

Letter to the Editor

Environmental and socioeconomic data do not improve the Predicting Asthma Risk in Children (PARC) tool

To the Editor:

Many preschool children present to their doctor with respiratory symptoms, but not all of them develop asthma. Prediction tools can help to distinguish children with a high risk of developing asthma from children whose risk is low. A good prediction tool selects children who need therapeutic intervention and reassures parents whose children have transient problems.

Five tools to predict school-age asthma in symptomatic preschool children are currently available. All predict only moderately well (Youden index ≤ 0.43 or area under the receiver operating characteristics curve [AUC] ≤ 0.74).¹⁻⁵ They include the asthma predictive index,⁴ the Prevention and Incidence of Asthma and Mite Allergy (PIAMA) prediction tool,³ and the Predicting Asthma Risk in Children (PARC) tool,² which we developed previously. The latter consists of 10 clinical predictors, including current respiratory symptoms. To develop the PARC tool, we deliberately included only those predictors that can be easily assessed clinically. Thus, we considered neither physiological measurements nor environmental or socioeconomic factors. These factors might not be generalizable to other populations.

Nonetheless, environmental and socioeconomic factors, such as second-hand tobacco smoke or house pets, have been associated with respiratory symptoms in children.^{6,7} Some asthma prediction tools for children and young adults do include such exposures, namely, maternal smoking or parental education.^{3,5} In this study, we test whether the addition of environmental exposures and socioeconomic factors improves the predictive performance of the PARC tool.

Our study population was the same that we used to develop the PARC tool. We used questionnaire data from a population-based cohort from Leicestershire, United Kingdom, described in detail elsewhere.⁸ We included children aged 1 to 3 years at baseline (in 1998) with parent-reported wheeze or chronic cough (cough without colds, or cough at night) who visited their doctor for wheeze or cough at least once during the past 12 months. The outcome “any asthma” was assessed 5 years later, at the age of 6 to 8 years. Any asthma was defined as current wheeze plus use of asthma medication within the past 12 months. For each child, we calculated the PARC tool risk score for developing asthma (range of score is 0-15).² We then investigated whether the following environmental and socioeconomic factors, assessed at baseline, improved the accuracy of the score’s prediction: nursery care, number of older siblings, heating or cooking with gas, pet ownership (cat, dog, other furry pets, bird), mother smoking during pregnancy, exposure to environmental tobacco smoke (mother or other persons in the household smoking), duration of breastfeeding, ethnicity (white vs South Asian), crowding, single parenthood, parental education, Townsend deprivation index,⁹ living in an urban area, and self-reported traffic density at home address.

As when we developed the PARC tool, we used least absolute shrinkage and selection operator–penalized logistic regression to identify important predictors without overfitting the data.¹⁰ The penalty for the regression coefficients is set using the penalization parameter λ . For large values of λ , no predictors enter the model. With decreasing λ , more predictors enter the model, in order of

their added predictive value. For our final model, we set λ to a value that maximized the AUC of resulting predictions in 10-fold cross-validation.

We varied λ to explore the order in which predictors entered the final model. We also used conventional logistic regression without penalization to estimate univariable associations of each potential predictor with later asthma to see how estimates changed when adjusted for the PARC tool score and when adjusted for all potential predictors. Methodologic details are given in this article’s [Online Repository](http://www.jacionline.org) at www.jacionline.org.

We had baseline data from 6808 children, of whom 2444 reported respiratory symptoms and a visit to the doctor due to their symptoms. We had outcome data at age 6 to 8 years for 1226 of 2444 children (50%), of whom 28% (345 of 1226) had asthma.

Those with school-age asthma differed little from those without regarding environmental exposures and socioeconomic factors, with few exceptions (maternal smoking, cooking fuel) ([Table E1](#)).

Of 31 potential predictors that entered variable selection, the PARC tool score was the only variable that remained in the final model (maximal AUC of 10-fold cross-validations = 0.783; $\lambda = 0.083$).

When we reduced λ of our final model by 70%, absence of nursery care entered the model as a second predictor (AUC = 0.780). When λ was lowered by 79%, maternal smoking (AUC = 0.780) and absence of crowding entered as well (AUC = 0.781).

In the regression models without penalization, few potential predictors showed an association with asthma ($P < .05$) (see [Table E1](#) in this article’s [Online Repository](http://www.jacionline.org) at www.jacionline.org). In multivariable logistic regressions, adjusted for the score and all potential predictors, only absence of nursery care was associated with later asthma.

This study found no evidence that addition of environmental and socioeconomic data improves the predictive performance of the PARC tool.

The PARC tool already contains detailed information on respiratory symptoms. Environmental factors such as air pollution, aeroallergens, and respiratory infections affect the prevalence of these symptoms in toddlers. Additional analyses showed that most environmental and socioeconomic factors were associated with some symptoms included in the tool (see [Table E2](#) in this article’s [Online Repository](http://www.jacionline.org) at www.jacionline.org). Potential effects of these factors on later asthma could be entirely mediated through early symptoms already contained in the PARC tool, which would explain their inability to improve prediction. It is possible that toddlers who wheeze and cough a lot because of increased exposure to infectious agents (nursery care, crowding) have a better prognosis than do peers who have these symptoms in the absence of exposure. This might explain the trend toward a poorer prognosis in children who were not in nursery care and did not live in crowded households, which was seen in some of the models with reduced penalization.

Our findings contrast with those reported by Balemans et al,⁵ who found that maternal smoking while children were toddlers predicted asthma in young adults in their cohort. Balemans et al included only a few symptoms as potential predictors and used stepwise logistic regression to derive the final model, which might explain why maternal smoking was a better predictor in their model than in ours. In our cohort, maternal smoking was one of

TABLE I. Characteristics of the study population (children seeing a doctor for wheeze or cough at age 1 to 3 years, by asthma outcome at age 6 to 8 years; N = 1226)

Characteristic	5 y later				P value*
	Asthma (n = 345)		No asthma (n = 881)		
	n	%	n	%	
Demographic factors					
Sex: male	224	64.9	454	51.5	<.001
Age (y)					
1	85	24.6	251	28.5	.388
2	204	59.1	498	56.5	
3	56	16.2	132	15.0	
Ethnicity					
White	267	77.4	643	73.0	.127
South Asian	78	22.6	238	27.0	
Current wheeze and total asthma prediction score					
Current wheeze	272	78.8	425	48.2	<.001
PARC tool score†, mean ± SD	6.7 ± 3.2		3.7 ± 2.3		<.001
Environmental exposures					
Nursery care	164	47.5	451	51.2	.254
Older siblings					
0	106	30.7	281	31.9	.548
1 or 2	202	58.6	523	59.4	
>2	37	10.7	77	8.7	
Heating					
Central heating only	245	71.0	638	72.4	.621
Gas, coal, other	100	29.0	243	27.6	
Cooking fuel					
Electrical stove only	102	29.6	197	22.4	.010
Gas, other	243	70.4	684	77.6	
Pet ownership					
Cat	63	18.3	161	18.3	1.000
Dog	66	19.1	153	17.4	.507
Other furry pet	43	12.5	78	8.9	.070
Bird	13	3.8	38	4.3	.752
Mother smoking during pregnancy	53	15.4	121	13.7	.467
Mother smoking (number of cigarettes/d)					
1-10	39	11.3	90	10.2	.045
>10	40	11.6	65	7.4	
Other person smoking in household (number of cigarettes/d)					
1-10	38	11.0	131	14.9	.201
>10	37	10.7	87	9.9	
Breast-fed (mo)					
<1	39	11.3	89	10.1	.320
1-3	54	15.7	164	18.6	
4-6	40	11.6	120	13.6	
>6	57	16.5	162	18.4	
Self-reported traffic density (at home)					
Low	142	41.2	343	38.9	.384
Moderate	176	51.0	447	50.7	
High	27	7.8	91	10.3	
Socioeconomic factors					
Crowding (persons/room)					
≤1	277	80.3	676	76.7	.353
1.1-1.5	53	15.4	152	17.3	
>1.5	15	4.3	53	6.0	
Single parents	42	12.2	84	9.5	.175

(Continued)

TABLE I. (Continued)

Characteristic	5 y later				P value*
	Asthma (n = 345)		No asthma (n = 881)		
	n	%	n	%	
Higher parental education†	200	58.0	506	57.4	.898
Townsend deprivation index§					
More affluent	71	20.6	172	19.5	.695
Affluent	73	21.2	168	19.1	
Average	74	21.4	187	21.2	
Deprived	59	17.1	181	20.5	
More deprived	68	19.7	173	19.6	
Living in an urban area	178	51.6	461	52.3	.849

*Fisher exact test.

†Range: 0 to 15 points, 0 represents low risk for having asthma 5 y later, 15 high risk.²

‡Age at the end of education is >16 y.

§The categories cover the following Townsend deprivation index intervals: (−5.522 to −2.981), (−2.886 to −1.264), (−1.250 to 0.908), (0.909 to 4.403), and (4.418 to 11.072).

||Living in Leicester postcode areas LE1 to LE5.

the first predictors joining the PARC tool score when we lowered the penalization, but it did not improve the predictive performance of the PARC tool.

The strength of our study lies in its large sample size and clinically relevant population. We used an objective approach for variable selection that minimized overfitting the data. A limitation common to other tools is that symptoms and exposures are parent-reported. This reflects the situation in clinical practice, in which many decisions are based on medical history taken from parents. Future research should evaluate whether such tools can be improved by including results from clinical tests, such as allergy tests, lung function, and exhaled nitric oxide.

In summary, the asthma risk assessment tool PARC, which uses detailed clinical data, performs moderately well. Adding information on environmental and socioeconomic exposures did not improve the PARC tool's predictive performance.

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METHODS

We used the R package glmnet to fit the penalized logistic regression. The parameter α was set to 1 so that only a least absolute shrinkage and selection operator-type penalty was included. This tends to retain only the most influential predictors. The parameter λ , which determines the magnitude of the penalty, was set to a value that maximized the AUC of resulting predictions in 10-fold cross-validation.^{E1} If $\lambda = 0$, this is equal to a conventional logistic regression including all potential predictors.

All potential predictors with more than 2 response categories were ordinal variables. We coded them as multiple dichotomous variables that represented all possible cutoff points, separating lower from higher categories. For instance, the number of cigarettes per day that a mother smoked (<1, 1-10,

>10) was coded into 2 dichotomous variables, indicating 1 or more cigarette per day and more than 10 cigarettes per day. This procedure resulted in 30 binary variables that entered variable selection in addition to the risk score of the PARC tool. Missing values in potential predictor variables did not exceed 5.5% (except for parental education; 11%) and were interpreted as the absence of the respective risk factor where possible, or were recoded with the most common category of the variable. Data were prepared using Stata 12.0 and analyzed using R version 2.15.2.

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TABLE E1. Associations of environmental and socioeconomic factors at age 1 to 3 years with asthma at age 6 to 8 years

Potential predictor	Unadjusted models			Score-adjusted models			Full model		
	OR	95% CI	P value	OR	95% CI	P value	OR	95% CI	P value
Environmental exposures									
Ethnicity									
South Asian	0.79	0.59-1.06	.113	1.25	0.90-1.75	.186	1.55	0.97-2.46	.065
Nursery care	0.86	0.67-1.11	.250	0.69	0.52-0.92	.011	0.66	0.49-0.89	.007
Older siblings									
≥1	1.06	0.81-1.38	.692	0.95	0.70-1.29	.735	0.95	0.68-1.32	.762
>2	1.25	0.83-1.90	.283	1.03	0.64-1.65	.911	1.15	0.67-1.96	.607
Heating									
Gas, coal, other (vs central heating only)	1.07	0.81-1.41	.623	1.13	0.83-1.54	.445	1.15	0.83-1.60	.397
Cooking fuel									
Gas, other (vs electrical stove only)	0.69	0.52-0.91	.008	0.91	0.66-1.25	.548	0.82	0.58-1.16	.268
Pet ownership									
Cat	1.00	0.72-1.38	.996	0.90	0.62-1.30	.567	0.91	0.62-1.35	.651
Dog	1.13	0.82-1.55	.469	1.05	0.73-1.50	.802	1.05	0.71-1.58	.796
Other furry pet	1.47	0.99-2.18	.058	1.12	0.71-1.77	.626	1.19	0.73-1.96	.484
Bird	0.87	0.46-1.65	.668	0.80	0.38-1.67	.554	0.74	0.34-1.61	.449
Mother smoking during pregnancy	1.14	0.80-1.62	.463	0.97	0.65-1.45	.900	0.70	0.37-1.30	.255
Mother smoking (number of cigarettes/d)									
≥1	1.39	1.03-1.89	.034	1.15	0.81-1.64	.419	1.33	0.74-2.38	.345
>10	1.65	1.09-2.49	.019	1.57	0.97-2.53	.067	1.70	0.85-3.39	.131
Other person smoking in household (number of cigarettes/d)									
≥1	0.84	0.63-1.14	.267	0.91	0.65-1.27	.570	0.76	0.47-1.21	.247
>10	1.10	0.73-1.65	.657	1.13	0.71-1.78	.613	1.39	0.73-2.63	.318
Breast-fed (mo)									
Any duration (vs no breast-feeding)	0.79	0.62-1.02	.070	0.92	0.70-1.29	.546	1.09	0.66-1.80	.744
≥1	0.76	0.59-0.98	.031	0.85	0.64-1.13	.254	0.70	0.40-1.24	.221
≥4	0.83	0.63-1.09	.185	0.95	0.70-1.30	.754	1.13	0.65-1.95	.664
>6	0.88	0.63-1.22	.443	1.01	0.70-1.46	.947	1.06	0.62-1.82	.820
Self-reported traffic density (at home)									
At least moderate	0.91	0.71-1.17	.473	0.86	0.64-1.14	.295	0.85	0.62-1.17	.314
High	0.74	0.47-1.15	.183	0.87	0.53-1.43	.591	0.93	0.55-1.59	.794
Socioeconomic factors									
Crowding (persons/room)									
>1	0.81	0.60-1.10	.179	0.77	0.55-1.09	.146	0.67	0.43-1.04	.076
>1.5	0.71	0.39-1.28	.253	0.88	0.46-1.69	.701	1.04	0.49-2.19	.919
Single parents	1.32	0.89-1.95	.172	0.87	0.55-1.36	.534	0.90	0.54-1.51	.699
High parental education	1.02	0.79-1.32	.864	1.13	0.85-1.51	.402	1.15	0.84-1.58	.388
Townsend deprivation index*									
More affluent	0.94	0.69-1.28	.677	0.92	0.65-1.31	.655	1.01	0.64-1.60	.969
Affluent	0.88	0.68-1.13	.311	0.88	0.66-1.17	.363	0.97	0.62-1.52	.900
Deprived	1.15	0.89-1.49	.277	1.21	0.90-1.62	.206	1.48	0.92-2.40	.108
More deprived	1.00	0.73-1.36	.977	0.93	0.65-1.33	.708	0.76	0.46-1.24	.264
Living in an urban area†	0.97	0.76-1.25	.817	1.10	0.83-1.46	.508	1.20	0.83-1.73	.327

OR, Odds ratio.

*The categories are cutoffs between the following Townsend deprivation index intervals: (−5.522 to −2.981), (−2.886 to −1.264), (−1.250 to 0.908), (0.909 to 4.403), and (4.418 to 11.072).

†Living in Leicester postcode areas LE1 to LE5.

TABLE E2. Associations of environmental and socioeconomic factors with symptoms included in the asthma prediction tool

Environmental/socioeconomic factor	Wheeze-related symptoms included in the prediction tool		OR	95% CI	P value
Townsend deprivation index (most deprived group compared with the rest)					
	Wheeze without colds		1.09	0.75-1.58	.640
	>3 attacks of wheeze		0.67	0.47-0.97	.033
	Interference with daily activity	Any	1.34	1.00-1.79	.046
		A lot	3.63	1.66-7.96	.001
	Wheeze causing shortness of breath	At least sometimes	0.95	0.70-1.28	.726
		Always	1.06	0.59-1.91	.844
	Exercise-related wheeze/cough		1.33	1.00-1.76	.052
	Aeroallergen-related wheeze/cough		1.38	0.83-2.28	.214
Mother smoking (number of cigarettes/d)					
≥1	Wheeze without colds		2.23	1.60-3.10	<.001
	>3 attacks of wheeze		1.30	0.94-1.81	.113
	Interference with daily activity	Any	1.56	1.16-2.08	.003
		A lot	1.01	0.38-2.71	.985
	Wheeze causing shortness of breath	At least sometimes	1.50	1.12-2.01	.006
		Always	1.20	0.68-2.14	.526
	Exercise-related wheeze/cough		1.51	1.13-2.01	.005
	Aeroallergen-related wheeze/cough		0.71	0.39-1.30	.266
>10	Wheeze without colds		2.26	1.45-3.51	<.001
	>3 attacks of wheeze		1.27	0.81-2.01	.298
	Interference with daily activity	Any	1.46	0.98-2.19	.066
		A lot	0.89	0.21-3.81	.872
	Wheeze causing shortness of breath	At least sometimes	1.11	0.73-1.68	.629
		Always	1.55	0.75-3.21	.239
	Exercise-related wheeze/cough		1.58	1.06-2.35	.026
	Aeroallergen-related wheeze/cough		0.91	0.41-2.01	.807
Pet ownership					
Cat					
	Wheeze without colds		1.09	0.75-1.58	.640
	>3 attacks of wheeze		1.08	0.76-1.52	.673
	Interference with daily activity	Any	1.11	0.82-1.50	.503
		A lot	1.07	0.40-2.86	.898
	Wheeze causing shortness of breath	At least sometimes	0.97	0.71-1.31	.830
		Always	1.39	0.79-2.44	.255
	Exercise-related wheeze/cough		1.22	0.91-1.64	.177
	Aeroallergen-related wheeze/cough		0.42	0.20-0.88	.022
Dog					
	Wheeze without colds		1.48	1.04-2.11	.029
	>3 attacks of wheeze		1.22	0.87-1.71	.246
	Interference with daily activity	Any	1.05	0.78-1.43	.742
		A lot	0.59	0.18-2.00	.400
	Wheeze causing shortness of breath	At least sometimes	1.25	0.93-1.69	.144
		Always	1.20	0.67-2.17	.537
	Exercise-related wheeze/cough		1.17	0.87-1.58	.292
	Aeroallergen-related wheeze/cough		0.43	0.21-0.91	.027
Other furry pet					
	Wheeze without colds		1.57	1.01-2.44	.046
	>3 attacks of wheeze		1.89	1.26-2.82	.002
	Interference with daily activity	Any	1.08	0.73-1.59	.694
		A lot	0.36	0.05-2.68	.319
	Wheeze causing shortness of breath	At least sometimes	1.30	0.88-1.91	.182
		Always	2.32	1.25-4.29	.007
	Exercise-related wheeze/cough		1.43	0.98-2.08	.066
	Aeroallergen-related wheeze/cough		1.47	0.78-2.79	.238

Symptoms during the last 12 mo.

Townsend deprivation index interval of the most deprived group: (4.418-11.072).

OR, Odds ratio.