

Statistical analysis

We used descriptive statistics to evaluate the baseline characteristics of the study subjects. Logistic regression was used to compare PEF and ACT-defined asthma control and potential predictors of asthma control including gender, age, allergen sensitivity as determined by skin test, asthma history, rhinitis, the number of positive skin tests, and dust mite sensitivity. Models were developed to evaluate the association between ACT-defined asthma control and PEF.

Results

Two hundred seventy-nine subjects participated in the clinics. We report herein data from 70 subjects who completed the questionnaire, had skin tests, and on whom a PEF was

conducted. Subjects ranged in age from 4 to 68 years; the sample population consisted of 49 females and 21 males. In that population, 82.85% of the subjects were 12 years old or older, 64.3% reported that they had a history of asthma but that they no longer suffered from it, 57.14% reported that they still had asthma, 81.4% reported that they suffered from rhinitis, and 78.57% were sensitized to at least 1 antigen (16).

Subjects who self-reported that they currently suffered from asthma were not well controlled in terms of their asthma, which is suggested by this population's mean ACT score of 18.97 (with a median of 21). In comparison, those with a past history of asthma scored an average of 23.83, with a median of 25 points, which is consistent with adequately controlled asthma. This difference was clinically and statistically significant ($p = 6.6 \times 10^{-6}$). The mean PEF rate for asthmatics was lower than it was for those with a past history of asthma: 87.6% (median = 88) vs. 93.4% (median = 95), respectively. This difference was statistically significant ($p = 0.02$) (Figure 1).

Exploratory analysis revealed that the variability of PEF increased as the ACT score increased, making the implementation of a traditional regression model difficult. Figure 2 presents scatterplots of the ACT score vs. PEF conditioning on gender and fitting a locally weighted polynomial regression (23). The nonconstant variance in the data is clear. Furthermore, the figure suggests that the strength of the association between the ACT score and PEF rate varies by gender. Hence, to determine the association of ACT-defined asthma control with PEF rate

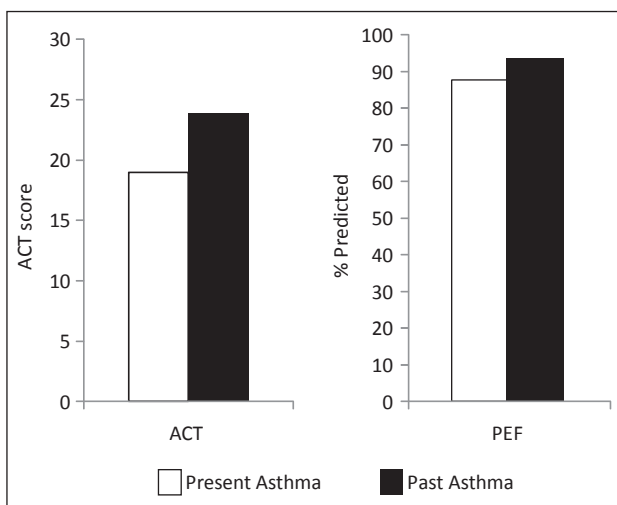


Figure 1. A comparison of the mean ACT score and PEF value of subjects currently suffering from asthma with those of individuals reporting a past history of asthma.

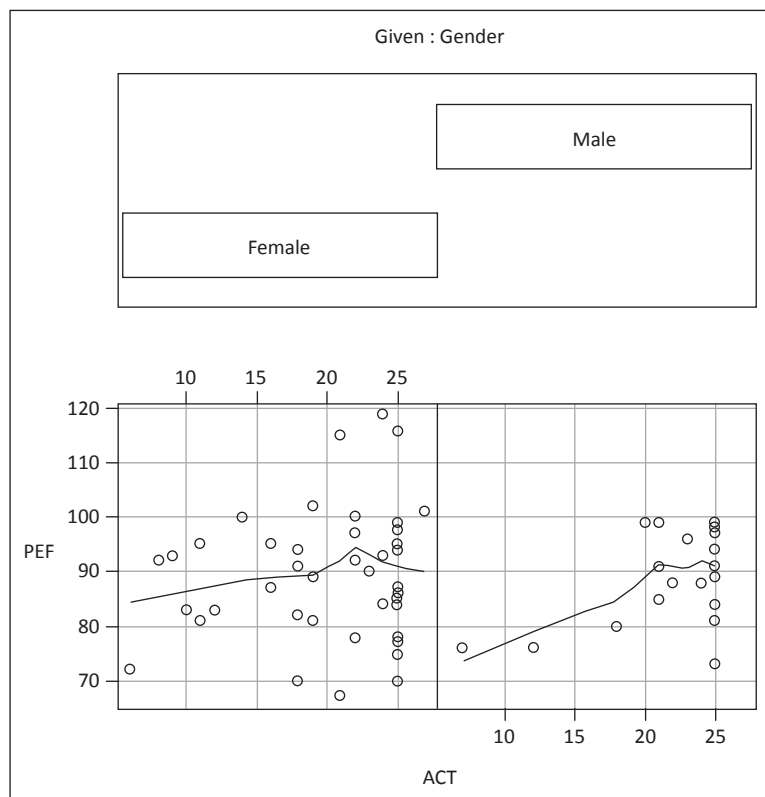


Figure 2. A comparison of the PEF value and ACT score by gender

without assuming a constant variance, a logistic regression model was constructed. The impacts of gender, allergen sensitization (defined as having a positive skin test), number of positive tests, rhinitis, and age on this association were taken into consideration. The effect of age was considered, treating the covariate as a quantitative variable and as a categorical variable (greater than 11 years old or not). The analysis showed that age had no impact on asthma control in our population ($p\text{-value} > 0.25$). On the other hand, it was found that the effect of PEF on the control of asthma varied with gender. The results presented in Table 1 indicate that gender is not a confounder (Model 2) but that it interacts with PEF (Model 3, $p\text{-value} = 0.01$). Rhinitis was also found to be associated with ACT-defined asthma control (Model 4). No other covariate was found to be statistically significant ($p\text{-value} < 0.05$).

Results of the logistic regression can be interpreted based on probabilities or on odds ratios adjusted for (the presence or absence of) rhinitis and for gender (Model 4, Table 1). For example, one way to do so is according to the maximum difference in the probability of the control of asthma (based on ACT score) corresponding to a unit increase of covariate x . In the case of PEF rates, the interpretation is that a difference of 1 unit in the PEF rate corresponds to a maximum difference in the probability of controlled asthma of 10.5% (from 0.42/4) for a male subject with no rhinitis. On the other hand, a difference

of 1 unit in the PEF rate corresponds to a maximum difference in the probability of controlled asthma of just 1% (from $(0.42 - 0.38 \times 1) / 4$) for a female subject with no rhinitis (24). In terms of odds ratios, the odds of controlled asthma for a male subject with no rhinitis are multiplied by 1.52 ($e^{0.42}$) for every unit of increase of the PEF rate. For a change in the PEF rate greater than 1 unit, simply multiply the coefficient by the unit increase of interest (25). Similarly, the model estimates that asthma control is about 1/10 as likely in people who suffer from rhinitis as it is in those who do not suffer from rhinitis. No other covariate or interaction was found to be statistically significant, and hence Model 4 was the best model. Moreover, through the interaction effect, (using the assigned gender code for the analysis: 1 for female, and 0 for male), this model suggests that increases in PEF have considerably more impact on ACT-based asthma control for men (an adjusted logistic regression coefficient of 0.42 for PEF) than for women (an adjusted logistic regression coefficient of 0.04 for PEF).

Table 1. Estimated coefficients and likelihood-ratio test p-values for 3 different values. The first p-value compares Model 1 with a constant model; the second p-value compares Models 1 and 2; the third p-value compares Models 1 and 3; and the last p-value compares Models 3 and 4. For the sake of the interpretation of the coefficient estimates, PEF was centered.

Model	Intercept	PEF	Gender	PEF X Gender	Rhinitis	p-value
1	0.98	0.056				0.039
2	1.93	0.059	-1.26			0.054
3	4.01	0.32	-3.37	-0.28		0.010
4	6.97	0.42	-4.25	-0.38	-2.29	0.033

Discussion

We evaluated asthma control using ACT scores and PEF measures in a convenience sample in Puerto Rico and discovered that asthmatics on the island did not generally control their asthma very well. ACT scores and PEF measurements were correlated, with gender and rhinitis being important covariates.

Multiple studies have evaluated the increased asthma severity, morbidity, and mortality seen in Puerto Ricans (26, 27). Fewer studies have evaluated asthma control in that population. Martin et al evaluated 101 Puerto Rican children in Chicago using the ATAQ (Asthma Therapy Assessment Questionnaire) and 4 questions on asthma control from the NHLBI guidelines. Most of the children in the sample were uncontrolled (69% over the 4 weeks prior to the study visit), with a mean score of 3.5 ± 1.8 . They identified poor compliance with controller medications, stress, and depression as factors related to poor asthma control in this population (9). Steinberg et al evaluated asthma control using the C-ACT with 120 children in New York, including 55 who were Puerto Rican, comparing PTSD, anxiety, and

depression levels among caregivers. Children whose caregivers experienced anxiety or depression were more likely to suffer from uncontrolled asthma (28). Further studies on factors associated with uncontrolled asthma are necessary.

Two reports have assessed asthma control in Puerto Ricans living on the island. In 2012, Oh et al identified in utero smoke exposure as a risk factor for poor asthma control in Latinos and blacks; this study included 877 Puerto Ricans among its sample population. Oh and his colleagues used the NHLBI score to measure asthma control (8). That same year, Canino et al evaluated children seeking acute asthma care in Puerto Rico. The study group reported that asthma control was at 1.1 (on a scale ranging from 0 to 2) in those children with private insurance compared to being at 1.3 in those with public insurance, with higher values correlating with worse asthma control. They used a computerized algorithm that evaluated symptoms and pre-bronchodilator FEV1 or PEF (3). We could not find a publication assessing (via the NHLBI-recommended clinical instruments validated for use in the assessment and monitoring of asthma) asthma control in Puerto Ricans living on the island.

Most self-reported current asthmatics in our cohort were not well controlled. It is noteworthy that even our stable sample of asthmatics, which is a group such as one that might be found at a health fair, had less than optimal asthma control. We might anticipate even lower scores among patients requiring immediate asthma care, such as those in an urgent care facility or emergency room. Contradictorily, Esteban reported better asthma control among Puerto Rican children visiting the ER than was seen in children from Rhode Island doing the same. They postulated that socioeconomic and medical-access factors may account for the inconsistency (7).

Our data support a complex association between ACT scores and PEF levels, one in which gender is a significant confounder. Among those with controlled asthma, female subjects had higher variability in their PEF rates than did males. Rhinitis increased tenfold the risk for uncontrolled asthma. Neither age nor atopy was associated with lower asthma control.

There are conflicting literature reports on the correlation between ACT scores and PEF levels in other cohorts. Pinto Pereira et al found an association between ACT scores and PEF in a cross-sectional study of 205 asthmatics in Trinidad, with a concordance of 0.56 (29). Shirai et al reported a weak correlation between ACT scores and PEF rates in 105 patients with asthma in Japan (19). Chan et al, however, did not identify a correlation between ACT scores and PEF rate measurements in a predominantly Hispanic population (30). The ACT measures control by assessing symptoms over a period of 1 month, while PEF measures lung function at 1 single point in time. The recent use of rescue medications for asthma could also alter the effort-dependent, 1-time PEF measurement, which is not the case with the ACT score.

Gender is an important variable in the interpretation of PEF. PEF is influenced by the pressure exerted in forced expiration (the power of the expiratory muscles), the build of the individual undergoing the test, and, particularly, that person's thoracic volume, for which height has been used as a surrogate (31). No PEF standards for Puerto Ricans have been developed. Esteban et al used Polgar's standard to measure their pediatric population (7); the GALA studies made use of Hankinson's age-adjusted prediction equations (32). The effect of build on PEF levels, particularly in Puerto Rican woman, must be further evaluated.

We found that rhinitis is inversely associated with asthma control. Consensus statements document the importance of rhinitis in asthma (33, 34, 35). Using ACT scores, Padilla et al recently reported that allergic rhinitis was associated with an inadequate level of asthma control in a cohort of 256 Peruvian children (36). Robyn et al identified a self-reported rhinitis prevalence of 26% in a population-based sample of 1526 children living in the San Juan–Caguas metropolitan area. Rhinitis was linked to parental asthma and exposure to violence. No association with asthma control was discussed (37). The effect of rhinitis treatment on asthma control in Puerto Ricans must be evaluated.

Neither the ACT score nor the PEF measurement differed between sensitized and non-sensitized asthmatics. Marcus et al analyzed 1009 asthmatic patients from allergists and pulmonary specialists in the United States and reported that atopics were more likely to receive multiple medications and suffer uncontrolled asthma than were non-atopics (38). Two other studies, these conducted in Puerto Rico, failed to identify an association of allergen in dust particles with asthma symptoms. Forno et al did not detect a relationship between mite, cockroach, cat, or mold exposure in dust samples and FEV1 in a cohort of asthmatics in San Juan (39). Montealegre et al failed to demonstrate such a relationship in a convenience sample of 72 asthmatic children in Bayamon, PR (40). Oh et al identified an association between poor asthma control and elevated IgE; however, no assessment of specific IgE was conducted (8). Recently, Rosas-Salazar et al found a strong association between prematurity and atopic asthma in Puerto Rican children (41). The different relationships between in utero environment, allergen exposure, sensitization, the development of asthma symptoms, and asthma control in a tropical environment deserve further evaluation.

Age was not associated with asthma control in our cohort. Poor asthma control was described in a large cohort of 64,929 asthmatics in the United Kingdom, particularly among subjects older than 50 years of age compared to those 13 to 49 years of age (42). Ahmed et al identified age, multiple ED visits, asthma severity, and education as important factors associated with poor asthma control in a cohort of asthmatics visiting an ED for asthma exacerbations (43). Differences in the study cohort

and sample size may account for the lack of association in our population.

Our study has certain limitations. First, an individual's asthma status (currently suffering from asthma or having a history of suffering from asthma) was determined via a self-report. Second, the study was based on a convenience sample, which could have been biased toward atopic and symptomatic subjects, which may in turn have resulted in the underestimation of asthma control. Third, the study was based on PEF instead of spirometry assessment, which is effort dependent. Moreover, neither test has been standardized for Puerto Ricans. Finally, the limited sample size, particularly in terms of male asthmatics with low ACT values, may bias our results. Nevertheless, an undeniable strength is that, this is the only published study identified using the ACT to measure asthma control in subjects living in Puerto Rico.

Our study supports the use of the ACT to evaluate asthma control in asthmatics living in Puerto Rico. Research into factors associated with poor asthma control, and the importance of rhinitis with regard to such control, is needed.

Resumen

Objetivo: El cuestionario del Control de Asma (ACT, por sus siglas en inglés) ha sido utilizado y validado en varios grupos étnicos, correlacionando con el juicio clínico de control de asma. Deseamos evaluar la relación entre el control de asma definido por ACT y medidas de flujo expiratorio entre sujetos viviendo en Puerto Rico. **Métodos:** Se evaluó la data tomada en una Clínica Ambulatoria en dos ciudades en Puerto Rico. Los participantes contestaron un cuestionario sobre asma y rinitis. Los asmáticos contestaron una versión en español del cuestionario ACT. Se obtuvieron tres medidas de flujo expiratorio (PEF, por sus siglas en inglés). Se condujeron pruebas de piel contra aeroalergenos locales. El estudio fue aprobado por el Comité de Revisión Institucional de la Universidad de Puerto Rico. **Resultados:** Evaluamos la data de 70 sujetos entre las edades de 4-68 años. El 82.85% de los sujetos eran de 12 años de edad o mayores. El 64.3% reportó un historial de asma, 57.14% reportó aun padecer de asma, 81.4% reportó rinitis y 78.57% estaban sensibilizados al menos a un alérgeno. Los aun asmáticos tenían un ACT promedio de 18.97, comparado con 23.83, entre los sujetos con historial de asma ($p = 6.6e-6$). La variabilidad de flujo expiratorio aumentaba con el ACT. La edad no afectaba el control de asma ($p > 0.25$), mientras que el efecto del flujo expiratorio en el control de asma dependía del género. Rinitis también se asoció a pobre control de asma. Ninguna otra variable era estadísticamente significativa ($p < 0.05$). **Conclusión:** El estudio apoya el uso del ACT para evaluar el control de asma entre asmáticos viviendo en Puerto Rico. Investigaciones sobre los factores asociados al pobre control de asma y el rol de la rinitis en su control, son necesarias.

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